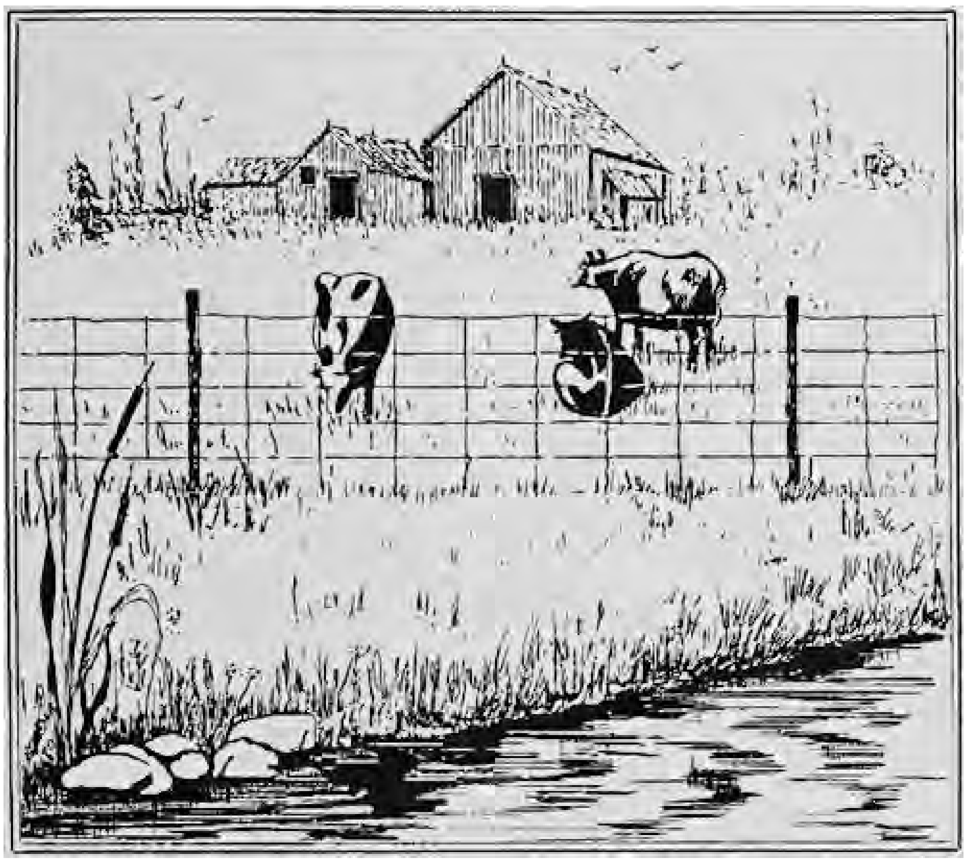
CLEAN UP RURAL BEACHES
(CURB) PLAN
FOR THE
BEAR CREEK - PERCH CREEK WATERSHEDS



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Clean Up Rural Beaches (CURB) Plan for the Bear Creek, Perch Creek

1992

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St. Clair Region Conservation Authority

for the
Ontario Ministry of the Environment

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DISCLAIMER

This report has been reviewed by the local Technical Steering Committee and approved for publication. Approval does not necessarily signify that the contents reflect the position and/or policies of the individual agencies.

FORWARD

This report is one of a series produced under the Provincial Rural Beaches Program. The objective of the Program is to identify the relative impact of pollution sources, and develop a course of action leading to the restoration and long term maintenance of acceptable water quality at rural beaches in the province.

Significant enrichment and bacterial contamination in southern Ontario rivers and lakes originates from rural sources. The discharge of waste material to streams can result in elevated bacterial concentrations, nuisance algae blooms, fish kills, and pose a potential health hazard to humans and livestock using the water. Watershed studies have found that a multitude of pollution sources and pathways may affect beaches in Ontario. These include:

1) Urban sanitary and stormwater runoff,
2) Direct livestock manure access to watercourses,
3) adequate manure management practices,
4) Direct discharge of milkhouse wastes,
5) Contaminated field tile systems, and
6) Faulty septic systems

The impact upon beaches of any of these sources, either singly or in combination, can range from a few days of elevated concentrations to complete seasonal closures.

