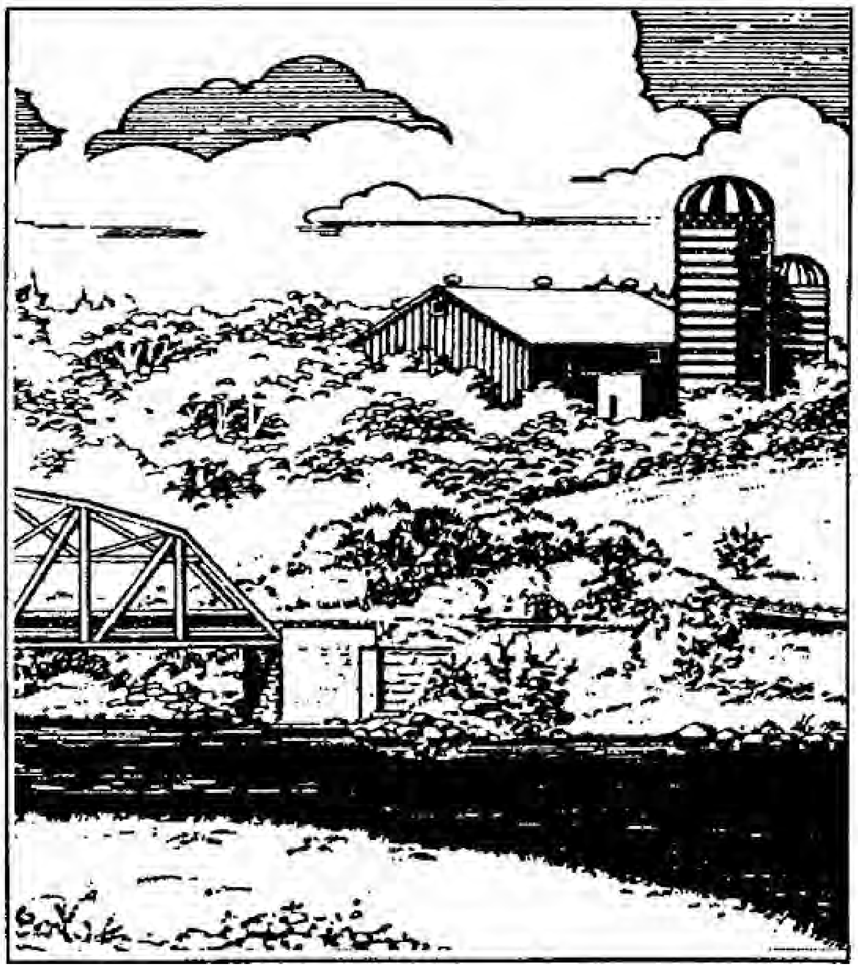
CURB

CLEAN UP RURAL BEACHES



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A CLEAN UP RURAL BEACHES (CURB) PLAN

Prepared for the Ontario Ministry of the Environment

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The Saugeen Valley Conservation Authority

March, 1992

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TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

The Clean Up Rural Beaches (CURB) Plan is the Saugeen Valley Conservation Authority's effort in outlining the relative impact of bacterial pollution and phosphorus loading sources on selected beach areas with the S.V.C.A.'s jurisdiction. Through funding made available by the Ontario Ministry of the Environment, a conservation beach area (Durham) affected by beach closures and a degrading river system (Penetangore) which outlets into Lake Huron were each investigated for a two year period. Shoreline cottages from Southampton to Point Clark were estimated and included in the CURB model due to the concern over their use of septic systems and their potential negative impact on Lake Huron.

This report outlines an implementation strategy which, if adopted, will reduce bacterial and phosphorus loading in the target areas and thereby reduce potential impacts at downstream swimming areas. What is presented in this CURB Plan is the amalgamation of two separate reports written by two different authors during separate study efforts. They are displayed as separate entities due to the differences in data collection and presentation and in the methodology used in the modelling process.

The CURB model estimates for the Penetangore River watershed demonstrate that unacceptable septic systems account for 81.5% of the bacterial contamination and 73.9% of the phosphorus load at the beach area. Livestock access to the river and its tributaries accounts for 17.6% of bacterial contamination and 6.8% of the phosphorus load. The Kincardine sewage treatment plant discharges account for most of the remaining bacterial proportion while it accounts for 18.7% of the beaches' phosphorus load.

Using a failure rate of 1%, the septic systems from lakeshore cottages contribute a minimum of 1.19 E+13 fecal coliform bacteria annually to Lake Huron per year. This is more than half of the Penetangore River watersheds total annual fecal coliform contribution to Lake Huron. Cottages with faulty septic systems contribute about 141 kg. of phosphorus annually to Lake Huron which represents about 4% of the Penetangore Rivers' contribution. Unacceptable cottage septic systems would be an important factor in remediation due to the potential threat of ground water contamination as well as the pollution to Lake Huron.

Of the seven potential contaminant sources to the Durham subwatershed, the greatest impact is from livestock access to watercourses. Livestock access provides 89.4% of the fecal coliform that enters the Durham subwatershed system and almost 25% of the phosphorus contribution.

Manure runoff is seen to have a moderate impact on the overall system quality of the Durham system. Approximately, 75% of the phosphorus contribution is a result of the manure runoff in the watershed, while about 11% of the bacteria comes from this source.

Septic systems were looked at qualitatively and not included in the PLOP outputs but was recognized as having a moderate contribution to the overall quality of the Durham subwatershed systems. Overall, subwatershed component 1 in the Durham subwatershed is the area of greatest concern in terms of bacterial contamination.

The validation process of computer modelling (undertaken in the Penetangore River watershed study only) has demonstrated that the CURB model predictions generally were consistent when compared to field assessment data. The same validation process could not be carried out for the phosphorus model due to a lack of phosphorus field verification data. Although, other Southwestern Conservation Authorities who have enlisted the same phosphorus modelling process as used by this author, have validated the phosphorus model and have also found consistency with field verification. Factors such as model assumptions and estimates, bacterial sedimentation and resuspension, lake effects on bacterial survival, and factors not accounted for in the model may explain variability outside of the CURB model predictions.

After examining cost effectiveness and efficiency reduction of the contaminants, the most efficient measure for control of both fecal contamination and phosphorus loading would be the remediation of unacceptable septic systems and completely fencing livestock from watercourses.

1.0 PROGRAM BACKGROUND AND DIRECTIONALITY

Program History

The Rural Beaches Program was the result of the growing concern in regards to beach closures across approximately 10% of Ontario monitored beaches. This repetitive trend commanded the attention of the Ontario Provincial Cabinet. As a result, Cabinet moved to improve water quality to meet safe beach water requirements. Consequently, 1985 saw the birth of the Beaches Management Strategy. The Rural Beaches Program was part of that strategy whereby identification of pollution sources within rural settings would be investigated. Agricultural land use practices would be studied in depth to verify and quantify their impact on downstream beach water quality. The Ontario Ministry of the Environment funds and administers the components of the management strategy.

Program Objectives

The S.V.C.A. Rural Beaches Program maintained three main objectives:

i) To maintain the recreational usage of the beaches within targeted areas (Penetangore River watershed and the Durham subwatershed)

ii) To develop a cost-effective remedial implementation strategy to alleviate the pollution impacts at the beaches - namely a Clean Up Rural Beaches (C.U.R.B.) Plan

iii) To develop a public information program on targeted areas in order to gain the interest and involvement of the area landowners

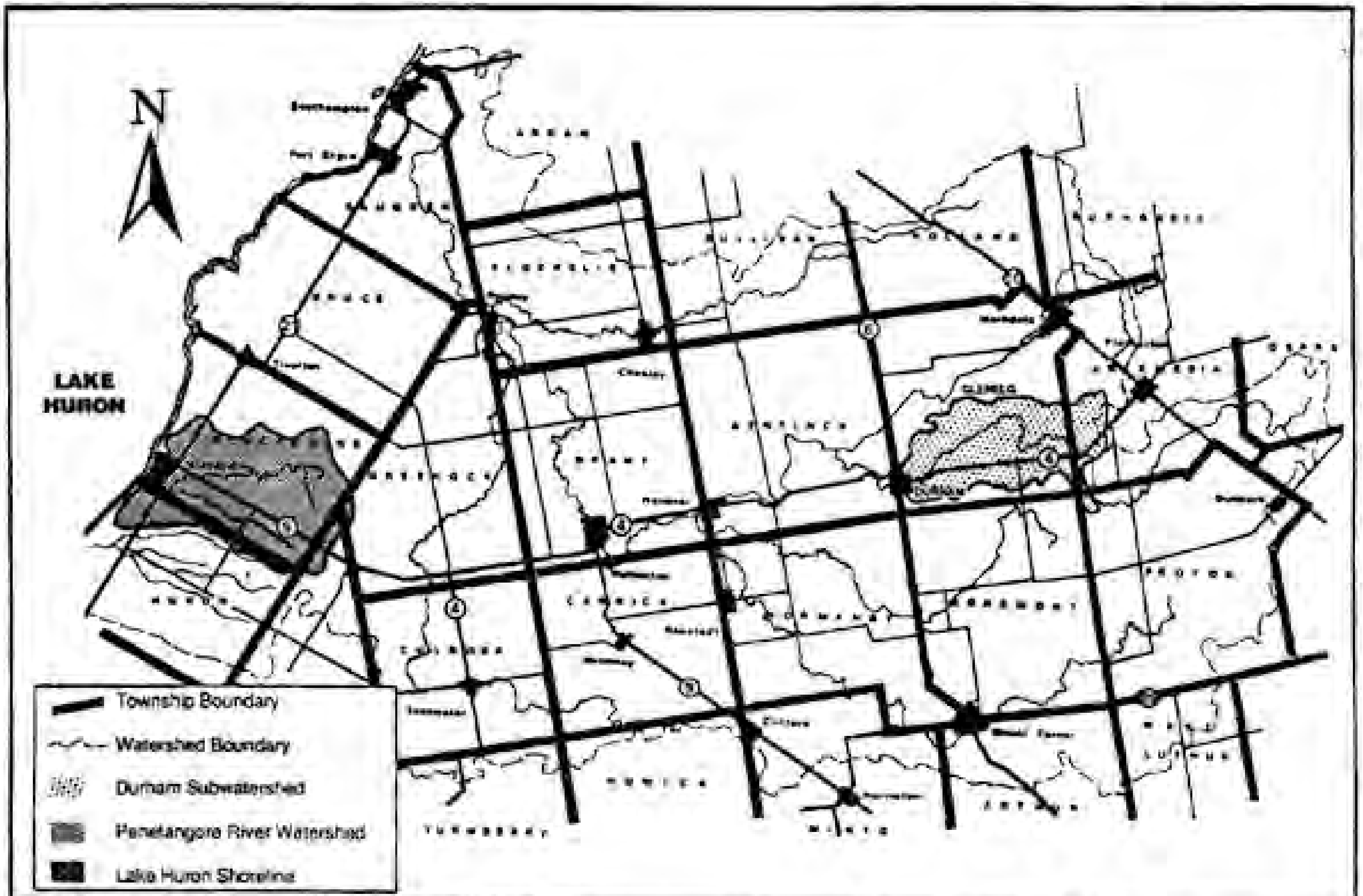
Program Directionality

When the Rural Beaches Program began at the S.V.C.A. in 1988, a targeted investigation began at the Durham reservoir - a Conservation Authority property suffering from reoccurring beach closures (Figure 1). After two years investigation into the potential pollutant sources behind the 1986, 1987 beach postings, a Clean Up Rural Beaches Plan was produced for the Durham reservoir in 1989. Water resource degradation and related health risk impacts at swimming beaches continued to be an area of concern for the S.V.C.A. The Penetangore River watershed was one of the areas noted by the Ministry of Natural Resources as severely degraded, with most of the area in livestock. The river's contents are released into Lake Huron at the Town of Kincardine.

The Penetangore River watershed, was the 2nd area targeted for investigation by the S.V.C.A. due to the potential influence its water quality may have on the outlet beach (Figure 1). A preventative approach was adopted for this study and began by studying land use activities within the watershed. Contributing pollutants to that watercourse were outlined and enumerated while running an extensive water quality monitoring program at several selected sites. As a result, an implementation strategy has been established to reduce the outlined sources of contamination. In this way, preventative studies such as this will help to reduce the likelihood that beaches on Lake Huron will close as a result of unacceptable septic systems or agricultural practices.

Due to the concern shown over the potential hazardous effects of cottage septic systems on Lake Huron's water quality by area landowners and shoreline professionals, a cursory investigation was carried out to ascertain bacterial and phosphorus loadings from this source and its potential impact upon the beach areas. The beach areas investigated are within the S.V.C.A. shoreline and are represented within the Penetangore River watershed investigation portion of the document (Figure 1).

The S.V.C.A. has sanctioned its commitment in the 5 year grant program known as the CURB Program which is funded by the Ministry of the Environment. As of April 1st, 1992 the beginning of the next phase of the Beaches Management Strategy - implementation of the remedial recommendations which have been designed to improve water quality will begin.



Saugeen Valley Conservation Authority

LOCATION OF STUDY AREAS WITHIN THE SAUGEEN WATERSHED

Figure 1

2.0 THE PENETANGORE RIVER WATERSHED

2.1 Introduction

The majority of the freshwater systems which exist within the Saugeen Valley Conservation Authority's (S.V.C.A.'s) watershed are seen as some of the best cold water streams in Southern Ontario. Unfortunately, some of the most severely degraded rivers and streams in the S.V.C.A.'s jurisdiction originate close to Lake Huron and empty their contents into this waterbody. The pollutants that enter these watercourses through land use activities (in this case mainly agricultural) leads to health concerns for the users of beach areas on Lake Huron.

2.2 Study Area - Penetangore River Watershed

<u>Description</u>

The focus of the 1990 Rural Beaches Program was on the Penetangore River basin which outlets into Lake Huron at the Town of Kincardine. This 185 sq. km. watershed lying within Bruce County, is composed of parcels of four townships: Greenock, Huron, Kinloss and Kincardine and the Town of Kincardine.

<u>Physiography/Topography</u>

The watershed is comprised of two physiographic regions: the Huron Slope and the Huron Fringe. Generally, the watershed primarily contains undrumlinized till plains with bevelled till plains to the southwest and central portion of the watershed.

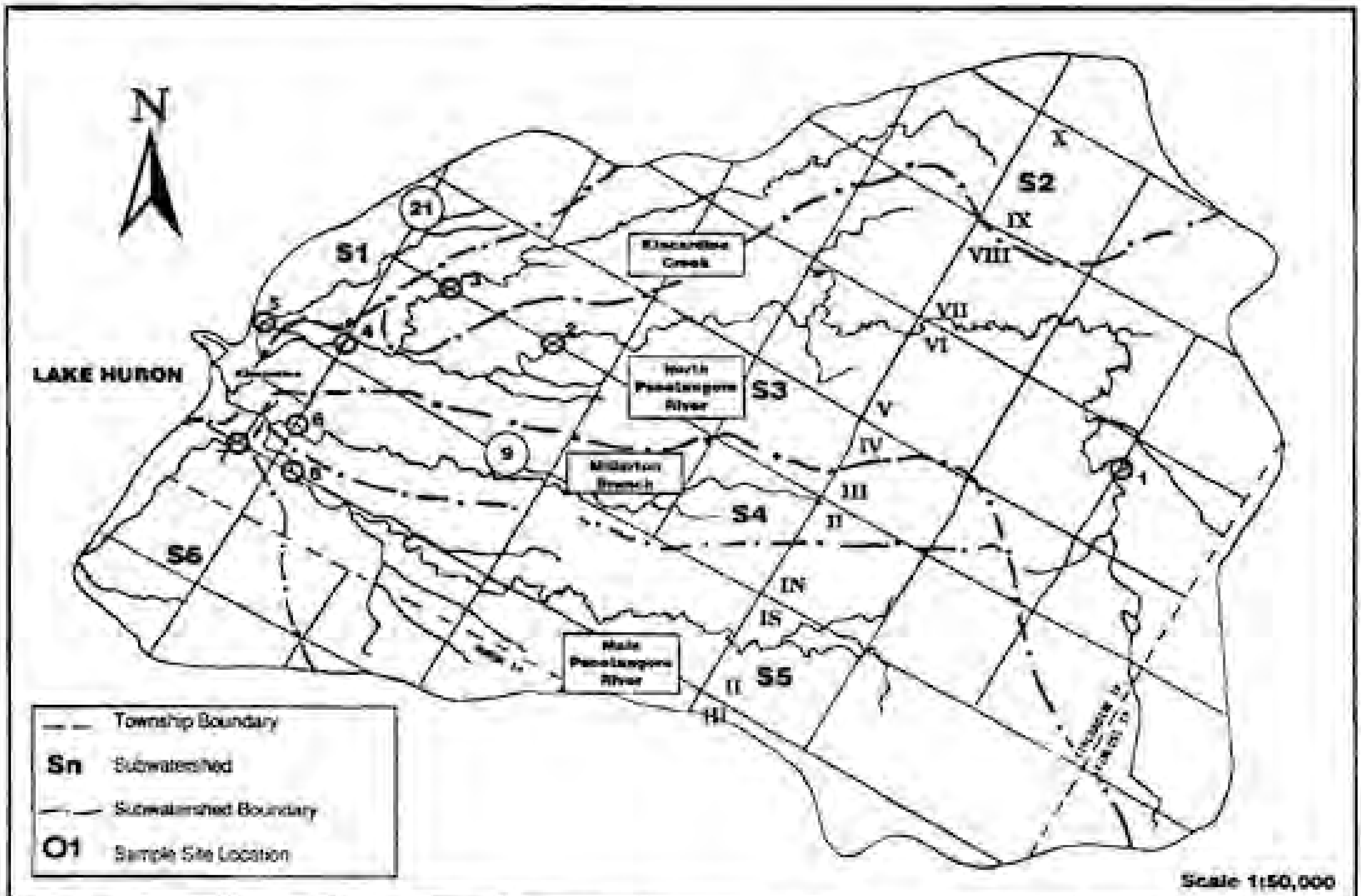
The majority of the watershed's topography consists of smooth gentle to very gentle slopes measuring 1-3 percent. There are some riverine areas with moderate to high slopes measuring 5-20%.

<u>Bedrock and Surficial Geology</u>

The bedrock formation found within the Penetangore River watershed is known as the Detroit River formation. Limestone and dolomite characterize this particular bedrock configuration. The Quaternary geology is mainly St. Joseph Till and is the youngest till found in the area. The composure ranges from clayey silt to silt clay till with very low stone content. The beaches of Kincardine consist of Lake Huron an Lake Nipissing sand and gravel. Older alluvium made up of sand and gravel can normally be found upstream of the river's confluence. Dolostone Detroit River out-crops occur near Kincardine on the Millarton and Main branches of the Penetangore River.

<u>Soil Resources and Agricultural Capability</u>

The dominant soil type is Perth clay loam while a substantial portion is made up of Perth silt loam. The Perth soil series is classified as having imperfect drainage. Scattered within the watershed is Brookston clay loam and dominates only in the southernmost part of the watershed in Huron Township. With natural drainage as it is, it has been to the betterment of the farming community to drain necessary areas through installation of artificial drainage



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THE PENETANGORE RIVER WATERSHED
DRAINAGE SUBDIVISION AND SAMPLE SITE LOCATIONS

Figure 2

systems. Tiling fields and filling in wetlands has been the normal farming practice in this province and the Penetagore River watershed is no exception. It is estimated that 70% of the watershed is tile drained.

According to the Canada Land Inventory rating systems, the watershed has been rated Class 1 in reference to its agricultural capability. This class indicates there are moderately severe limitations that restrict the range of crops that can be grown and suggests the usage of conservation farming practices may be required.

Land use

The entire S.V.C.A. watershed is predominantly agricultural and the area the Penetangore River and its tributaries flows through is well known for its beef production - Bruce County. It has been ranked as the most highly pastured county in Ontario's Southwestern Region (MOE, 1986). The standard type of operation consists of beef cattle and crop production.

The watershed has several hamlets and the Town of Kincardine within its boundary. The tourist industry flourishes along the lakeshore during the summer months, bringing in thousands of visitors every year. Cottages, permanent homes, condominiums and resort developments line the shores of Lake Huron within the jurisdiction of the S.V.C.A.

Water Quality/Quantity

Unfortunately, the Penetangore River system has not been part of the Ontario Ministry of the Environment's Monitoring Network since 1973 therefore, no regular historical data is available from that period until the water sampling program began in May of 1991. Eight routine sampling sites were chosen at areas across the study watershed (Figure 2).

The Penetangore River and its tributaries do have a history of not meeting Ontario's guidelines bacterially for water quality. Evidence of this was seen during the S.V.C.A. Rural Beaches Sampling Program. The Rural Beaches Sampling Program carried out chemical and bacteriological sampling for every two weeks for lab analysis. Non-routine sediment and parasitology sampling also took place. When sampling from May to October, 1991 at 8 regular sampling sites, (excluding beach samples) geometric means for fecal coliform (fc) bacteria exceeded the Ontario Ministry of the Environment guideline of 100 fc/100 ml. (OMOE, 1984) at all stations with the exception of station 4 (Figure 3). Reoccurring Pseudomonas aeuriginosa (a disease causing organism) was also found at several stations in relatively high numbers.

Generally, the sampling program highlighted the bacterial problem inherent in the river system. The non-routine segments included sediment collection which also tested for the presence of Giardia and Cryptosporidium. The ensuing data only reinforced that the Penetangore River system has a bacterial water quality problem and is also susceptible to parasitology presences.

The Penetangore River has characteristically low flows in the summer months with annual rates ranging from 0.00 cm to 12.0 cm in a normal year.

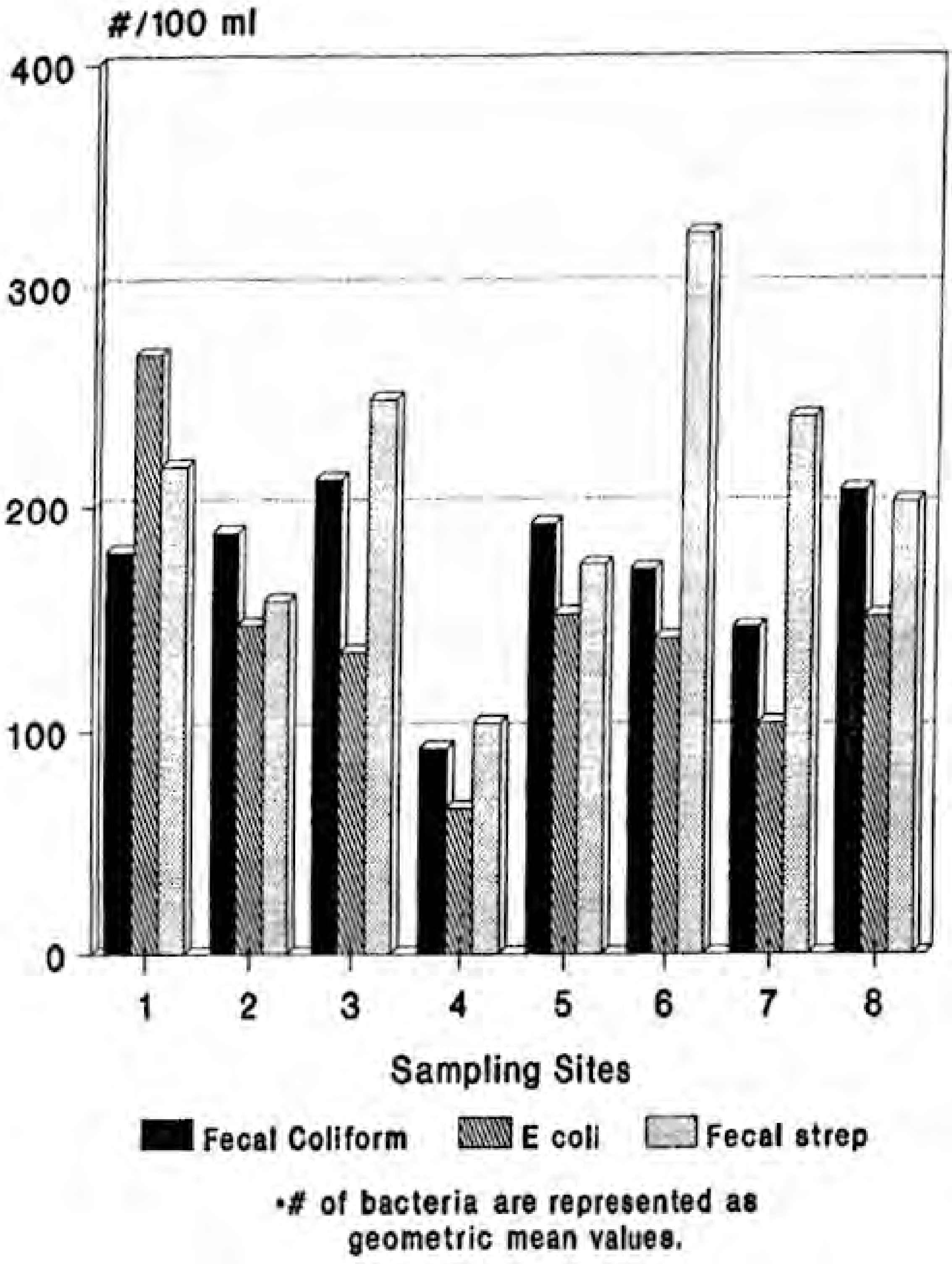


Figure 3: Penetangore River - 1991: Bacteriological Data Results*

2.3 The S.V.C.A. Lake Huron Shoreline

Description

The Lake Huron shoreline within the S.V.C.A.'s area of jurisdiction consists of an 80 km. stretch that extends from Point Clark in the south and north to Southampton. This physiographic region is known as the Huron Fringe. The soils are composed of sand and gravel and generally, from Inverhuron Bay southward. Net alongshore movement of sediment is to the south (Reinders, 1990). It is estimated that about 7,000 -10,000 cottages are located along this stretch of shoreline. Virtually all cottages are on septic systems.

Water Quality at the Beaches

The beach water quality data enlisted for this study were utilized from the Bruce-Grey Owen Sound Health Unit. They seasonally monitor beach water bacteria along selected swimming beaches of Lake Huron (Appendix 1). During the swimming season, the Health Unit normally monitors twice monthly.

Along the shoreline, the majority of bacterial samples over the last several years have found concentrations under the M.O.E. guideline of 100 fc/100 ml. of water sample although high bacterial counts have been recorded throughout the sampling program. Bacterial beach water sampling over the last 4 years for Station Park Beach have had samples over the guideline a number of times over the last several years (Tables 1 & 2). Wind and wave activity have presented potential health hazards at the beach by stirring up lake bottom sediments and increasing the amount of bacteria in the water column. For example, at Station Park, July 27, 1989, the geometric mean for fecal coliform stood at 826 fc/100 ml. due to an expected severe summer storm.

In the northern reaches of the shoreline, pollutants are potentially trapped within headland/bays that exist there; southern reaches have a general tendency to convey pollutants southward due to the alongshore transport (G. Peach, SVCA, pers. comm.). Bacterial survival or die-off rate in Lake Huron sediments has been noted at at least two months in length (O.M.O.E., 1985).

Beach Closing History

Looking at the beach closings at Kincardine only, August of 1988 saw Station Park Beach posted for almost the entire month due to a number of problems with the Town's sewage treatment plant which discharges into Lake Huron.

2.4 Livestock operation and rural residence surveys

Livestock farms were rated as high or low priority. Those operations within 150 metres of a permanently flowing watercourse within the study area were designated as high priority. This distance was established upon the 122 metre nutrient attenuation distance investigated in the PLUARG activities (Robinson and Draper, 1978). The critical zone was increased due to the lack of surface cover, and the soil infiltration capacity and texture.

Table 1: 1990/91 Beach Sampling Results For Lake Huron Within The SVCA Shoreline That Exceed The Moe Guideline Of 100 fc/100 ml.

Locations sampled	Date	Geometric mean #fc/100 ml
Inverhuron public Beach	August 27, 1991	105
Inverhuron Provincial Park	July 5, 1991	266
Boiler Beach	May 27, 1991	145
Poplar Beach	May 27, 1991	821
Station Park	July 19, 1990	161
Station Park	May 27, 1991	135
Huron Ridge	July 19, 1990	238
Huron Ridge	May 27, 1991	110
Lansdowne Park	July 5, 1990	120
Lansdowne Park	July 12, 1990	213
Lansdowne Park	May 27, 1991	373
Miramichi Bay	July 15, 1991	156
MacGregor Point Prov. Park	June 4, 1991	150
Port Elgin	June 4, 1991	158
Southampton	July 8, 1991	699

Table 2: Station Park Beach: Beach Water Quality Data From 1988-1992 Samples Which Exceed Moe Guideline

Date sampled	Geometric mean (#fc/100 ml)
May 27, 1991	135
July 19, 1990	161
July 27, 1989	826
July 7, 1988	244
August 9, 1989	105
August 3, 1988	299
August 4, 1988	270
August 5, 1988	234
August 6, 1988	617
August 9, 1988	166

Those outside the 150 metre setback were denoted as low priority. The high priority operations were those surveyed. Ninety livestock operation surveys were mailed as well as 37 rural residence surveys. (Residences on sewers were excluded.)

Information on livestock operations, manure management practices, milkhouse operation, septic system age, installation and maintenance behaviour and general information was gained from the surveys. A summary of these results are found in Table 3. Information gained from the livestock surveys that were completed (76%) was utilized in the CURB model.

Table 3: Summary of survey information from identified high priority livestock operations in Penetangore River Watershed & the Durham Subwatershed

	Penetangore	Durham
study area (km^2)	185.11	117.8
high priority livestock operations(#)	90	22
% surveyed	76	43
density (#/km^2)	0.49	0.19
Livestock Access		
access sites (#)	46	20
density (#/km^2)	0.25	0.17
average hours	24	20
average length	331	167.5
average animal units	56	48
Milkhouse Wash wawater		
discharge sources (#)	2	-
density (#/km^2)	0.01	-
average discharge	125	-
Feedlot/Manure		
runoff sources	26	15
density (#/krn^2)	0.14	0.13
storage area (sq.ft.)	135,026	-

3.0 THE PENETANGORE RIVER WATERSHED CLEAN UP RURAL BEACHES MODEL

3.1 Purpose of the CURB Model

The Clean Up Rural Beaches Model quantifies pollutants from:

1) milkhouse waste discharges
2) livestock access to watercourses
3) manure stack/feedlot runoff
4) winter and summer manure spreading
5) unacceptable septic systems
6) urban non-point sources
7) sewage treatment plants
8) manure spills/discharges
9) wildlife
10) the effects of liquid manure and tiling

The model predicts the impacts of those inputs listed above on the local watercourse or drain and the downstream beach for fecal coliform bacteria and phosphorus.

3.2 Model Development

In order to produce a Clean Up Rural Beaches (CURB) Plan, an assessment of all potential pollution sources that would contribute to the degradation of beach water quality had to be produced. To quantify these sources a modelling theory was utilized. A model is an assembly of concepts in the form of one or more mathematical equations that approximate the behaviour of a natural system or phenomena (McCutcheon, 1989).

The mathematical equations are written in a algorithmic form and can be computer coded. This customized model was taken from the Pollution from Livestock Operations Predictor (PLOP) Model produced under contract to the Ministry of the Environment (Ecologistics, 1988). This model can be labelled as a one-dimensional model which is the most common approach to describing stream water quality (McCutcheon, 1989). This model primarily predicts the impacts of agricultural sources on water quality although significant urban factors have also been included. Fecal coliform and phosphorus were measured. Modifications to the P.L.O.P. model were needed and was therefore further developed and refined (Bos, 1988).

After these modifications, generally similar CURB Models were applied by the Conservation Authorities participating in the Rural Beaches Program (i.e. Hocking *et al*, 1989; Hayman, 1989; and Fuller *et al*, 1989). This model has been primarily formatted under the Upper Thames River Conservation Authority's CURB model (Hayman, 1989) and is depicted in Table 4. Since occurrences of elevated bacteria and algal blooms exists in both the study watercourse and the beach area, both phosphorus and fecal coliform were modelled for. The survey information was averaged to depict a typical situation for the Penetangore River watershed and then calculated into the corresponding algorithm. The concept of averaging flows and loads is one used in steady state water quality models (McCutcheon, 1989).

Table 4: CURB Model

CONTINUOUS

Livestock access (access)*

	# of farms x	#/defecations (kg)	prob of	defecations x	# of waterings x	days of access x	% of days x	# Of animal units
fecal coliforms	Survey	8.90 x 10^{8}	0.10		2.50	180.00	Survey	Survey
total phosphorus	Survey	1.20 x 10^{-2}	0.18		2.50	180.00	Survey	Survey

Milkhouse (milk)

	# of farms x	volume/day x	# liters x	discharge days x	growth
fecal coliforms	Survey	Survey	2000	365	500
total phosphorus	Survey	Survey	35		

Unacceptable Septic systems (permanent dwelling) (septics)

	# of homes x	1/person x	people /house x	#/1(kg/) x	% faulty x	discharge days
fecal collforms	Survey	137.00	2.8	1.00 x 10^{7}	0.30	365.00
total phosphorus	Survey	137.00	2.8	3.00 M 10^{-5}	0.30	365.00

Unacceptable Septic system (cottage)

	# of cottages x	1/person x	# people/cot x	#1(kg/) x	% faulty x	discharge days
fecal coliform	Survey	137.00	2.4	1.00 x 10^{7}	0.01	144
total phosphorus	Survey	137.00	2.4	3.00 x 10^{-5}	0.01	144

Sewage Treatment Plant - 1991 conditions (STP)

fecal conforms	STP information
total phosphorus	STP information

PULSE

Manure/Feedlot (runoff)

	# of problems x	# /ha-mm (kg/)	store area (ha) x	rainfall (ha-mm) x	delivery
fecal coliforms	Survey	5.00 x 10^{9}	Survey	600	0.70
total phosphorus	Survey	0.25	Survey	600	0.70

Manure Spread

Total Produced		
	Vol. Produced x	5.0 x10^{11} (#/m^2)
	Vol. Produced x	0.662 (kg/m^2)

winter (spr.w)

	total x % Vol.	produce x op.	spread x	amount spread	x delivery to	stream x storage sur. x	field survive
fecal coliforms	above calc'n	0.25	0.21	0.75	0.032	1.00 x 10^{2}	3.40 x 10^{2}
total phosphorus	above calc'n	0.25	0.21	0.75	0.032		

spring, summer [1] & fall (spr. S)

Total (vol. left	- minus access)	x op. overspread	x amount overspd.	x delivery to stream x	field x stor. surv
fecal coliforms	See	0.05	0.25	0.012	3.40 x 10^{-4}
total phosphorus	above	0.05	0.25	0.032	

Urban Non-Point Source (urban)

	Area (ha) x	rain (mm/ha) x	#/m (kg/)
fecal coliforms	Town of Kincardine	2845	1.10 w 10^{7}
total phosphorus	Town of Kincardine	2845	9.00 x 10^{5}

NOTE:

* (short form)

1 - Summer spreading denoted spr.su in graphical analysis

3.3 Pollutant Sources / Boundary Conditions

Boundary conditions are the set of data that describe the mass and energy that enters the model domain ie. load and flow (McCutcheon, 1989). The pollutant sources or boundary conditions of this model are listed below. The information in the brackets distinguishes between sources that continuously discharge in low flow (dry) conditions or discharge in pulses in high flow conditions (event induced). Flow was not incorporated into the boundary conditions but was utilized in the decay rate procedure and the validation process.

Agricultural

1) livestock access to watercourses (continuous)
2) milkhouse washwater (continuous)
3) manure storage/feedlot runoff (pulse)
4) manure spreading (pulse)

Non Agricultural

1) septic systems failures (continuous)
2) urban storm sewer runoff (pulse)
3) sewage treatment plant discharges (continuous)

The manure spills algorithm was not incorporated into the model since no spills were reported in Bruce County in 1991 (L. Struthers, MOE, pers. comm.). Loadings from wildlife were not quantified due to the fact that there are no significant wildlife populations in the watershed and natural areas account for less than 25% of the study area (Bos, 1988). The impact of liquid manure and extensive tiling was not quantified due to the fact that all surveyed farmers at the time were on solid manure systems.

3.4 Bacteria die off rates and transport

Bacterial reduction occurs in downstream transportation. A number of factors reduce the survival of bacteria in the water column such as nutrient levels, temperature, pH, etc. The actual amount delivered to the beach is a small proportion of that that enters the watershed system.

Die off rates for bacterial survival were estimated in an effort to quantify the actual amount of bacteria that would enter Lake Huron (from its watershed sources) at the Town of Kincardine annually and for the swimming season. Working under the assumption that all sources are uniformly distributed throughout the watershed, travel time for bacteria was calculated using the watershed midpoint to the beach (Hayman, 1989).

Travel times for contaminants to reach the beach area were calculated using two regimes: a low flow regime and a high flow regime. Since no gauging equipment is maintained for the Penetangore River, travel times were determined using the American Soil Conservation Service (SCS) method for estimating the time-of-concentration for the study watershed. The time-of-concentration is measure of the time for a particle of water to travel from the hydrologically most distant point in the watershed to the point of interest (McCuen, 1982). The point of interest is the beach area of Lake Huron at the outlet of the Penetangore River.

Curve numbers were generated, again using the SCS method, where low flow conditions were assigned antecedent moisture condition I (dry soils) while antecedent moisture condition III was assigned for the high flow model. The centroid travel time associated with event conditions is 27.175 hours while low flow or dry conditions travel time is 84 hours.

Based upon the findings of various studies, the decay rate used in this model was 0.0146 logs/ hour. The die off estimate for the Penetangore River watershed is consistent with the Ausable River water column die off rate of 0.0158 logs/hour, 0.0091 logs/hour utilized for river bacteria die off rates seen in the Upper Thames River Conservation Authority CURB Plan and the range of seasonal values listed in the Maitland Valley Conservation Authority CURB Plan. Die off rates for bacteria sources were calculated under low flow (daily) conditions and during high flow (event) conditions.