Numerous beach closings in 1983 and 1984, drew public and government attention to the severity of this water quality problem. In 1985, the Ontario Ministry of the Environment's (MOE) Water Resources Branch formulated the Provincial Rural Beaches Strategy Program. Directed by the Provincial Rural Beaches Planning and Advisory Committee, it includes representatives from MOE, Ministry of Agriculture and Food (OMAF) and Ministry of Natural Resources (MNR).

With financial and technical assistance from the MOE, local Conservation Authorities carry out studies under the direction of a local technical steering committee. Chaired by an MOE regional staff, the committees typically include representation from OMAF, MNR, the Medical Officer of Health, and a local farmer. The chairs of the local committees assure communication between all the projects by participating on the Provincial Committee.

The primary objective of each local study is to identify the relative impact of pollution sources, their pathways to beaches, and to develop a Clean Up Rural Beaches (CURB) plan specific to the watershed upstream of each beach. The CURB Plan develops remedial strategy options and respective cost estimates for each beach through:

1) Field inspections,
2) Farmer consultations,
3) Water quality monitoring, and
4) Basic mathematic modelling techniques.

Recommended actions will include both measures for specific beaches and broader scale Provincial measures based on cumulative results of component studies.

The following related research projects were also MOE funded and undertaken by various Conservation Authorities to improve our understanding of bacterial and nutrient dynamics:

1) *In-situ* bacterial survival studies determine longevity in watercourses, offshore of beaches, in sediments, and in milkhouse washwater tiles.

2) Biotracer studies determine the speed and nature of travel for bacteria introduced into a watercourse.

3) A liquid manure spreading study examines bacterial movement through the soil column and exiting field tile drains.

4) A target sub-basin study evaluates the effectiveness of a watershed with comprehensive remedial measures.

Numerous demonstrations farms have been established with the cooperation of local farmers to display innovative management practices. Research continues on their effectiveness at improving water quality.

Comments and/or questions on this report are welcome. Please send written comments to:

Chair
Provincial Rural Beaches Planning and Advisory Committee
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Toronto, Ontario
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EXECUTIVE SUMMARY

Clean Up Rural Beaches (CURB) plans were completed for the Bear Creek watershed upstream of the Warwick Conservation Area beach and for Perch Creek upstream of the Bright's Grove beach on Lake Huron. A mathematical model was used to estimate the number of bacteria which enter the creek and beach from various rural land uses in these watersheds. Beach closures as a result of high fecal coliform levels are problematic at these beaches.

According to the model results, the largest source of bacterial pollution in these watersheds is faulty septic systems. In Bear creek, ft accounts for 65% of the total load and in Perch Creek for almost 73%.

In Bear Creek, water pollution from manure spreading, primarily liquid manure, was the second largest contributor at almost 15% of the total load. Tile contamination is now known to be a serious problem, especially on clay soils where cracks and channels to the tiles exist. In the Perch Creek area, spreading was only the 4th largest contributor. Many of the farms here are small and deal with solid manure.

In Perch Creek, the second largest source of bacteria was projected to come from cattle access. This accounted for 19% of the total load. In Bear Creek, cattle access ranked 3rd, contributing 11% of the bacteria to the creeks.

Runoff from barnyards (feedlots and manure stacks) ranked 4th in the Bear Creek watershed (5%), whereas it ranked 8th in Perch Creek. Urban runoff ranked 3rd in the Perch Creek watershed, due to the large input from the Bright's Grove suburban lands. In Bear Creek, urban runoff ranked very low due to the small size of the Village of Warwick which is the only 'urban' area in the watershed.

Pollution from untreated milkhouse wash water accounted for under 2% of the problem in both watersheds. Other sources contributing less than 2% included runoff from pasture lands, manure spills and sewage treatment plant discharges.