The log decay formula utilized was:

$$N = n \times 10^{-kt}$$

where k = die off rate
t = travel time
n = # bacteria

The frequency of events was assumed to be approximately 15 days of the year. That is, precipitation greater than 20 mm., or enough to generate runoff from the Penetangore River watershed (D. Pybus, SVCA, pers. comm.) occurs 15 days in a calendar year. Without a gauging station on the Penetangore River, the Greenock Precipitation Station gauging data was reviewed to also define event days. Four events were estimated to occur in the summer season or between June 15 to September 14. These dates were standardized with the PLOP model (Ecologistics, 1988).

The die off calculation for event conditions incorporated the formula shown above with an event travel time of 27.175 hours and a low flow travel time of 84 hours. 'The total number of bacte-ria at the source was then multiplied by the die-off factor. The beach impact was calculated for each source ie. livestock access bacterial total, milkhouse washwater bacterial total, etc.

Beach bacterial load
for each source = [(Source bacterial load)(die off rate)]
x % of year in low or high flow regime

3.5 CURB Model Predictions and impacts

This report displays bacteria in an exponential format. For example, 2.04 E+04 is the same as 20400.

Penetangore River watershed - Annual contribution

a) Bacteria

Figure 4 displays the annual bacterial input at its source and delivery to the beach in both high (event situations) and low flow (dry) situations. The principle contaminant is unacceptable septic systems. By examining Figure 4, it is evident that for the sources of livestock access, unacceptable septic systems, milkhouse washwater discharge and sewage treatment plant discharge, dry weather bacterial inputs are far greater than wet weather inputs. About 1.6% of the source contaminant bacteria is estimated to reach Lake Huron under high flow conditions. Three times as much, or 5.5% of the bacteria is delivered to Lake Huron under low flow conditions. It would seem evident that the majority of bacteria is discharged under dry weather conditions. Figure 5 depicts the annual contri-butions to Lake Huron. In order of their contribution to Lake Huron:

Unacceptable septic systems	81.58%
Livestock access	17.65%
Sewage treatment plant discharge	0.72%
Manure runoff	0.04%
Urban non-point source	0.01%

Manure spreading in all seasons, and milkhouse washwater fell below 0.01% annual contribution to Lake Huron. These sources appear to have a limited impact upon the beach area. It appears that unacceptable septic systems and livestock access to watercourses are the greatest bacterial contribu-tors to Lake Huron for the Penetangore River watershed.

b) Phosphorus

Phosphorus loading by source to Lake Huron has shown septic systems to be the leading source an estimated 3111 kg on an annual basis with the urban non-point source component estimated as extremely low, 0.09 kg. per year. Figure 6 depicts the sources annual contribution as a percentage. The three significant factors seem to be unacceptable septic systems - 73.89%, sewage treatment plant discharges - 18.74% and livestock access at 6.78 percent. The remaining sources are all below 1 percent in contribution.

Soil erosion was not addressed in the model but should be recognized as a leading factor in phosphorus loading to watercourses (D. Hayman, MOE, pers. comm.).

Penetangore River watershed - Summer contribution

a) Bacteria

A breakdown was also estimated for bacterial inputs into Lake Huron at the Penetangore River outlet during the summer season (Figure 7). This was primarily done in order to evaluate the impacts around swimming season time. Unacceptable septic systems summer contribution was the greatest at 1.83 E+13 with the lowest contribution from summer spreading at 5.51 E+07. Due to the typical pasturing season (May-October), access contributes the greatest

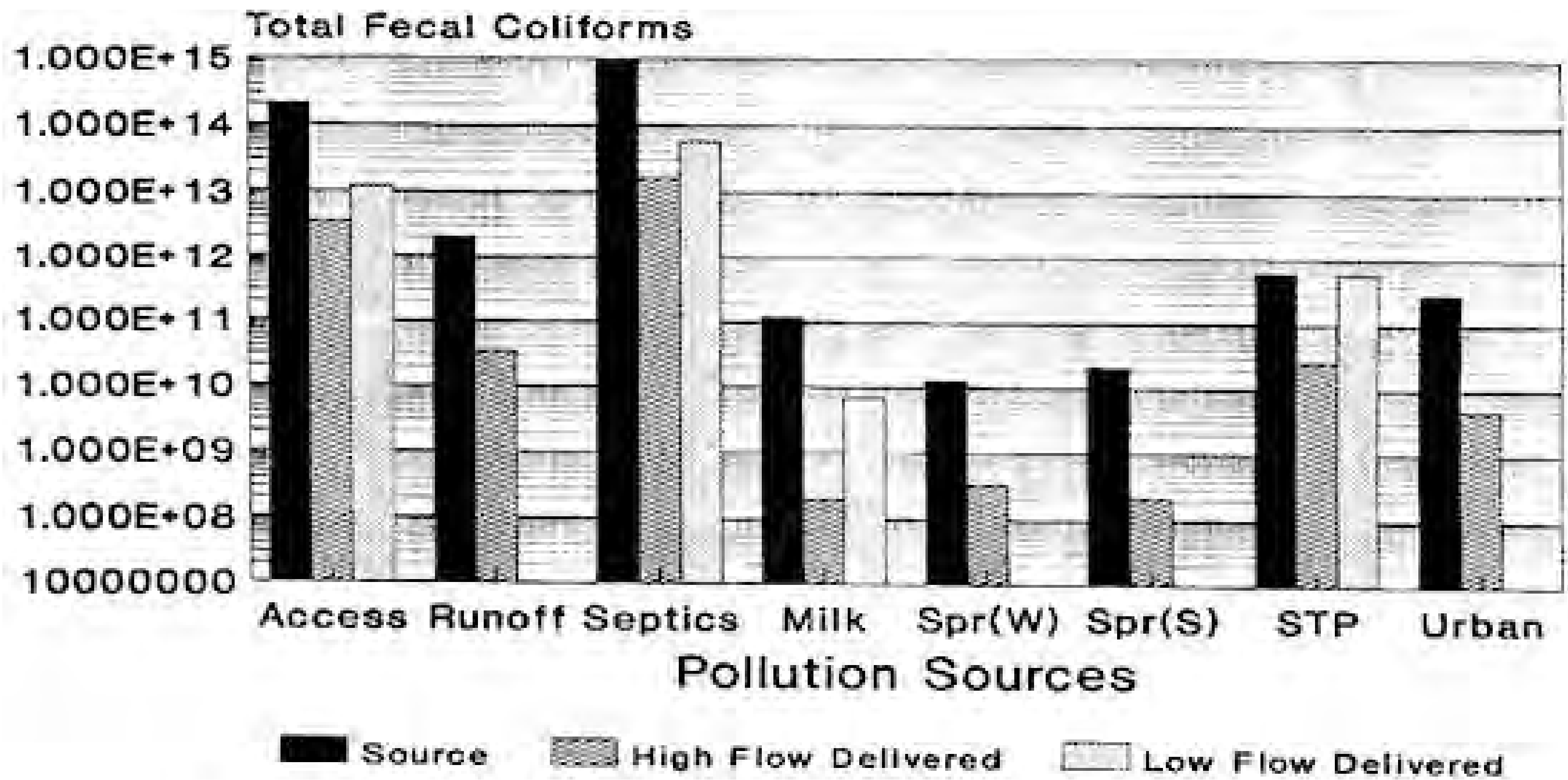


Figure 4: Penetangore River - Bacteria Source Input vs Bacteria Delivered to Lake Huron Annually

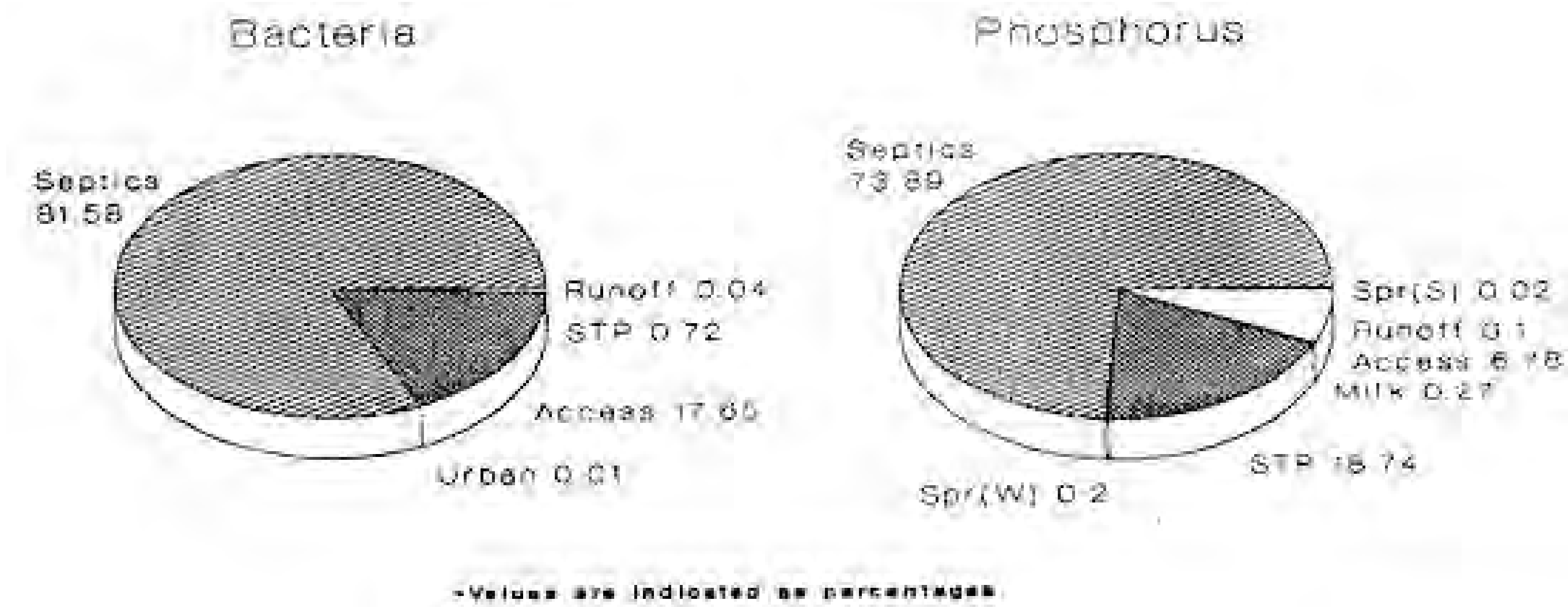


Figure 5: Penetangore River - Annual Contributions To Lake Huron*

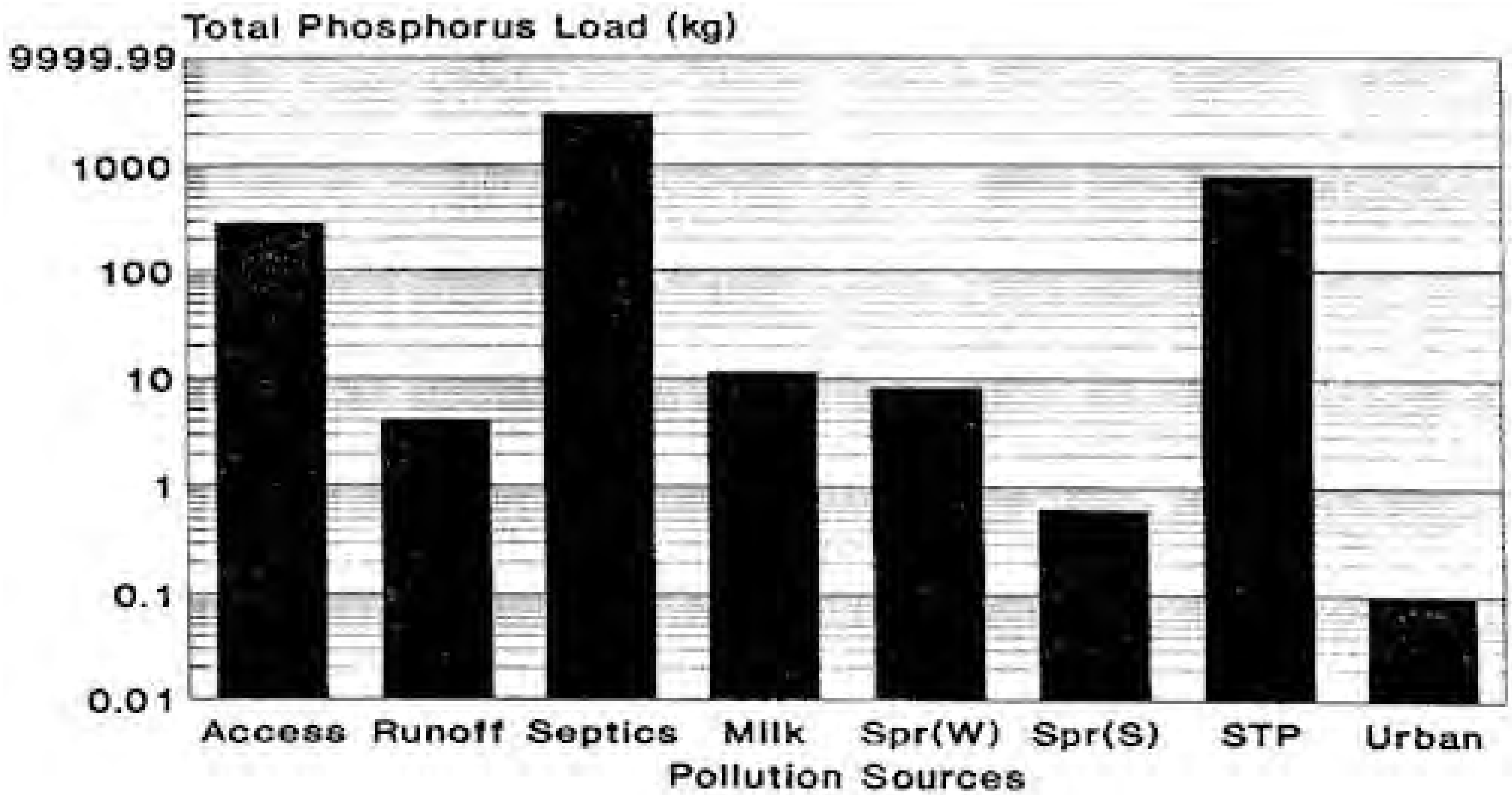


Figure 6: Penetangore River - Phosphorus Loading by Sources Delivered to Lake Huron Annually

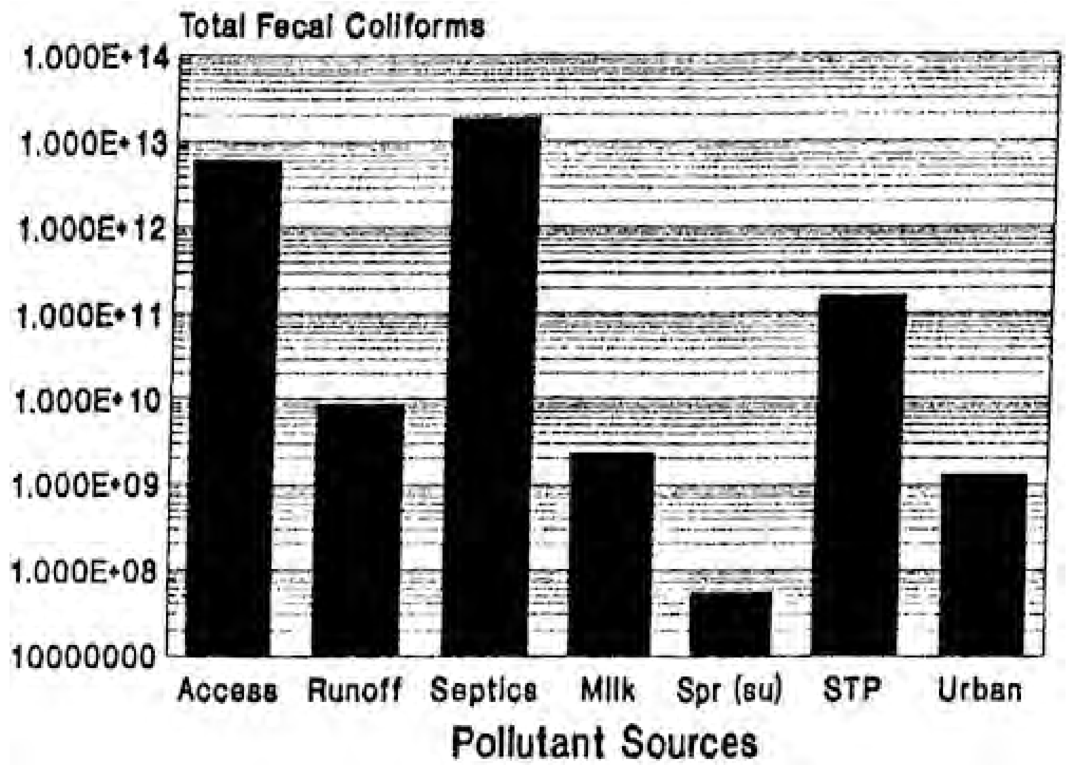


Fig. 7: Penetangore River - Summer Bacteria Contribution to Lake Huron

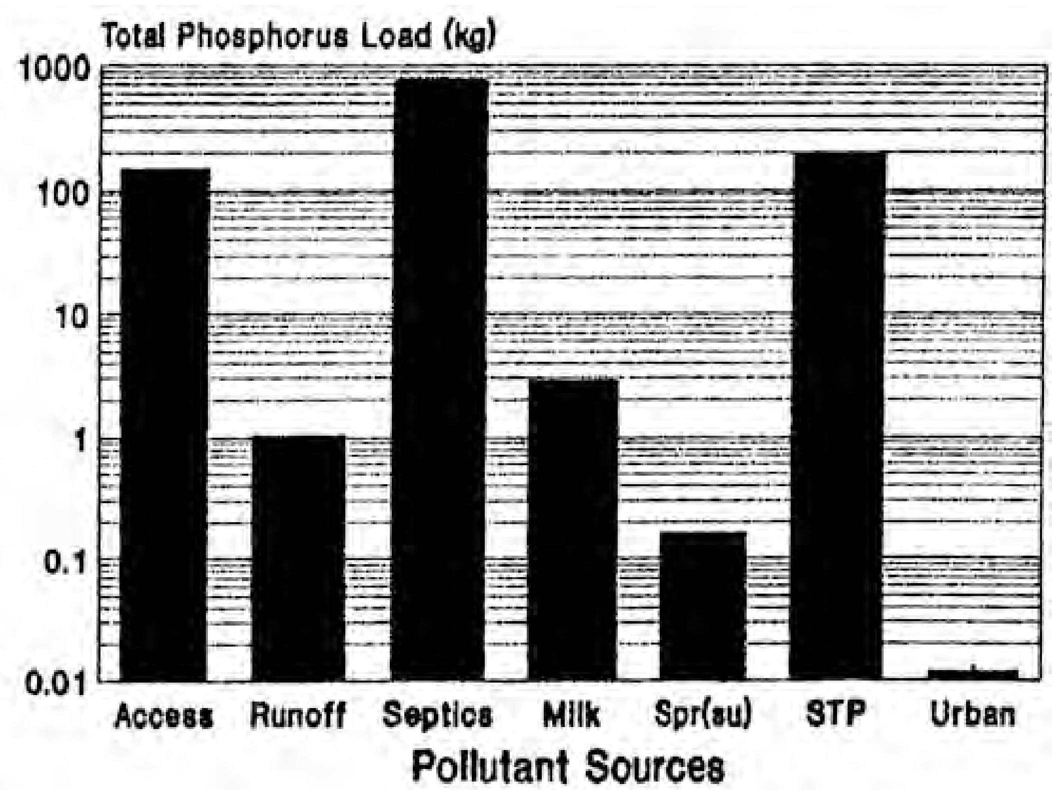


Fig. 8: Penetangore River - Summer Phosphorus Contribution to Lake Huron

percentage of its bacteria load throughout the summer season than any other source. In summer, approximately 52% of the livestock access bacteria total is delivered to Lake Huron.

It is important to note that winter spreading was not included in the summer contribution model due to the lack of information on bacterial survival in Lake Huron sediments and having recognized that the MOE 1985 study noted survival in Lake Huron sediments at least 2 months. If winter spreading occurred as late as March, all or most bacteria would have died off by May. The author does not eliminate the possibility of potential impact from this source on the swimming season.

b) Phosphorus

Phosphorus contributions according to source is illustrated in Figure 8. Unacceptable septic systems remain the leading contributor at 749 kg. but sewage treatment plant discharge now runs a close second with livestock *access* - 199 kg. and 146 kg., respectively. The other sources contributions for the summer season all remain below 3 kg.

S.V.C.A. Shoreline - Annual contribution

a) Bacteria

With an estimated 1% of the lakeshore cottages with faulty septic systems (J. Patton, Health Unit, pers. comm.), approximately 4.7 E+13 fecal coliform bacteria enter Lake Huron (Figure 9). This amount is about half the total annual fecal coliform contribution to Lake Huron from the Penetangore River watershed. With the cottages on the lake there is no significant die-off factor therefore, 100% bacterial entry into Lake Huron was assumed.

b) Phosphorus

The phosphorus load annually delivered from unacceptable cottage septic systems is 141 kg. (Figure 10).

S.V.C.A. Shoreline - Summer contribution

a) Bacteria

Approximately, 3.0 E+13 fecal coliform bacteria enter Lake Huron as a result of unacceptable septic systems (Figure 7). The bulk of the annual bacterial contribution is realized in the summer months at 64%.

b) Phosphorus

The phosphorus load delivered from unacceptable cottage septic systems is 90 kg (Figure 10).

3.6 CURB Model Validation

Validation testing for the CURB model was carried out in order to evaluate the accuracy of the model's predictions. The predictions were matched against actual field measurements and

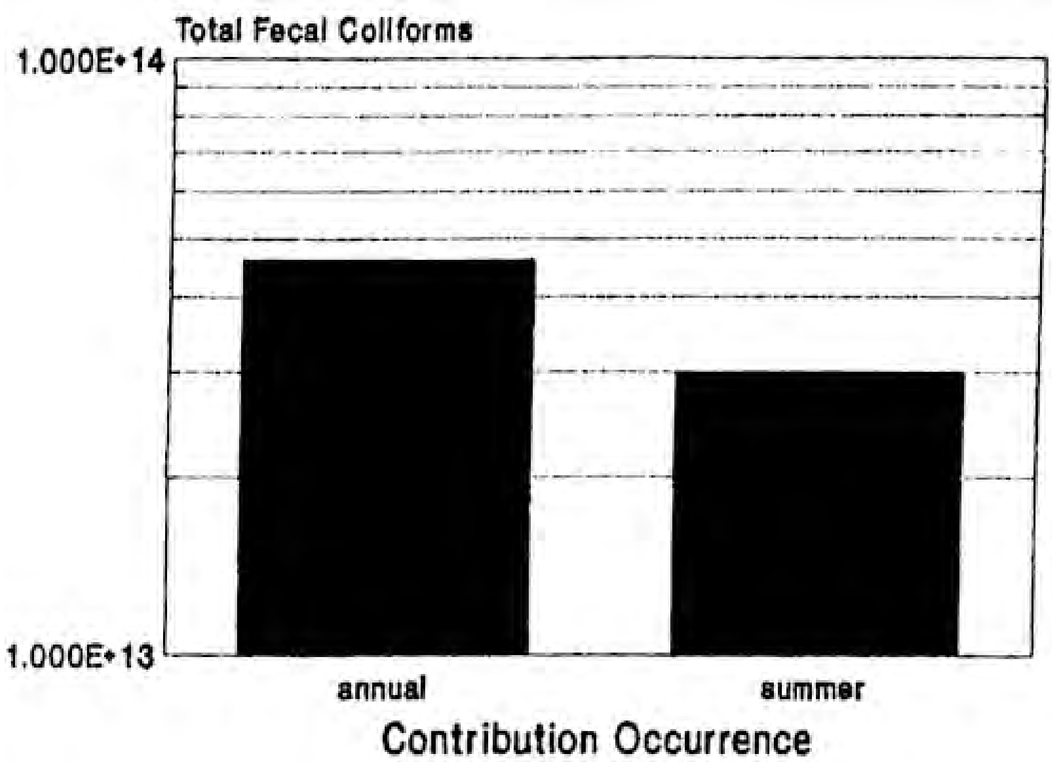


Figure 9: Lakeshore Cottages - Bacterial Contributions to Lake Huron

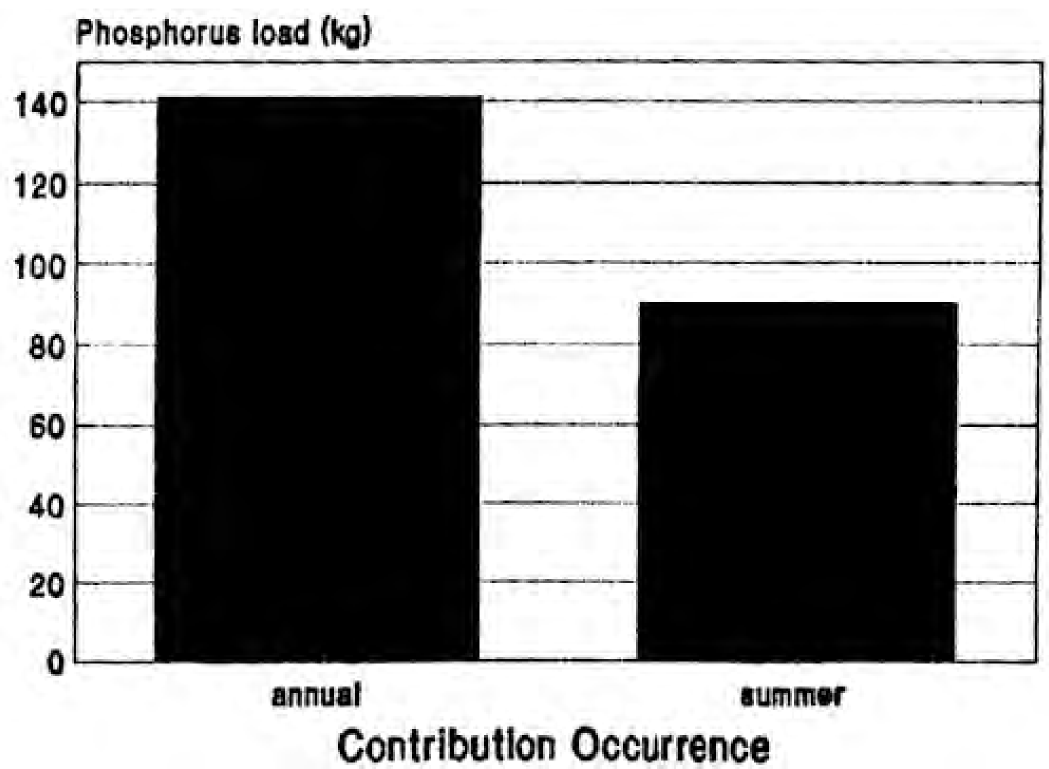


Figure 10: Lakeshore Cottages - Phosphorus Contributions to Lake Huron

then analyzed. It is important to note that this validation process should not be confused with typical stream water quality models' verification or confirmation testing, Once the empirical coefficients were established they were not re-calibrated according to the field data found in the validation process.

This process tested bacterial CURB model predictions only. Phosphorus CURB Model validation could not be completed using this method due to a lack of field measurements for this parameter at the beach site. The high flow CURB Model prediction was estimated at 1.32 E+12 # FC/day while the low flow CURB Model prediction was evaluated at 1.96 E+11 # FC/day. These numbers served as the prediction factors used in the process.

Field measurements consisted of pro-rated stream discharge data and bacterial water quality data obtained through the Bruce-Grey Owen Sound Health Unit. With no gauging station on the Penetangore River, discharge values were derived by pro-rating the discharge values of the Pine River. This river flows directly south of the Penetangore River and shares pertinent hydrological characteristics with the Penetangore River. The gauging station at Lurgan Beach was expressed for the Penetangore River through this process. The beach water quality sampling data (measured in geometric means) at Station Park Beach for the years 1988-1991 was used for the validation process. With alongshore net movement of sediments moving southward, Station Park Beach water quality data was chosen rather than the beach site north of the outlet point in the Town of Kincardine.

Results

This process found that the field measurements were for the majority, below the low flow CURB Model predictions. This process has demonstrated that the CURB model overestimates the contributions made to Lake Huron bacteriologically. Analysis also found that concentrations of bacteria are higher in low flow conditions.

Many factors combine to make the modelling exercise a complex one. Many influences may effect the model predictions:

1) number and variability of sources
2) tile drainage impacts on contaminant transportation and decay rates for bacteria
3) deposition and resuspension of bacteria in water column and beach sediments
4) the impact of winter spreading on summer beach water quality
5) consistent low flows characteristic of the Penetangore River system may restrict the actual amount of contaminants that would be transported along in the water column.

Measurement errors, conceptual errors in equations or approximation errors due to the nature of the model may also cause discrepancies between predictions and validation data. Measurement uncertainty can be estimated using a first order error analysis or sensitivity analysis (Brown *et al*, 1987). One such analysis was carried out by the Maitland Valley Conservation Authority (Fuller *et al*, 1989) who found that variations to the concentration of fecal coliform bacteria shows the most significant variations when altered. This would establish that errors that would have significant prediction variation would be within the fecal coliform bacteria portion.

Considering these factors and their potential to skew model forecasts, the predicted loads for the beach appear to be reliable for the sources included into the model. With the degree of variability inherent in the system, loads must be considered as estimates only.

3.7 CURB Model Limitations

1. Since non-point sources cannot typically be measured, only estimates may be derived.

2. The limitations of the empirical derivations have not been clearly defined by the authors.

3. As stated in section 3.6, a number of factors or outside variable can potentially influence the model predictions

4.0 THE DURHAM SUBWATERSHED

4.1 Introduction

Significant fisheries resources and recreational opportunities characterize many areas within the Saugeen River watershed. Water quality in a number of tributaries and parts of the main river cannot be compared to the more seriously threatened southern Ontario streams. Despite these generalizations, there are areas of serious concern in the Saugeen system and the main river itself is prone to considerable fluctuation in water quality.

In light of the hazard posting in 1986 and 1987 closure of the swimming areas in the Durham reservoirs, a more critical examination of water quality was warranted. The Saugeen Valley Conservation Authority's Rural Water Quality Program is funded by the Ontario Ministry of the Environment, the objective of the program was to assess the impact of various diffuse pollution sources on recreational swimming areas.

4.2 Description

McGowan Falls or the Upper Durham dam was formerly known as the Edge's Mill dam. The instream reservoir that was created by the installation of the first control structure in 1847 provided hydraulic power for various milling operations. The mills burned in 1887, but were replaced the following year by McGowan's mill which utilized the same power source.

The original Middle Durham dam was constructed in 1909 to utilize water power for an oatmeal mill. After washing out, the control structure was rebuilt in 1911. Several mill structures have been built and burned on the site over the years. In 1938 the milling operation was bought by Knechtel Mills of Hanover and electricity replaced the hydraulic power source. The dam structure deteriorated until it was reconstructed in a slightly westward location for flood control and recreation purposes.

Use of the Durham reservoirs intensified with the development of the conservation area park camping and recreation facilities. The beach areas are heavily utilized by Durham residents, campers and the local recreational department for swimming lesson facilities.

The rolling moraine topography leaves much land unsuitable for agriculture and remains forested with some recreational usage. Small to medium sized farm operations utilize mainly pasturing systems and cropping areas where suitable.

The first year of the study characterized the watershed as a moderately impacted area with land use restricted by topography and drainage. Considerable natural areas provide riparian buffer zones throughout the drainage basin.

4.3 Water Quality History / Beaches Closures

The Grey-Bruce Owen Sound Health Unit routinely samples public swimming areas once per week, but the Durham beaches have been sampled twice per week during swimming lesson use periods. In the summer of 1986, complaints of ear infections by swimmers at the Durham Conservation Area prorated an increase in sampling intensity to three times weekly for fifteen sites.

Analysis results showed that mid-July water quality at the McGowan Falls swimming area had exceeded the provincial criteria for fecal coliform 6 out of 12 days. *Pseudomonas Aeruginosa* was isolated in 6 out of 8 days analysed. Samples at the Middle Dam swimming area exceeded the provincial criteria on 5 out of 12 days while PsA was isolated 7 out of 7 days.

The interpretation by the Health Unit was that 48 hours of heavy rain had washed contaminants into the watercourse and resulted in a very high bacteria count on July 17, 1986. In summary, the Health Unit stated that the fecal coliform count at times exceeded guidelines. The known pathogen PsA had been isolated at a time of ear infection reports and no testing had been done for agricultural chemicals which could be a health hazard.

Recommendations by the Health Unit were to post all swimming areas stating that "Bacterial Levels May At Times Exceed Provincial Standards" - "Swim At Your Own Risk" and to consider suspending swimming up to 24 hours following severe rain storms.

On July 23, 1987, the Director of the Health Unit called to inform that the geometric mean fecal coliform bacteria analysis of the swimming area water samples had exceeded the provincial criteria over the past 7 sampling days. The situation had been discussed with the Medical Officer of Health and it was decided the reservoir areas should be posted with "No Swimming" signs.

Daily sampling was conducted by Conservation Authority and Health Unit staff beginning on July 4. Analysis of samples from all three swimming areas for the period July 22 to July 30 showed geometric mean levels well below the provincial guidelines. The signs were removed and the beaches were reopened to the public on July 31. Ironically, July 31 sample results showed geometric mean levels again exceeding the criteria. The next samples were taken after the long weekend on August 4 and showed lower levels, but still in exceedance of the criteria.

4.4 The Durham Subwatershed Sampling Program

Twelve routine sampling stations were established as part of the study in (Figure 11). From 12 stations on the subwatershed, over 400 water samples were collected for analysis between August 8 and December 6, 1988 (Appendix 3). Nine of the twelve stations were within the MOE recreational use criteria more than half the time. The highest FC count observed during the sampling period was 71500 org/100 ml. at station No.1 in mid-August while some of the best water quality was observed at station 12 on the main river just above the swimming areas.

Potential source areas were recorded with 33 landowners being identified for contact in 1989. The importance of the location of these farming operations in relation to the swimming areas was evaluated. The main channel and some significant tributaries have fairly steep gradients; in some areas offering fast delivery of contaminants to in-stream swimming areas. Conversely, contaminants were also observed to be retained and attenuated in many natural and artificial pondings upstream of the swimming areas. These factors figure prominently when evaluating rates of natural purification of water through ultraviolet radiation, settling and bacterial predation by other microorganisms.

Water sampling and field survey results showed that the practice of allowing livestock access to watercourses is the most significant source of contamination to the system. The presence of the pathogen *Pseudomonas Aeruginosa* was confirmed in the reservoirs on several occasions and less frequently upstream. Sources of this contaminant could not be located though local domestic septic systems were an assumed origin.

The second year of the Durham subwatershed study allowed for the collection of spring, summer and fall water quality data. As in 1988, conditions of reservoir water quality did not warrant beach closures though short term fluctuations were cause for concern.

4.5 1989 Landowner Surveys

As part of the analysis of the Durham subwatershed, an information gathering system was devised to more fully assess the extent of farm activity. Though agriculture was the original focal point for the program, concerns were raised about the potential effect of cottaging and rural residential development along the river, necessitating a second survey group.

The farm operation questionnaire was developed through the review of previous study interviews (UTRCA, MVCA), data requirements of the PLOP model format and consideration of local conditions and farm types. Survey interviews were conducted by appointment during the summer of 1989.

The criteria for selection of the target farming operations was based on potential to deliver contaminants to the drainage system using factors of proximity to flowing water and livestock access to streams. Farm operations were identified for future contact through the field inventory and survey work during the fall of 1988. Fifty-six per cent of the proposed farm contact group was surveyed. Most were owner/operators but some had land and buildings rented out to other farmers. Many operators worked at off farm jobs to augment income and small herd size reflects that in some cases.

Analysis of the results of the priority farm interviews showed that cow/calf operations were the majority farm type in the subwatershed. Most of the farms were working in a part time capacity with 15-25 cows. The smallest operation housed only two cows while the largest totalled 400 cattle. A small number of horses were enumerated along with a very large flock of sheep. The effects of the sheep were of interest in that they were pastured throughout the area and accessed watercourses in many locations.

Only one liquid manure storage was encountered among the surveyed farms. The majority of the storages were solid stacks of varying dimension on concrete pads. Most storage capacities were undefined and some were stockpiling manure for composting in areas separate from the primary storage.

Much of the manure generated in the study area is spread on pasture lands and not incorporated. Chemical fertilizers are in general use on land under tillage to improve yields. None of the contact group reported routinely spreading manure during winter months, though with part time operations, available time and weather conditions sometime dictate actions. Only two dairy operators were among the interview group and both had milkhouse waste water treatment systems in place, described as a treatment trench and a septic tank and tile.

Review of information concerning domestic waste disposal showed that most of the group was familiar with septic system operations as they were long time owners of the property. System ages varied between recent installations to more than 25 years.

Runoff potentials varied with location and farming practice. Operations with obvious runoff problems were aware of the situation and generally seemed open to consideration of improvements where practical.

In-stream watering for cattle on summer pasture was very common among the contact group. No examples of alternate watering facilities or intentional restrictions were found. Many expressed satisfaction with open stream watering for their livestock as pollution has not been apparent locally.

None of the contact groups used surface water for domestic purposes, but three farms utilized an upwelling spring source. Drilled wells were the most common with some shallow dug wells still in use. No apparent contamination of domestic water supply was noted through the interviews. A summary of survey information gained through the farm operator interviews is shown in Figure 18.

Concern about the potential affect of cottaging and rural residential development along the Saugeen River prompted a survey of the non-fanning rural population. The purpose of the survey was to gather information concerning septic disposal systems, environmental perceptions and recreational user numbers.

Rural residential, both full and part-time, is a significant land use in the study area. Currently undergoing change due to increasing development, it is of interest that over 60 per cent of the tax assessment in Glenelg Township is from non-resident landowners.

Sixty cottage or rural residential households were selected for the survey because of their close proximity to the river within the study basin. The questionnaire was based upon a similar survey conducted by the Maitland Valley Conservation Authority in 1989 to gather data concerning cottaging on the Lake Huron shoreline.

Survey forms were hand delivered where owners could be contacted, or otherwise they were left in a prominent location within a screen door or other weatherproof location. Hand delivery was necessitated by a general lack of mail boxes and delivery addresses.