By examining the cost and effectiveness of various structures in controlling bacterial water pollution, it was found that cattle access restriction through fencing was the cheapest measure. This was followed by septic system repairs and replacements.

Additional watersheds which empty into Lake Huron and the St. Clair River were also described with a recommendation to include them in the CURB Program. These include the Hickory, Aberarder, Patterson and Pulse Creeks along Lake Huron and the Talfourd, Baby and Clay Creeks along the St. Clair River.

ACKNOWLEDGEMENTS

Many people have contributed ideas, knowledge and feedback throughout the production of this CURB Plan and report. The St. Clair Region Conservation Authority Beaches Steering Committee deserve a special thanks for their guidance. Members include:

1. Murray Blackie, MOE, Chairman
2. Dave Hayman, MOE/UTRCA
3. Mike Gaeropy, Sarnia-Lambton Health Unit
4. Earl Morwood, Federation of Agriculture
5. Chris Hutt/Michelle Vandenheuvel, MOE Sarnia
6. Dave Posliff, County of Lambton, Planning
7. Peter Johnson, OMAF
8. Reg McMichael, City of Sarnia, Engineering
9. Ken Brooks, SCRCA Member
10. Donald Craig, SCRCA
11. Margaret Steele, SCRCA
12. Ann Marie Weselan, SCRCA

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

This CURB (Clean Up Rural Beaches) Plan is one of several developed across the province as part of the Provincial Rural Beaches Program. The aim of these plans is to study, document and quantify pollution problems in rural watercourses and beaches and to recommend solutions to improve water quality.

1.1 RURAL BEACHES PROGRAM HISTORY

Numerous beach closings throughout Ontario in 1983 and 1984, drew public and government attention to the severity of water quality problems. In 1985, the Ontario Ministry of the Environment's (MOE) Water Resources Branch formulated the Provincial Rural Beaches Strategy Program. The program is directed by the Provincial Rural Beaches Planning and Advisory Committee which includes representatives from MOE, Ministry of Agriculture and Food (OMAF) and Ministry of Natural Resources (MNR).

Conservation Authorities were asked to participate by conducting the studies. They operate on a watershed basis and therefore are ideally suited to working with water related problems. Financial and technical assistance were provided by MOE. Local steering committees were formed in each area to provide direction. Chaired by staff from MOE regional office, the committees typically included representation from OMAF, MNR, the Medical Officer of Health, the Conservation Authority and a local farmer. The chairs of the local committees assure communication between all the projects by participating on the Provincial Committee.

S.C.R.C.A. Involvement:

The St. Clair Region Conservation Authority (SCRCA) began its involvement in the CURB program in 1989. Two years later, CURB Plans were completed on the Upper East Sydenham River watershed upstream of Coldstream Conservation Area and the Highland Creek watershed upstream of Highland Conservation Area. The SCRCA then received additional funding in 1991 to complete CURB Plans on the Bear Creek watershed upstream of the Warwick Conservation area and Perch Creek which empties into Lake Huron at Bright's Grove. This report focuses on the Bear Creek and Perch Creek watersheds while the CURB

Plan for the Coldstream and Highland Creek watersheds follows at the back of this report. Table 1 summarizes the four areas and their location within the SCRCA is illustrated in Figure 1.

The local steering committees for each contract were made up of representatives from MOE, OMAF, Ontario Federation of Agriculture, Lambton County Planning Department, City of Sarnia Engineering Department and the SCRCA.

1.2 PROGRAM OBJECTIVES

The primary objective of this study is to identify the relative impact of pollution sources on the creeks and beaches, and to develop a Clean Up Rural Beaches (CURB) Plan specific to the Bear Creek and Perch Creek watersheds. The CURB Plan also lists options for remediation and estimates the cost of carrying them out.

1.3 STUDY AREAS

The Bear Creek and Perch Creek watersheds located in Lambton County are the focus of this CURB Plan. They include Bear Creek and Perch Creek. These areas were selected for study due to the history of beach closures at the downstream public beaches and the fact that the land use is predominantly agricultural.