Accompanying the survey forms was a covering letter explaining the relevance of the survey to the water quality program and soliciting support. A self-addressed and postage paid envelope was provided for questionnaire returns.

Concern for the bathing water quality of the river was apparent as undefined numbers of children use the watercourse for summer recreation. Some requests were made for information on the health safety of specific swimming areas along the river.

5.0 THE DURHAM SUBWATERSHED CLEAN UP RURAL BEACHES MODEL

5.1 Model Development

The Pollution From Livestock Operations Predictor (PLOP) program software utilized in the Durham subwatershed study was produced in 1988 by Ecologistics Limited for the Ontario Ministry of the Environment. The model is based on United States Department of Agriculture (USDA) programs developed for the estimation of phosphorus delivery potentials and modified with additional algorithms to estimate bacterial loading.

The modelling process is necessary in order to quantify the effects of changes in rural land and livestock management practices. Valuable in two respects, a model can provide input predictions from source operations for use in targeting remedial action promotion and alternately, various remedial techniques can be evaluated for a particular operation prior to implementation. The model can also be used to assess target watershed programs like "Beaches" to determine their effectiveness in addressing diffuse source contamination programs.

The PLOP software estimates inputs of phosphorus and fecal coliform and fecal streptococcus bacteria. Potential pollution sources addressed by the program include barnyards, solid manure stacks, cattle access points and milkhouse wastes.

Phosphorus is considered the main contributor to the eutrophication of surface waters. Fecal coliform bacteria is currently used by the O.M.E. and health units as an indicator for the presence of pathogens and is produced in the intestines of warm blooded animals. Fecal streptococci counts are used in comparisons with FC numbers to determine possible source types as a FC/FS ratio of less than 0.7 indicates livestock while greater than four indicates a human source.

The model performs calculations on a seasonal basis based on 90 day periods of winter, spring, summer and fall. The reason for the distinction is based on seasonal changes in farm activity and climate. The input information and calculation are on a seasonal basis but the output is both on a seasonal level and as a total annual pollutant level.

The PLOP model uses rainfall characteristics for the watershed area to determine runoff characteristics. Necessary information is obtained from a data array containing seasonal information on the frequency of rainfall events for a group of event class sizes for an average year. Runoff estimates are determined by the American Soil Conservation Services (S.C.S.) curve number method which accounts for soil moisture condition, soil type and vegetative cover (Ecologistics, 1988).

Materials chosen for evaluation through the modelling process are those of concern in rural watersheds. Runoff containing animal waste and milkhouse waste contain these potential pollutant materials which may increase nutrient and suspended solids concentration, decrease the dissolved oxygen content of the water and potentially threaten the health of livestock.

The model evaluates livestock numbers in terms of equivalent livestock units (EAU) which were developed through evaluation of a standard 455 kg beef feeder or slaughter steer. Using this equation of 1 steer =1 EAU, calculations are made based on average concentrations of phosphorus and bacteria in wastes of various livestock types.

Included in the evaluation is a calculation of animal unit density and per cent manure pack on barnyard surfaces to determine the volume of runoff water in contact with manure while passing over the yard. This component is based on an approximation that one EAU will produce manure to cover 0.001 acres per day. At this rate, it would take ten days for 100 EAU to produce 100 per cent coverage on one acre of land.

The concentration of pollutants at the source was determined through review of recent literature concerning bacteria release from fecal material and other modelling attempts. A concentration of 85 mg/L phosphorus was utilized for confinement area runoff with values decreasing with per cent manure pack. Concentrations of FC and FS were estimated at 1.0E7 and 2.5E7 organisms per 100 ml respectively, varying linearly with per cent manure pack.

The phosphorus buffering effect of overland flow on a vegetated surface is accounted for with a concentration reduction algorithm. Differentiation is made between sheet flow buffering and channel flow buffering with estimations dependent upon travel time to a receiving body of water.

The buffering of bacteria concentrations during overland transport in runoff is a complex process involving die-off factors, adsorption to soil particles and infiltration. The PLOP model accounts for these relationships with an analysis based on runoff contact time with the buffer strip.

The main limitation of the PLOP model is that it relies on numerous generalities and averaged values due to limited available data on specific conditions. Also, model estimates of pollutant loadings are to the point of stream or receiving water entry and no assessment of subsequent transport relationships is attempted. The impact of pollutant sources on groundwater is not addressed by this model.

The PLOP model, as produced by Ecologistics under contract to the Ministry of the Environment is a site specific pollution predictor. Information required to operate the program turned out to be in much greater detail than had been obtained through most large scale Beaches area surveys.

Through discussion and review by program staff, a second model was produced which was more adaptable to available information. The Clean Up Rural Beaches (CURB) model utilizes a series of algorithms to evaluate and quantify potential sources of fecal coliform and phosphorus impacting beach areas. The CURB model as utilized by several southwest region conservation authorities involves the separation of the study watershed into areas defined by travel time and tributary basins. Algorithms are then applied to field and survey data to determine typical annual bacteria and phosphorus loading to the system for each operation. These typical loadings are grouped into high flow pulse discharge and low flow continuous discharge categories. Averaged and multiplied by the number of sources in an area, these figures are then subjected to a reduction factor based on die-off estimates and travel time to the beach area.

The Saugeen Valley Conservation Authority Rural Water Quality Program uses a combination of the two modeling approaches. Since the component subwatersheds and farm operations numbers are relatively small, it was possible to obtain the detailed information required for PLOP data entry.

Contaminant loading predictions generated through the PLOP model for specific sites were then subjected to CURB concepts of pulse and continuous delivery processes.

5.2 Subwatershed Drainage, Bacterial Transport and Die Off Factors

In order to determine the relative importance of the various input sources, the mechanics of delivery to the swimming areas were approximated mathematically. Travel time and discharge volume is important to the prediction of water quality as delivered to the beach areas.

Figure 12 shows a discharge hydrograph for the Saugeen River at Durham. With weight given to the monthly average discharge volumes for 1988, high and low average flows were established for purposes of the CURB evaluation.

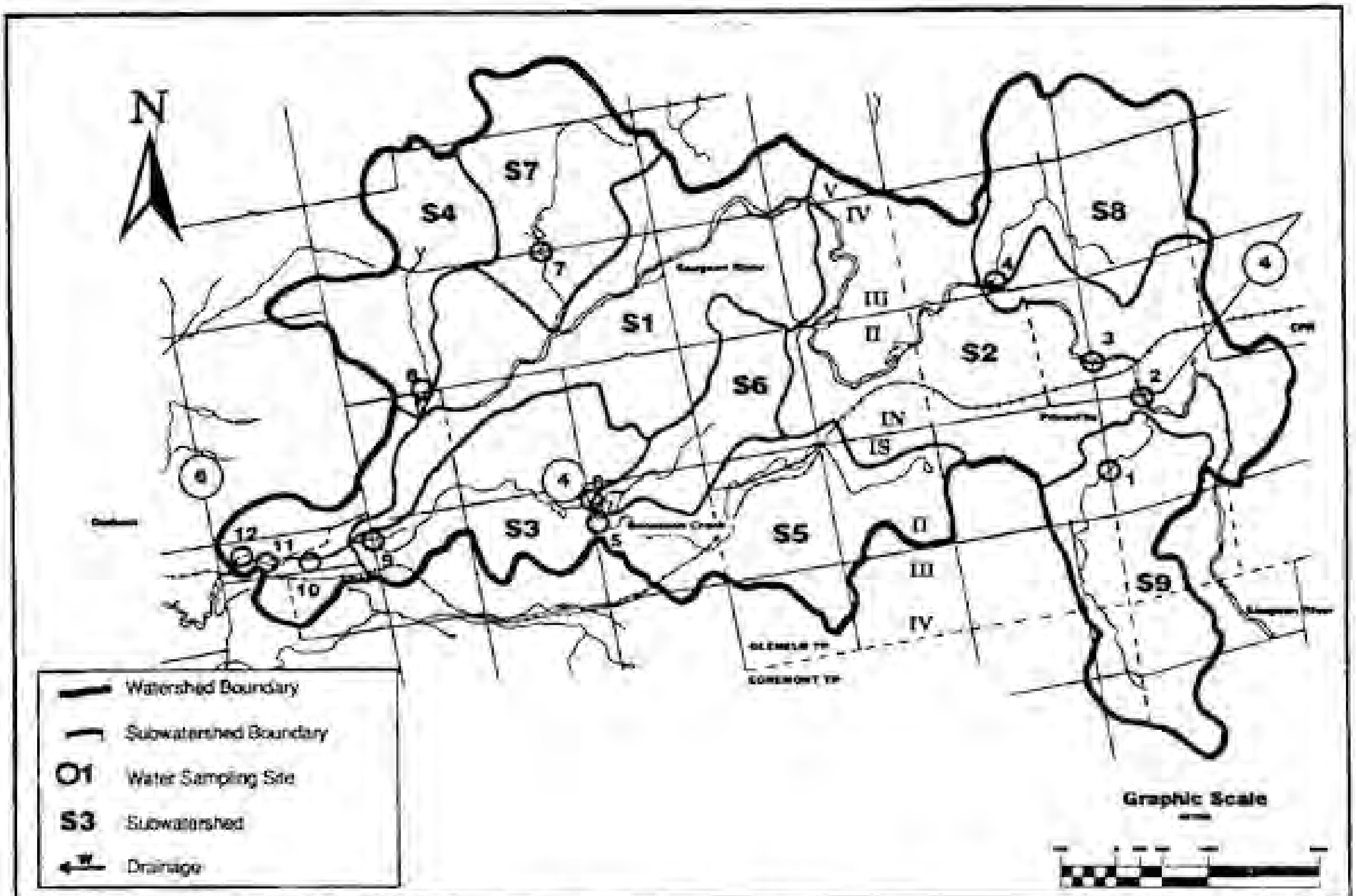
Travel times from a theoretical centre point of each component drainage basin was determined using field measurements or estimates where unavailable (Table 6). Delivery can be described as rapid from all component basins under high flow rates, reducing the significance of in-stream die-off processes.

CURB plan processes were utilized to estimate the relationship between annual fecal coliform numbers at the contaminant source and bacteria concentrations in river water entering the Durham reservoirs. Calculations in the CURB adaptation include factors to account for increasing water volumes in downstream flows under conditions of high and low average discharge.

Evaluated input sources were divided into those occurring on a continuous basis (cattle access) and those occurring as pulse loads during runoff events (manure stacks and barnyard runoff). For this evaluation it was assumed that high average flows would occur 20% of the time or for 73 days annually, resulting in pulse load inputs for that time period.

The high average flows period of 73 days was based on an annual mean of 87 days with measurable precipitation (Environment Canada, 1982) and allowances for snow melt and other hydrological factors. The hypothetical high and low average CURB discharges were created to reflect 1988 monthly average flows with references to 1976 -1988 flow data.

Under a low flow setting, die-off factors reduce significantly the inputs of component basins 5, 7, 8 and 9. In-stream ponds and wetlands increase retention time and attenuation of contaminants in components 3, 5, 6, 7, 8 and 9. These effects were noted through field observations and sample analysis.



THE DURHAM SUBWATERSHED
DRAINAGE SUBDIVISION AND SAMPLE SITE LOCATIONS

Figure 11

Table 5: Subwatershed Data Summary

Subwatersheds	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Geography									
Area (km^2)	24.8	29.0	8.8	8.1	11.8	5.0	8.9	10.5	10.9
Operations (#'s)	14	6	5	4	6	5	3	5	6
Density (#/km^2)	0.56	0.21	0.57	0.49	0.51	1.0	034	0.48	0.55
High Priority Farms (#)	7	2	2	2	3	2	1	1	2
Percent Surveyed	57	50	100	0	33	0	100	0	50
Barnyards									
Sources (#)	2	2	1	2	3	2	2	1	0
Area (km^2)	0.0011	0.0016	0.0004	0.001	0.0012	0.0008	0.0012	0.0004	0
Density (#/km^2)	0.08	0.07	0.11	0.25	0.025	0.17	0.4	0.09	0
Livestock Access									
Sites (#)	5	1	2	0	6	2	2	1	1
Length (avg. m)	190	20.0	205	0	350	20	425	120	10
Animals (#eau)	20.6	12	35	0	100	90	25	30	70
Months (#)	10.8	8	6	0	12	12	12	6	6
Density (#/km)	0.2	0.03	0.23	0	0.13	0.51	0.22	0.09	009
Hours (avg.#/d	24	24	24	0	24	24	24	24	12

Table 6: Travel Times to McGowan Falls Reservoir from Component Drainage Area Centroids

Component Basin	Flow Condition	Distance (km) Main Stream	Distance (km) Tributary	Distance (km) Tributary Br.	Velocity(m/sec) Main Stream	Velocity(m/sec) Tributary	Velocity(m/sec) Tributary Br.	Time (hrs)	Retention Factors
1	High	8.5			1.7			1.39	
	Low	8.3			1.5			1.57	none
2	High	10	10		1.7	1.0		4.41	
	Low	10	10		1.5	0.8		5.32	none
3	High	1.5	4		1.7	0.9		1.48	
	Low	1.5	4		1.5	0.5		2.5	in-stream ponds (2)
4	High	4.5	15		1.7	0.4		2.47	
	Low	45	2.5		15	0.13		6.18	none
5	High	1.5	55	6	1.7	0.9	0.4	6.11	
	Low	1.5	55	6	1.5	0.5	0.09	21.85	in-stream ponds (2) wetland
6	High	1.5	55	3	1.7	0.9	0.5	3.61	
	Low	1. 5	55	3	1.5	0.5	0.26	6.54	in-stream ponds (2)
7	High	7.5	3		1.7	0.5		2.89	
	Low	7.5	3		1.5	0.01		84.72	in-stream ponds (2) wetlands
8	High	13	9	3	1.7	1.0	0.5	6.29	
	Low	13	9	3	1.5	0.8	0.01	88.86	wetlands
9	High	13	13	42	1.7	1.0	0.5	8.07	
	Low	13	13	42	1.5	0.8	0.01	123.59	in-stream pond

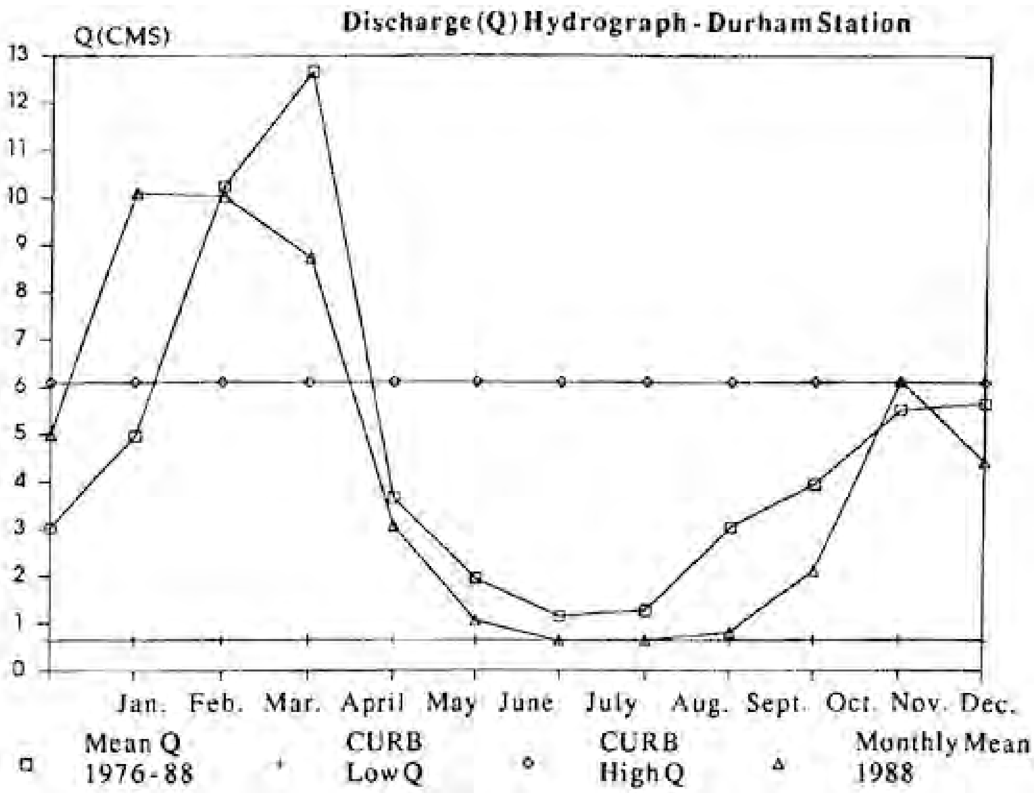


Figure 12

5.3 Model Predictions

The model analysis of the Durham subwatershed was accomplished primarily through generated PLOP data outputs of site specific loadings form priority farm operations. Data for model input was gathered through the 1989 field survey of farm operations.

Figure 13 shows a breakdown of annual contaminant inputs by source type on a percentage contribution basis. These estimates represent the PLOP model predictions for total contaminant loading to the point of stream entry from all defined sources in the subwatershed. Pre-buffer loads represent contaminants at the source, before overland transport attenuation effects.

Estimates of the PLOP attribute 89.4% of agriculturally - sourced fecal coliform bacteria to livestock access to streams. Estimates of phosphorus inputs show about half the annual loading originating in manure storage stacks. The model does not estimate phosphorus loadings from other sources such as eroding soil and wetlands.

As fecal coliform concentrations were the primary concern of the Durham subwatershed study, a predictions summary for this parameter is shown in Table 7. The process relates total annual loadings from each component subwatershed to stream volume upon delivery to the reservoirs in Durham.

Table 7: CURB Model Predictions

Comp Drain-age	F.C. Organisms Annual Pulse Loading*	F.C. Organisms Annual Continuous Loading*	Avg. High Flow Discharge (Q) (L/day)	Avg. Low Flow Discharge (Q) (L/day)	Avg. High Q Pulse Conc. (org/100 ml)	Avg. Low Q Continuous Conc. (org/ 100 ml)	Conc. Reduction Factor (org/100ml)	Conc. Reduction Factor Low Q	F.C. Conc. (red. factor applied) (org/100ml) High Q	F.C. Conc. (red. factor applied) (org/ 100ml) Low Q
1	7.83 E11	5.17 E12	5.27 E8	5.53 E7	5	26	1	1	5	26
2	5.97 E11	3.17 E10	3.97 E8	1.24 E7	1	2	0.753	0.224	1	0
3	8.43 E10	1.52 E12	5.19 E7	2.30 E7	10	18	0.098	0.416	1	7
4	3.43 E11	N/A	3.11 E6	1.55 E6	151	N/A	0.006	0.028	1	N/A
5	2.43 E11	1.21 E13	2.33 E7	6.05 E6	156	5.49	0.044	0.011	7	6
6	4.08 E11	1.83 E12	2.76 E7	1.21 E7	38	41	0.052	0.219	2	9
7	5.25 E11	7.5 E12	1.73 E7	8.64 E4	161	23,800	0.033	0.002	5	48
8	8.42 E11	4.0 E12	3.46 E6	8.64 E4	650	13,000	0.006	0.002	4	26
9	5.68 E11	4.82 E12	4.32 E12	8.64 E4	486	1.530	0.008	0.002	4	3
								Totals	30	125

* PLOP data outputs adapted to Ontario (Harris, 1984) bacterial estimates

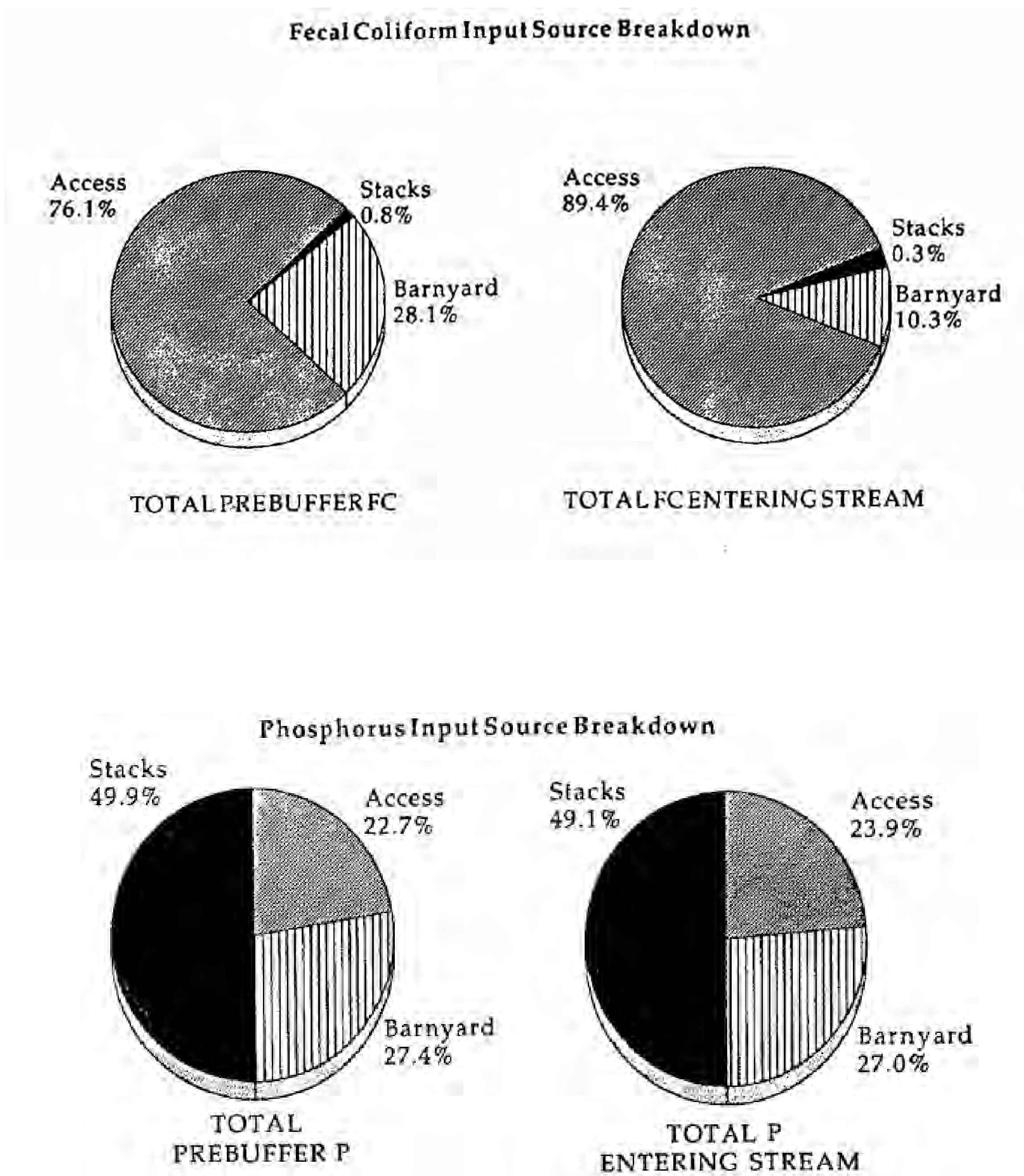


Figure 13: 1989 Durham Subwatershed Plop Data

Prior to evaluation, PLOP output FC loading figures were converted to correspond to Ontario (Harris, 1984) estimations of bacteria numbers per manure volume. This involved a reduction in total numbers by a factor of 60.

Predicted concentrations of bacteria from component subwatersheds were reduced by a dispersal factor proportional to the ratio between component discharge and main river discharge to the reservoir. Upon application of the dispersal factor, the net system contribution of each component subwatershed was determined.

Total system loading rates of 30 org/100ml under high flow conditions and 125 org/100ml under low flow conditions are expected concentrations. Given the relatively small number of input sources and the large dilution factor of high flow discharges, reduced bacterial concentrations are probably the normal situation for the Durham subwatershed during spring and fall periods.

The CURB analysis summary shows component subwatersheds 1, 7 and 8 as being significant sources of bacteria during low flow periods. When the retention and attenuation factors of components 7 and 8 are taken into account, their effect is greatly reduced, leaving component 1 as the most serious threat to reservoir water quality during the swimming season.

Travel time is also a consideration in determining the impact of components 5, 7, 8 and 9. At an assumed die-off rate of 0.5 logarithm units per day, near complete attenuation may occur under summer base flow conditions.

The effect of wildlife is not assessed by the CURB model and may be significant under some conditions in the Durham subwatershed because of a high degree of forest cover.

6.0 CAPITAL COST and COST EFFECTIVENESS FOR REMEDIAL ACTION IN TARGETED AREAS

Capital costs required to reduce fecal coliform bacteria an phosphorus loads for the Penetangore River watershed, the Durham subwatershed and the S.V.C.A. shoreline have been estimated and are summarized in Table 8.

Table 8: Estimated capital cost of remedial measures to reduce bacteria and phosphorus inputs from the Durham subwatershed, Penetangore River watershed and the shoreline cottages

Study area	# of sites	Estimated capital costs
1. Penetangore River watershed:		
livestock access	46	$ 460,000
milkhouse washwater	2	18,000
unacceptable septic systems	707	3,535,000
manure runoff	26	780,000
Total projects	781	$4,793,000
2. Durham subwatershed:		
livestock access	20	200,000
manure runoff	15	450,000
Total projects:	35	$ 650,000
3. S.V.C.A. shoreline		
unacceptable cottage septic systems	85	$ 425,000
Total projects:	85	$ 425,000
Combined total		$5,868,000

Costs have been averaged using the remedial price estimates noted in Appendix 2. On the average, capital construction costs for the targeted watersheds and the shoreline would be approximately $5,868,000.

A cost effectiveness analysis regarding remedial action was undertaken for both of the targeted areas. The first analysis includes the Penetangore River watershed and shoreline septic system remediation. This examination measures the number of bacteria and phosphorus that would be reduced with each dollar spent (Table 9).

Table 9: Cost effectiveness of remedial measures for the Penetangore River watershed and S.V.C.A. shoreline cottage septic systems according to contamination source

Contaminant Source	Bacteria reduction per $ spent	Phosphorus reduction per # spent
unacceptable septic systems (excludes cottages)	2.04 E+07	0.0008 kg
livestock access	3.39 E+07	0.0006 kg
runoff	4.12 E+04	0.0000 kg
milkhouse	3.88 E+05	0.0006 kg
unacceptable cottage septic systems	1.10 E+08	0.0003 kg
Total bacteria reduced/dollar spent = 2.59 E+07		
Total phosphorus reduced/dollar spent = .0003 kg		

It would appear that the most cost effective (the greatest reduction per dollar spent) remedial projects measure would be cottage septic systems first, livestock access second and residential septic systems third but with this analysis actual annual contributions from each source must be examined to implement a plan that takes these factors into consideration. The greatest contributor of fecal coliform bacteria to Lake Huron in the Penetangore River watershed is septic systems at 81.58%. If the estimated $3,535,000 is used to correct this source a significant portion of the bacterial pollution would be solved. Also, if the estimated $460,000 was spent on removing livestock from watercourses and providing alternative water, another 17.65% of bacterial contamination would be reduced resulting in a 99.23% overall reduction for the Penetangore River watershed.

In terms of cost effectiveness and phosphorus, remedial work on cottage septic systems, livestock access to watercourses and milkhouse washwater are the most cost effective, respectively. When compared to actual phosphorus contributions to Lake Huron by source, if remediation on unacceptable septic systems and livestock restriction from watercourses would occur, over 80% of the estimated phosphorus would be reduced. If exclusively milkhouse washwater and manure runoff would be remediated, less than 1% of the phosphorus for the watershed would be reduced.

To examine cost effectiveness of remedial measures for the Durham subwatershed, a reduction of particular source's contaminant contribution percentage per dollar spent was completed. Actual loading numbers for the Durham swimming beaches were not available as in the Penetangore River watershed study.

Table 10: Cost effectiveness of remedial measures for the Durham subwatershed according to source

Contaminant Source	Percentage of Bacteria Reduced per # spent	Percentage of Phosphorus Reduced per # spent
livestock access	0.0044 %	0. 0001 %
manure runoff	0.0000 %	0.0001 %

This analysis has shown that remedial work pertaining to livestock access would be the most cost effective for reducing bacteria to the Durham subwatershed. Excluding cottage septic systems, these findings are consistent with the Penetangore River watershed cost effectiveness analysis.

Looking at source contributions, if all livestock access was remediated, almost 90% of the bacterial input to the Durham subwatershed would be eliminated and almost ¼ of the phosphorus contribution. If only manure runoff sources were remediated, only 10% of the bacterial problem would be reduced but ¾ of the phosphorus would be reduced. Balancing the cost effectiveness with the source contaminant contributions, the livestock access would provide the greater overall improvement.

7.0 THE S.V.C.A. CLEAN UP RURAL BEACHES IMPLEMENTATION PLAN

As a result of the source contribution and cost effectiveness analysis, it is suggested that remedial work take place on both cottage and residential septic systems and livestock access projects. This would cost an estimated $4,620,000. This plan would reduce over 99% of the outlined bacterial sources and more than 80% of the phosphorus loading to Lake Huron from the Penetangore River watershed and shoreline cottages. Eliminating livestock from watercourses also reduces soil erosion which has been known to greatly contribute phosphorus to water resources.

With this implementation proposal, almost 90% of the bacterial contribution and ¼ of the phosphorus load would be eliminated from the Durham subwatershed.

Water Quality monitoring would be required during the implementation phase in order to document the water quality improvements that occur as a result of remedial activities.

A heavy promotional campaign would be suggested to inform/educate area landowners on the S.V.C.A. CURB Implementation Plan and Program. This will encourage participation in remedial projects and hopefully promote stewardship of water resources.

Cottage septic systems have significant bacterial contribution to Lake Huron's beaches. At 1% failure rate for these cottages, they input more than half of the contribution coming from a watershed roughly 200 sq. km's. For both bacterial and phosphorus loading contributions to Lake Huron it rates the best in terms of cost effectiveness.

8.0 POTENTIAL NON-BEACH BENEFITS AND IMPACTS

Several other benefits would be gained from the remedial work described in this report:

1) Fisheries Improvement

Without the disturbance to streambanks and streambeds, caused by livestock, fish spawning and rearing areas would be improved and protected. Also, migratory routes would not degrade as a result. In general, the quality of water has the opportunity to improve. The potential to upgrade streams from warm water to potential cold water fisheries would exist. Without streams widening and water warming with trampling and less nutrients going into watercourses, degrading, algae-filled streams would be reduced and fisheries improved.

2) Improved Herd Health

By taking livestock out the contaminated stream/creek water, herd health will improve. Water is known to be an excellent carrier of disease. Leptospirosis, salmonellosis, foot and mouth disease, hog cholera and giardiasis name but a few. The livestock operator would benefit by fewer veterinarian bills.

3) Protection of Human Health

The livestock operator will also protect his/her and other handlers health by removing cattle from the stream. Some diseases contracted from contaminated water can be passed on from animal to man. Giardia and Crytosporidium are parasites that have the potential to cross species borders. With less potential for bacterial and nutrient contamination in streams and beaches, prevention of human health threats to users of that water resource is effected.

4) Economic Improvements

With beaches and swimming areas open for bathing, the surrounding area's economy is benefited monetarily. Keeping beaches open will help to maintain important tourism revenues which are especially important to small towns and cities.

The C.U.R.B. Program over the next five years will be providing capital money to constructing remedial projects to improve water quality. The watershed businesses will be in receipt of that money as supplies and services are provided. Jobs will be generated in order to carry out the goals of the program by technical staff.

5) Water Quality Upgrade

In general, water quality will be improved as a result of the remedial measures carried out in the program. This program will also assist in achieving the goals of the Great Lakes Water Quality Agreement.

6) Social Benefits

As the public becomes more aware of their environment, as the program is promoted, a renewed belief in the commitment of their government to help farmers and water pollution may occur. With the continuance of open beach areas, social gatherings can be maintained. Many people seek relief from daily pressures and relaxing at the beach or at the cottage is highly valued. People also value the purity of their recreational waters.

7) Erosion Control Benefits

Streambank vegetation would naturally regenerate with the installation of fencing and soil erosion would be greatly reduced due to increased bank stability.

8) Increased public awareness of impact on water resources.

As the CURB Program begins, public awareness will increase in regards to the importance of stewardship of water resources.

9.0 RECOMMENDATIONS

1. Correcting unacceptable domestic septic systems should be seen as the highest priority in terms of remedial action.

This problem has been outlined as the #1 contributor to bacterial pollution for the Penetangore River and is a concern from cottages that line Lake Huron since there is no chance for bacterial die off to occur and therefore would indicate the highest rate of contaminant delivery during the swimming season (apart from occasional STP occurrences). Livestock access was the #1 bacterial contributor for the Durham subwatershed but septic systems were not a factor in the model.

2. Livestock access to watercourses should be eliminated.

As evident in this CURB plan, livestock access has a profound effect on water quality. The Durham subwatershed evaluation indicated this source as the most significant source of bacteria to the Durham reservoirs and the second highest source to Lake Huron through the Penetangore River watershed. Aside from adding significant amounts of bacteria and nutrients into watercourses, good pasture land is lost each year by associated erosion and quality fisheries lost or degraded through trampling. Access for both study areas is listed in the top three contributors of phosphorus to perspective beach sites.

3. An intensive promotional campaign should be carried out regarding the CURB program with respect to agriculture and rural water quality issues.

Since the CURB program works on a cost-share basis, the benefits that the program has to offer must be made clear to possible participants (landowners) through various media.(ie. workshops, newsletters, radio/newspaper ads). Not only will this aid in achieving the goals of the CURB program, it will also better educate watershed residents on issues of water quality in a rural environment.

4. The local Health Unit should endeavour to maintain an extensive beach water sampling program during the summer season in order to protect the public from health hazards.

The number of sampling events should be increased in order to more accurately represent the beach conditions so that public health is protected.

5. More investigative work should be pursued in the field of bacterial survival in lake sediments.

This work would present a more realistic picture of the factors effecting beach water quality during the summer season.

6. Custom operators of livestock waste should be formally educated in a training course.

A joint course between O.M.A.F. and M.O.E. would help to protect water resources from this source of contamination.

7. Consider establishing legislation that would prohibit in-stream access of livestock.

This would reduce the necessity for remedial work for this source and would also help to guard against soil erosion.

8. **An extensive water monitoring program be continued throughout the remedial action process.**

Improvement records should be kept during the implementation programs in order to estimate the effectiveness of the remedial measures put in place.

9. Land use impacts in the targeted watersheds should be monitored while the CURB Program is in place.

Various land use developments that would impact the success of the program should monitored ie. new sewage treatment facilities, the growth or decline of the cottage and agricultural industries, etc. This monitoring process will assist in evaluating the effectiveness or success at the end of the program.

10. Considerations should be made to couple existing grants to increase the grant rates of the CURB Program.

Combining existing government grant programs which have similar goals may help to increase program participation and also the program's water quality improvement achievements.

11. An investigation should be undertaken to discover the actual impact of shoreline septic systems on beach water quality.

With a realistic portrait of their impact, precautions can be made where necessary to serve short and anticipated long term needs.

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APPENDIX 1

Figure 14:

Recreational Water Sampling Locations

APPENDIX 2

APPENDIX 2 Capital Costs

Pollution Source	Cost	Remedial Work
Livestock access	Minimum - $ 6,000	Fence one side & alt. water
	Maximum - $15,000	Fence 2 sides & alt. water
(Source: Past fencing projects constructed by S.V.C.A. staff)		
Milkhouse washwater	Minimum - $ 6,000	Treatment trench
	Maximum - $10,000	" " & storage tank
(Source: OMAF Dairy Branch)		
Septic system	Minimum - $5,000	Treatment trench
	Maximum - $7,000	" " & fill
(Source: Bruce-Grey Owen Sound Health Unit		
Manure runoff	Minimum - $20,000	Concrete storage
	Maximum - $40,000	Covered solid storage
(Source: OMAF Engineering Services)		

APPENDIX 3

APPENDIX 3:

Fecal Coliform (FC):

Figure15 illustrates the maximum, minimum and geometric mean concentrations of fecal coliform bacteria for the 12 regular sampling stations in the study area. All 12 stations had geometric mean FC concentrations below the Ministry of the Environment objective for recreational water use. Concentrations ranged from a low of 4 organisms per 100 ml at all stations to maximum levels of 600 organisms per 100 ml at stations 001, 004 and OIL The average geometric mean concentration for the watershed as sampled was 26 organisms per 100 ml. Consistently elevated concentrations were observed at station 001 in the late summer and fall as cattle were rotated onto an upstream pasture that had open access to the water. Very low flow rates and wildlife populations resulted in regular moderate contamination of the stream at station 004. The uncharacteristic level of 600 organisms per 100 ml at the McGowan reservoir station 011 occurred when construction activities caused flow disruption and turbid conditions.

Escherichia Coli (E. Coli):

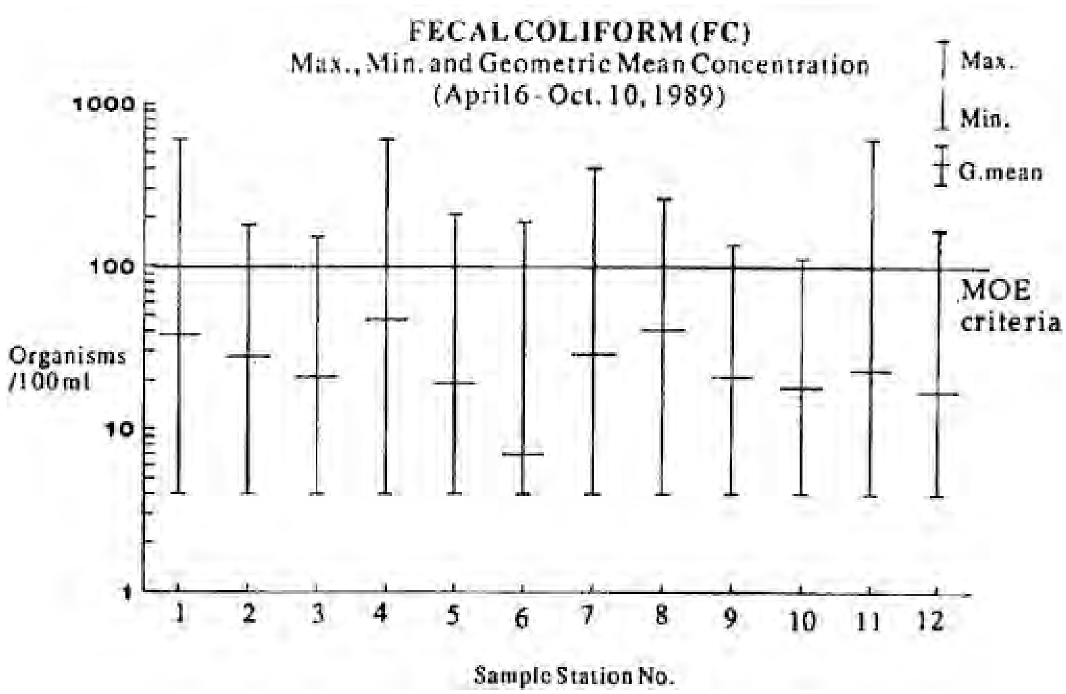

Figure15

E. Coli concentrations were proportionately similar to those of fecal coliform. Analysis results are shown on Figure16.

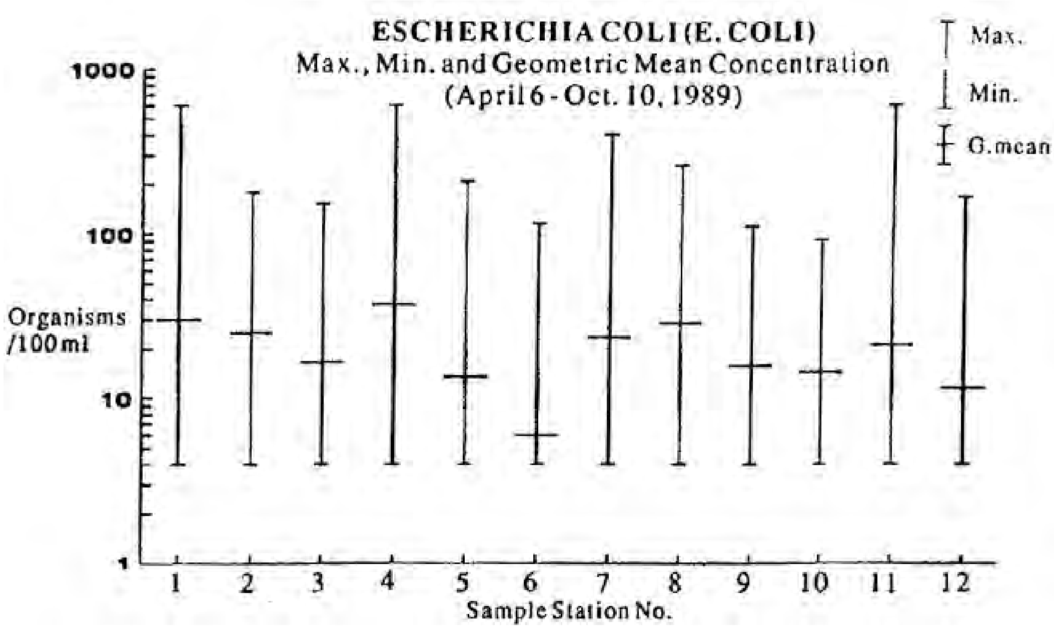

Figure 16

Fecal Streptococci (F.S.):

Fecal Streptococci are also indicators of pathogenic bacteria. F.S. is known to be found in greater numbers in animal waste material than that of human origin. Fecal streptococci are also known to be more resistant to sunlight inactivation than fecal coliform bacterial (Fujioka, 1982).

Figure 17 illustrates the maximum, minimum and geometric mean concentrations for the 12 regular stations.

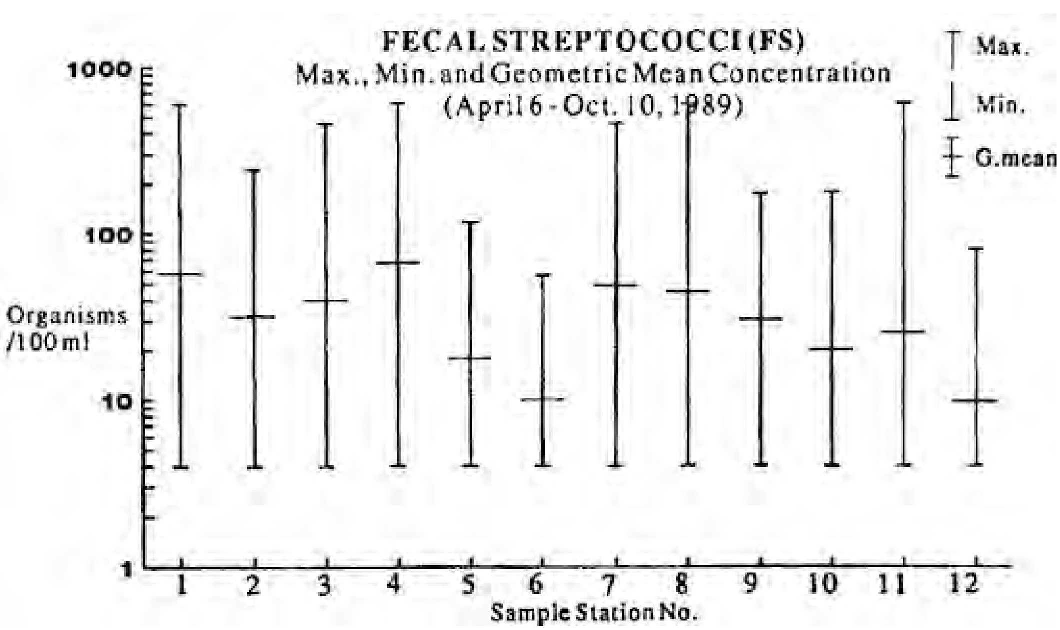

Figure 17

Pseudomonas Aeruginosa **(PsA)**

A potential health risk exists when the pathogenic organism PsA can be enumerated and frequently isolated from the water (MOE, 1978). A lower analysis limit of less than 4 organisms per 100 ml is accepted as defining natural background river water quality. As shown in Figure 18, PsA was detected above background levels at stations 009 and 012. The repeated observations of PsA at station 012 is significant because of the pathogenic nature of this organism.

The Grey-Bruce/Owen Sound Health Unit confirmed the detection of PsA on many occasions in the Durham swimming areas, including during the time of the postings and closure in 1986 and 1987. Reports of illness attributed to contact with reservoir water seem to correspond with observations of PsA.

Enumerations of PsA through the rural water quality program were not associated with expected high concentrations of other (indicator) bacteria. A July 5,1989 sample at the station 012 swimming area showed a PsA level of 424 organisms per 100 ml with a fecal coliform concentration of only 16.

This bacteria is known to be associated with human waste and a potential source would be faulty or inappropriately installed septic systems.

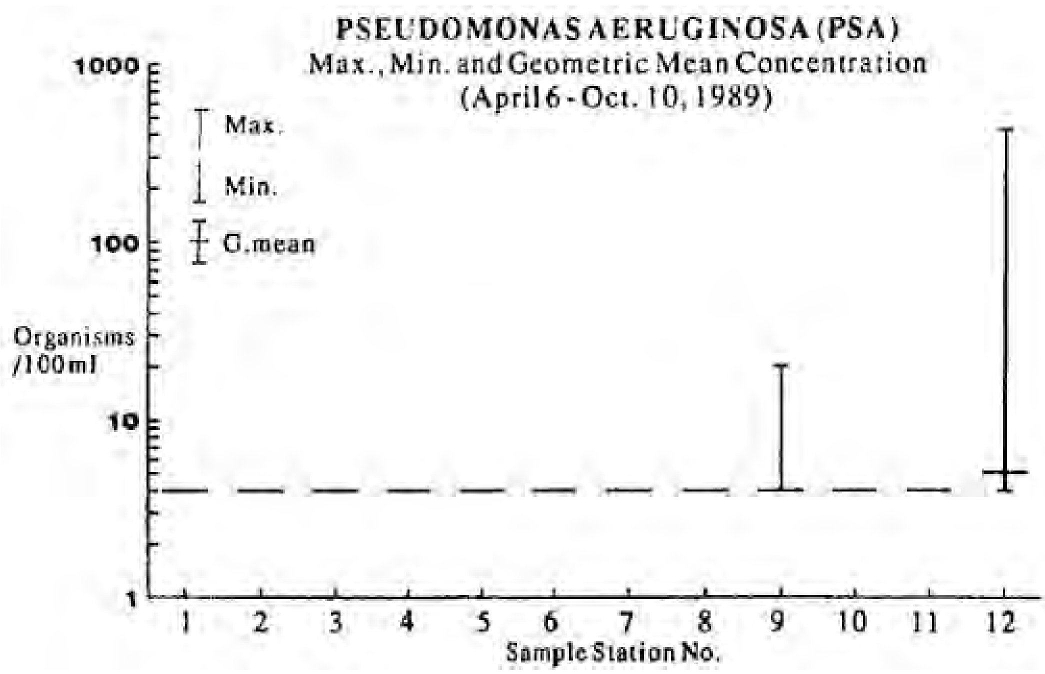

Figure 18

Free Ammonia (NH_3):

High concentrations of NH_3 may suggest recent organic pollution, either by decaying plant material or animal waste. The free ammonia concentration, along with temperature and pH dictate the concentration of un-ionized ammonia. The provincial water quality objective for un-ionized ammonia is 0.02 mg/L for the protection of aquatic life (MOE, 1978).

Free ammonia analysis for the watershed shows levels characteristic of a good quality system. Occasional increased concentrations at stations 001, 006 and 007 are probably due to wetland influences. The highest recorded NH_3 concentration at observed temperature and pH condition resulted in an unionized ammonia concentration of 0.006 mg/L, well below the provincial criteria. Figure 19 describes observed concentrations of free ammonia.

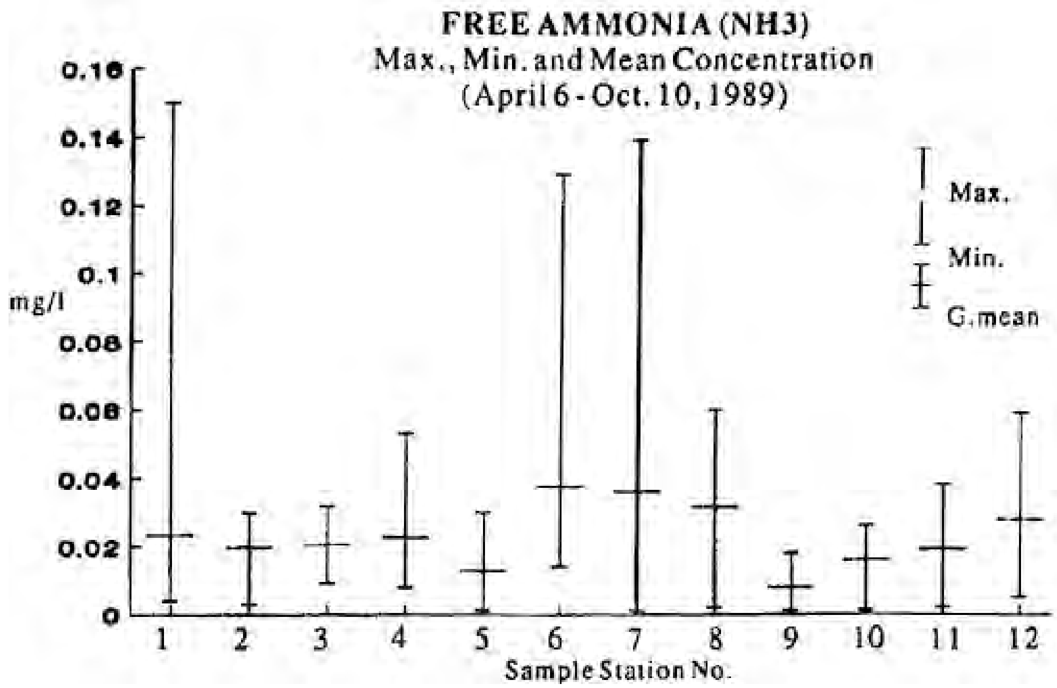

Figure 19

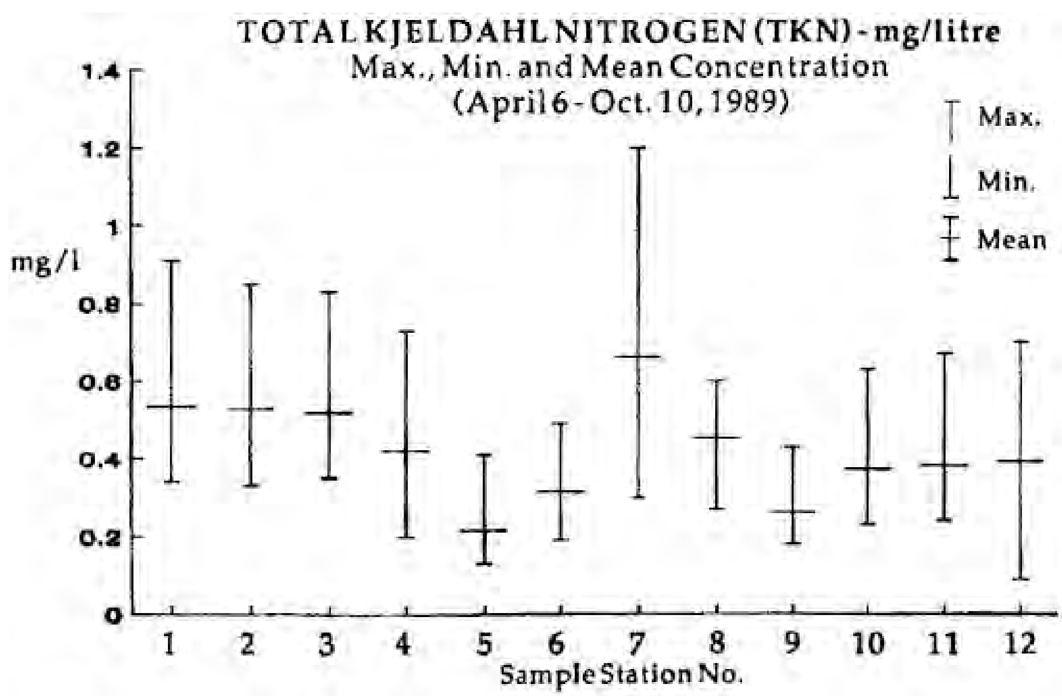

Figure 20

Total Kjeldahl Nitrogen (TKN):

McNeely (1979) suggests a TKN range for watercourses not affected by excessive organic inputs of between 0.1 and 0.3 mg/L. Mean levels for all stations except those on Bunessan Creek exceed this range. Some form of organic input is inferred for the main stream and other tributaries.

Nitrite (NO_2):

Nitrite is seldom present in surface waters in significant concentrations. The presence of this component in concentrations greater than 0.001 mg/L can indicate active biological processes and therefore organic pollution (McNeely *et. al.*, 1979).

All stations show a departure from the base level of 0.001 mg/L (Figure 21) during the sampling period. Although mean levels didn't exceed 0.02 mg/L at any station, higher concentrations were observed at stations 008 and 012.

Nitrate (NO_3):

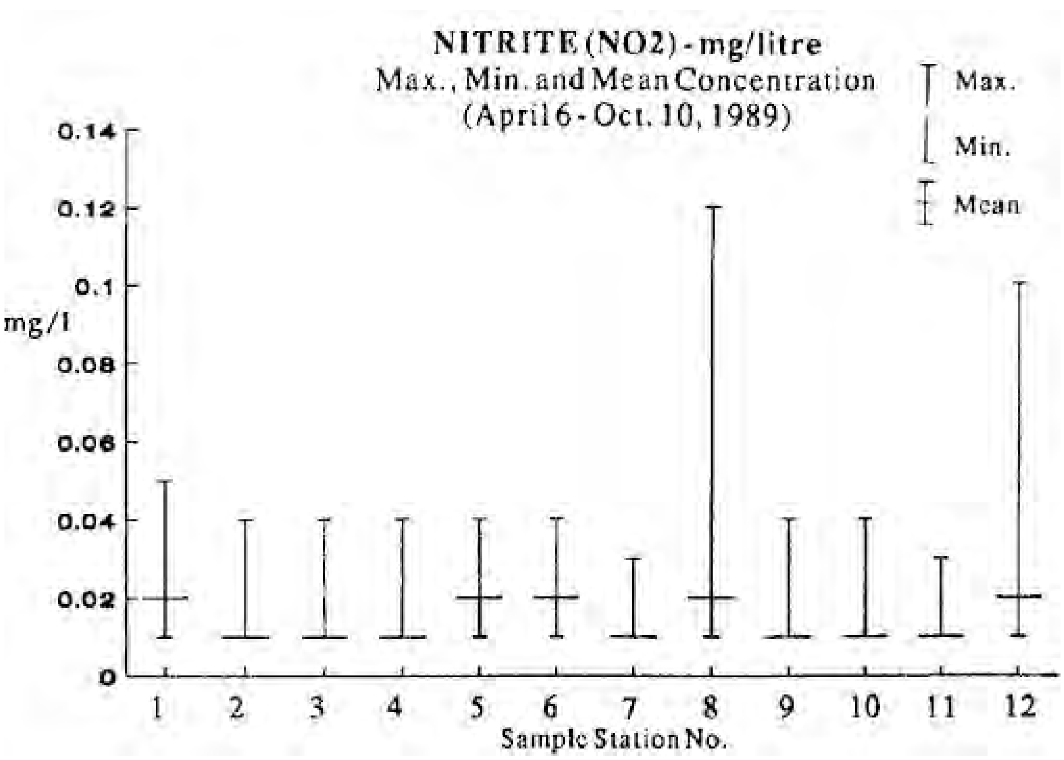

Figure 21

Concentrations of NO_3 ranged from 0.1 to 1.5 mg/L as shown in Figure 22. As NO_3 is usually not abundant in surface waters, elevated levels at stations 005 and 006 may result from percolating groundwater in this headwater area. The higher concentrations are reflected in the downstream station 009 and seem to influence the river and reservoir water chemistry at 010, 011 and 012.

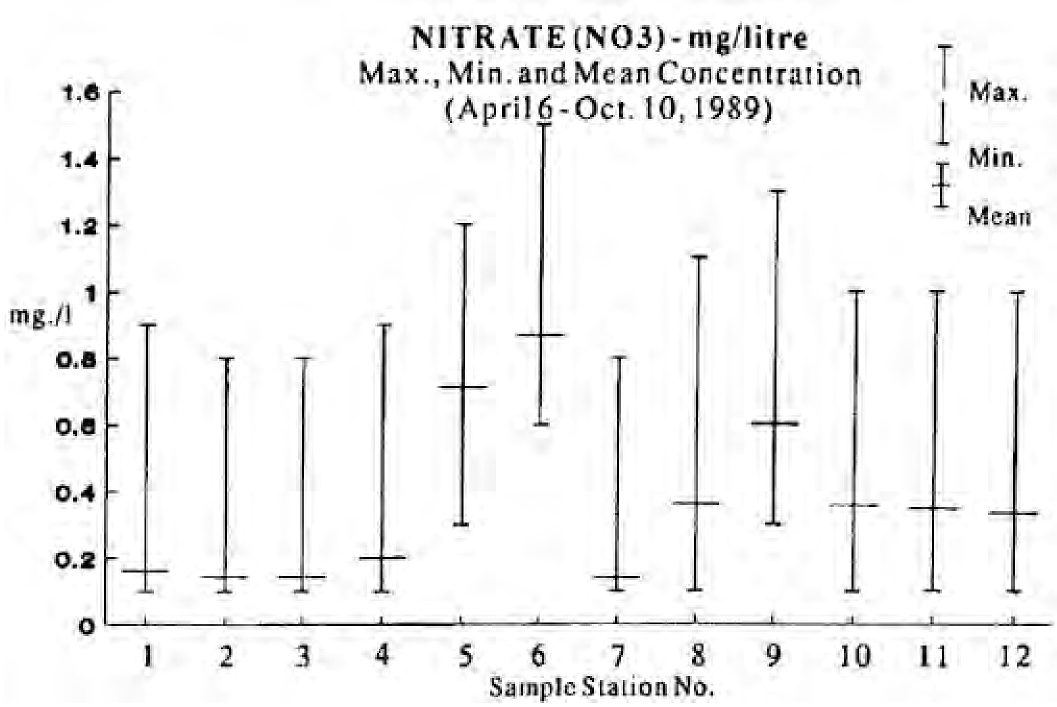

Figure 22

Total Phosphorus (TP):

An MOE guideline maximum concentration of 0.03 mg/L has been established for the prevention of nuisance plant growth. Station 007 had average concentrations in exceedance of this guideline but with minimal discharge through the summer months.

Station 007 is located on a sluggish stream that originates in an area of agricultural drainage subsequently flowing through a wetland where some of the phosphorus could be generated through plant processes. Figure 23 shows the concentrations for all stations.

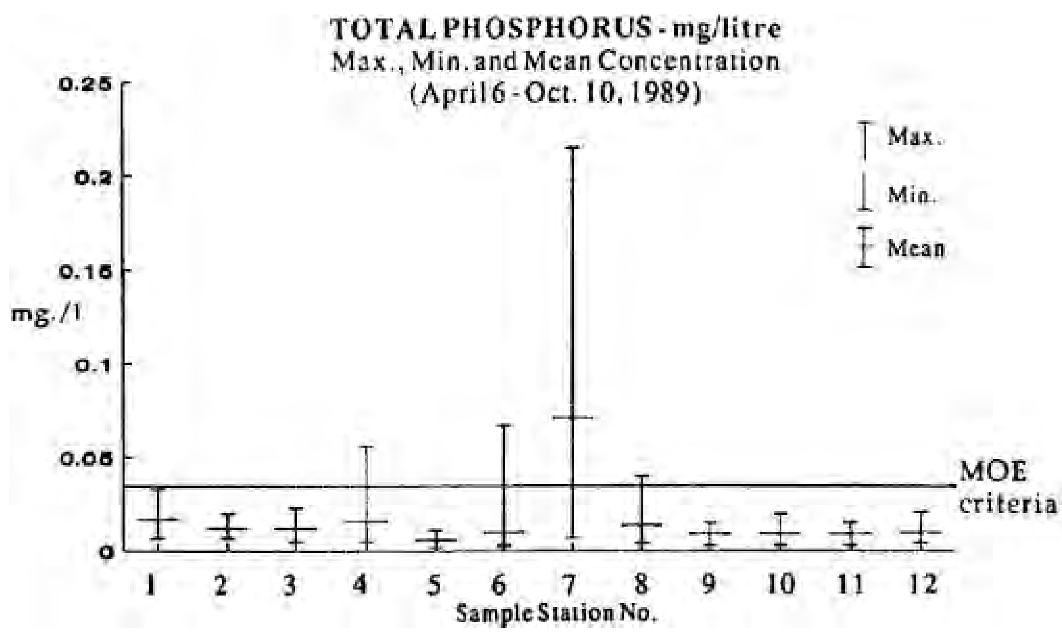

Figure 23

Soluble Reactive Phosphorus (RP):

Stations 001 and 007 showed higher average concentrations of RP as shown in Figure 24. Agricultural activity or wetland processes could be responsible for these fluctuations in quality. Other station concentrations were low and showed little variance.

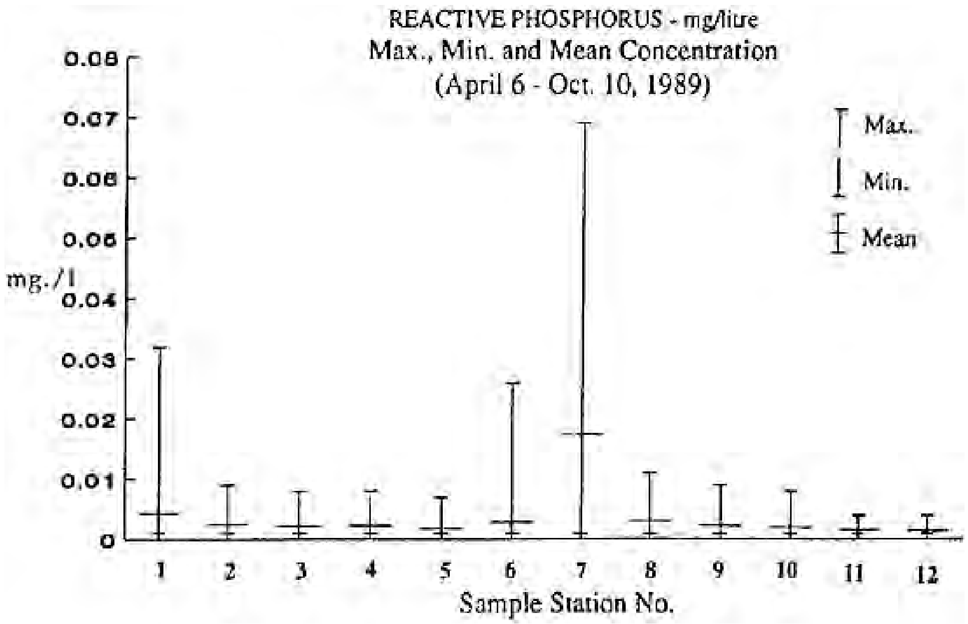

Figure 24

pH:

The MOE Water Quality Objective (1978) range for pH is 6.5 - 8.5. Average pH levels for the 12 stations were within this range as described by Figure 25.

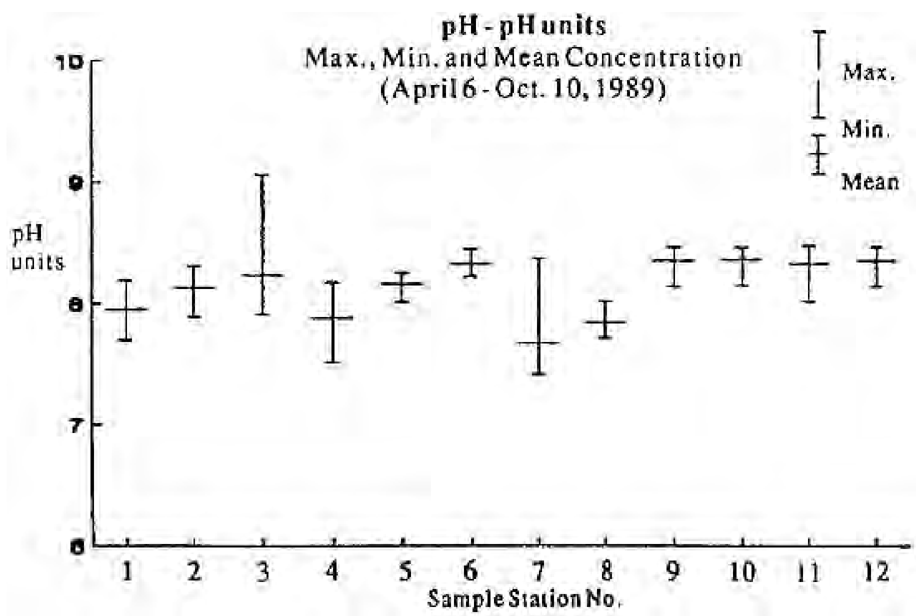

Figure 25.

Turbidity:

Turbidity levels are generally low, with mean figures not exceeding 4 Formazin turbidity units (FTU) (Figure 26).

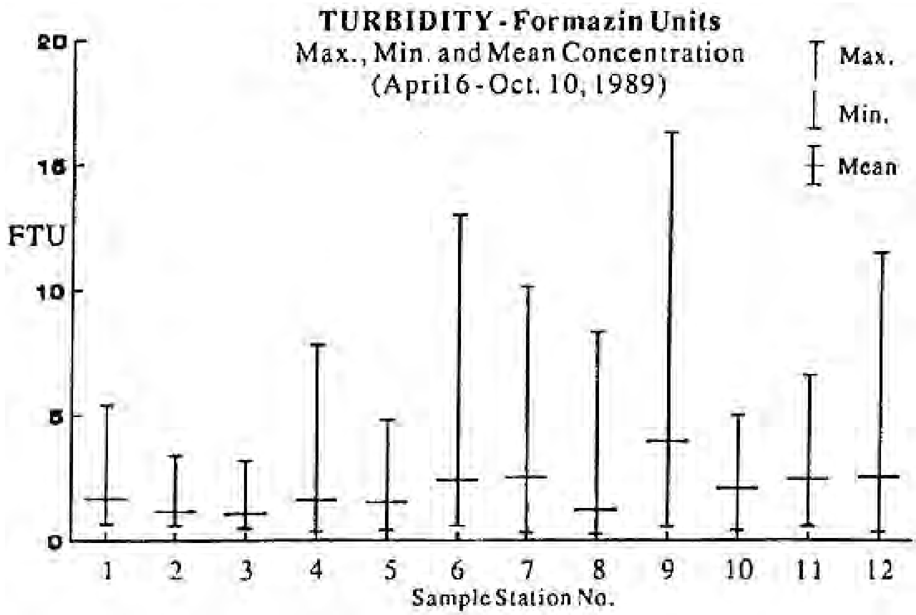

Figure 26

Chloride:

Chloride concentrations ranged from a low of 0.6 mg/L at station 004 to a high of 23.3 mg/l at station 006. As shown in Figure 27, average levels ranged between 2.34 mg/L and

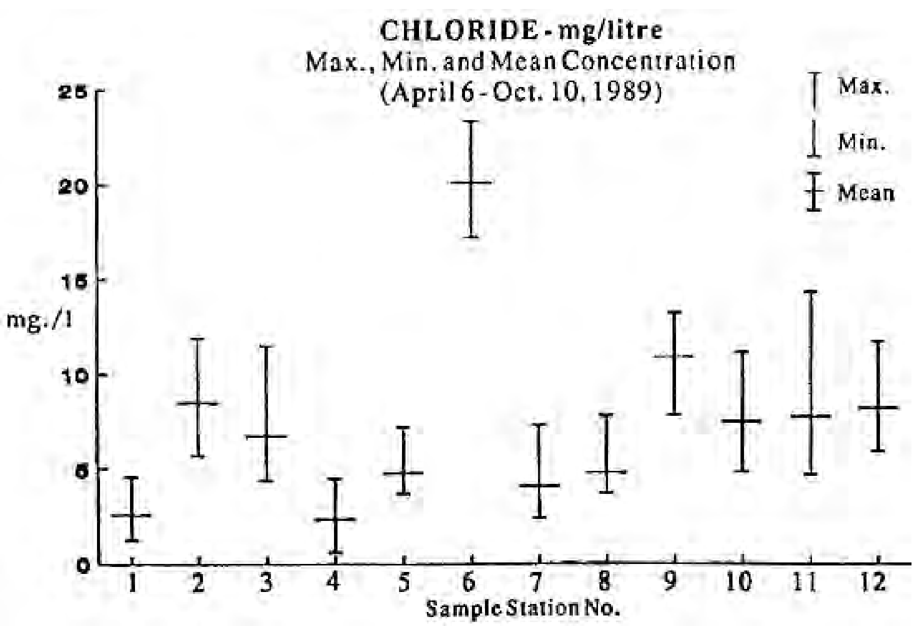

Figure 27

10.88 mg/L with the exception of station 006 with a mean of 20.08 mg/L.

Higher chloride concentrations can result from salt contaminated highway runoff or domestic waste inputs, but in this case the influence of aquifer material on groundwater may be the cause. Though above background levels for the watershed, the concentrations at station 006 are well below the 250 mg/l guideline criteria set by the MOE for public water sources.

Conductivity:

Conductivity levels, which relate to the concentration of dissolved solids, ranged from a low of 249 µmho/cm to a high of 843 µmho/cm , both observed at station 001. Average levels of conductivity ranged from 405 to 488 µmho/cm .

Main stream stations seem relatively stable with stations 002 and 003 at Priceville resembling closely the levels observed at station 010, just above the reservoirs. Elevated conductivity levels are probably a result of concentrations of chloride, nitrate, phosphate or combinations thereof. Figure 28 shows the range of conductivity observed.

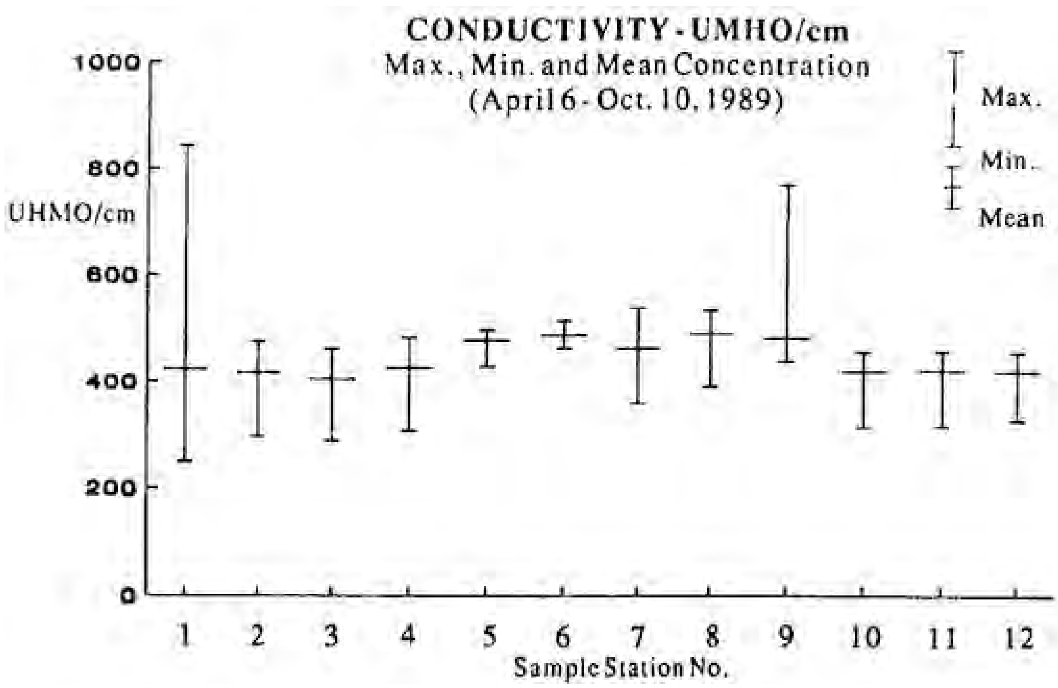

Figure 28

Temperature:

Though unrelated to bathing water quality, temperature is an important component of stream character and relevant to fish and wildlife concerns.

Temperature ranges are illustrated in Figure 29. Bunessan Creek is classified as a coldwater stream as shown by stations 005 and 009. Station 006 shows the warming effect of an upstream pond with a top draw drain. Stations 010, 011 and 012 show the warming effect of the reservoirs at Durham.

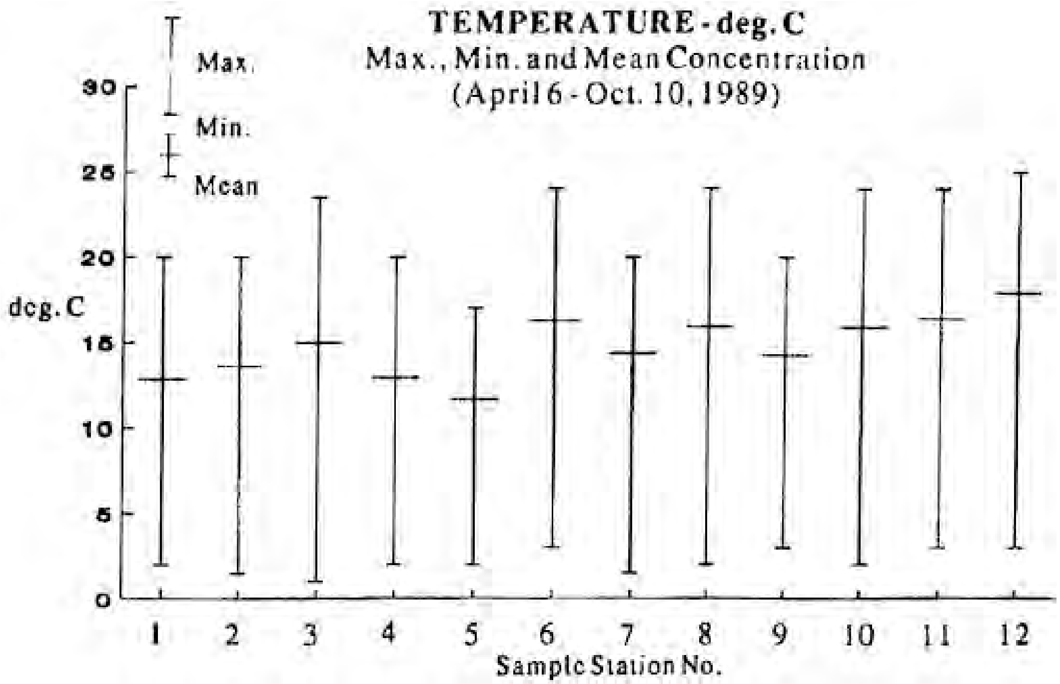

Figure 29

Conclusions:

Fecal coliform bacteria levels are low to moderate throughout Durham subwatershed. Low volume tributaries carried higher concentrations of bacteria at specific locations due to agricultural land use influences and in some cases, probably wildlife inputs. Sediment disturbances and runoff events can greatly increase bacteria numbers in the Durham reservoirs and result in sudden quality fluctuations.

The pathogen *Pseudomonas Aeruginosa* was detected on several occasions in and near the Durham reservoirs. Faulty domestic septic systems may be responsible for these inputs.

Chemical constituents are generally low in concentration with most increases in loading accounted for through the effect of wetlands. Excessive plant growth has not been a problem in the study watershed through submergent aquatic plants do occur in both Durham reservoirs.

Low turbidity levels are probably the result of stable bank and streambed conditions occurring throughout the basin. Water clarity may facilitate high rates of bacterial destruction by the ultra violet portion of the sunlight spectrum.

Temperature analysis shows some tributaries in the subwatershed to be cold water in character as defined by 22°C non exceedance criteria. Bunessan Creek in component subwatersheds 3, 5, and 6 sustain trout populations, offering justification for remedial activities in terms of fishery and bathing water quality enhancement.

Water quality analysis indicates in general a good quality system capable of considerable self purification. Most parameters show quality improvement at the reservoirs over the inflow from the headwater above Priceville, due to dilution, attention and the small number of contaminant inputs.