Bear Creek Watershed:

The Bear Creek watershed is located in the northeast corner of Lambton County in the Township of Warwick. Bear Creek forms the headwaters of the North Branch of the Sydenham River which travels in a southwesterly direction towards Lake St. Clair.

The Bear Creek watershed is approximately 77 square kilometers (30 square miles) in size. The watershed is almost entirely agricultural and hog farms are the most common type of livestock farm. The Police Village of Warwick is the only "urban" settlement in the watershed. Figure 2a illustrates the location of the watershed farms and roads and Figure 2b identifies the farm types.

Table 1: St. Clair Region Conservation Authority CURB Watersheds

Creek	Beach	Watershed Area (km^2)	No. of Livestock Farms	No. of Homes
Bear Creek	Warwick Conservation Area Reservoir	77	52	183
Perch Creek	Bright's Grove Public Beach (Lake Huron)	69	49	231
Upper East Sydenham River	Coldstream Conservation Area Reservoir	59	60	160
Highland Creek	Highland Glen Conservation Area Beach (Lake Huron)	47	33	167
TOTAL		252	194	741

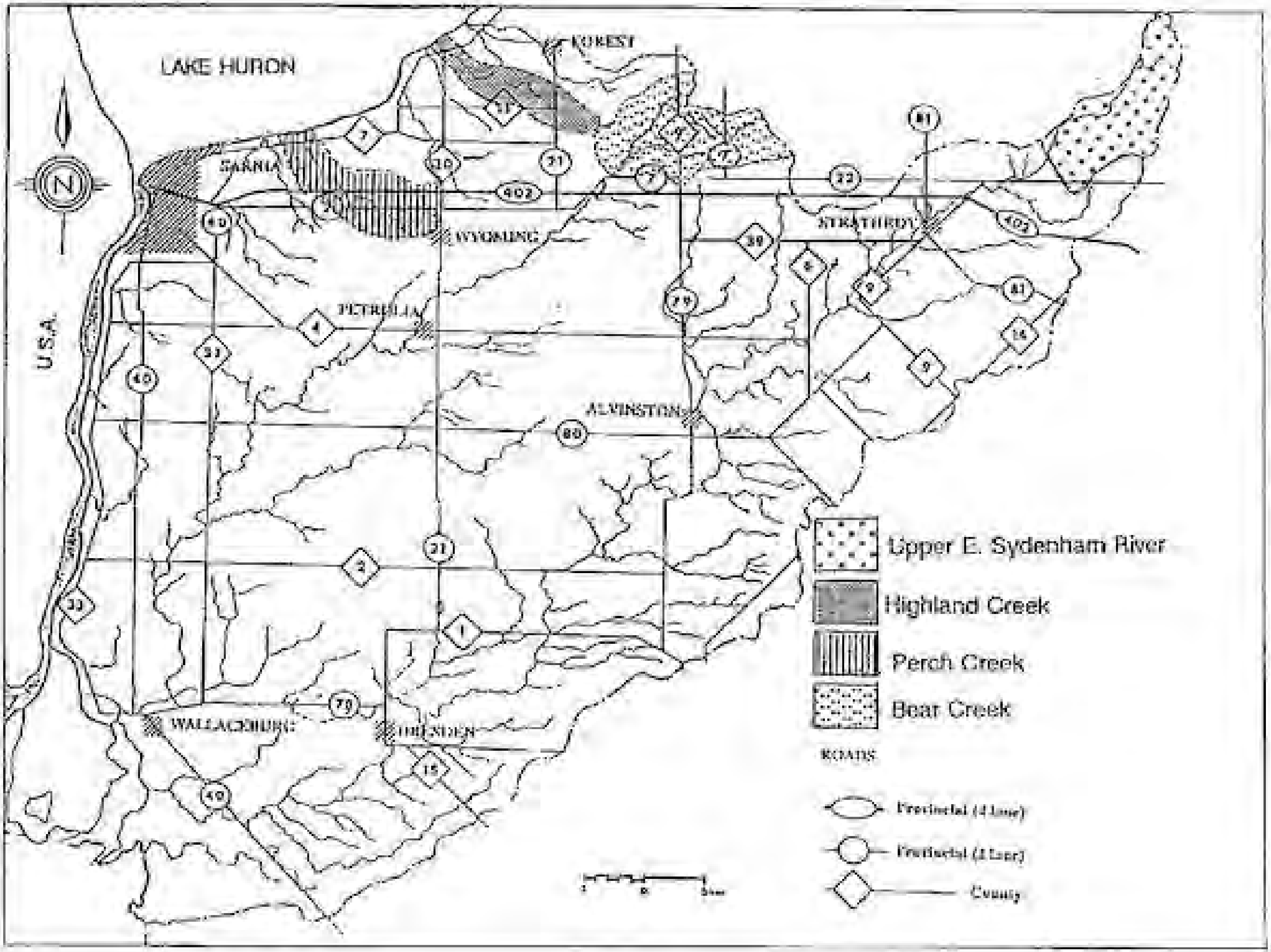

Figure1: Location of the Bear Creek, Perch Creek, Highland Creek and Upper East Sydenham River (Coldstream) watersheds- within the SCRCA.

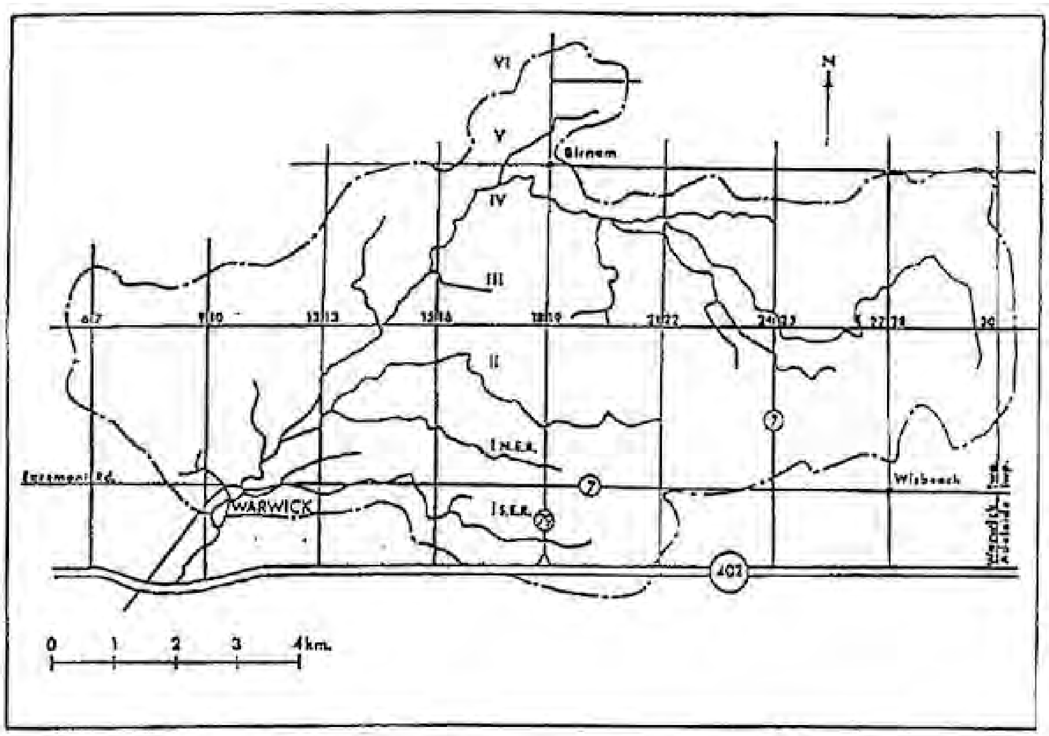

Figure 2a: Bear Creek watershed showing lots and concessions.

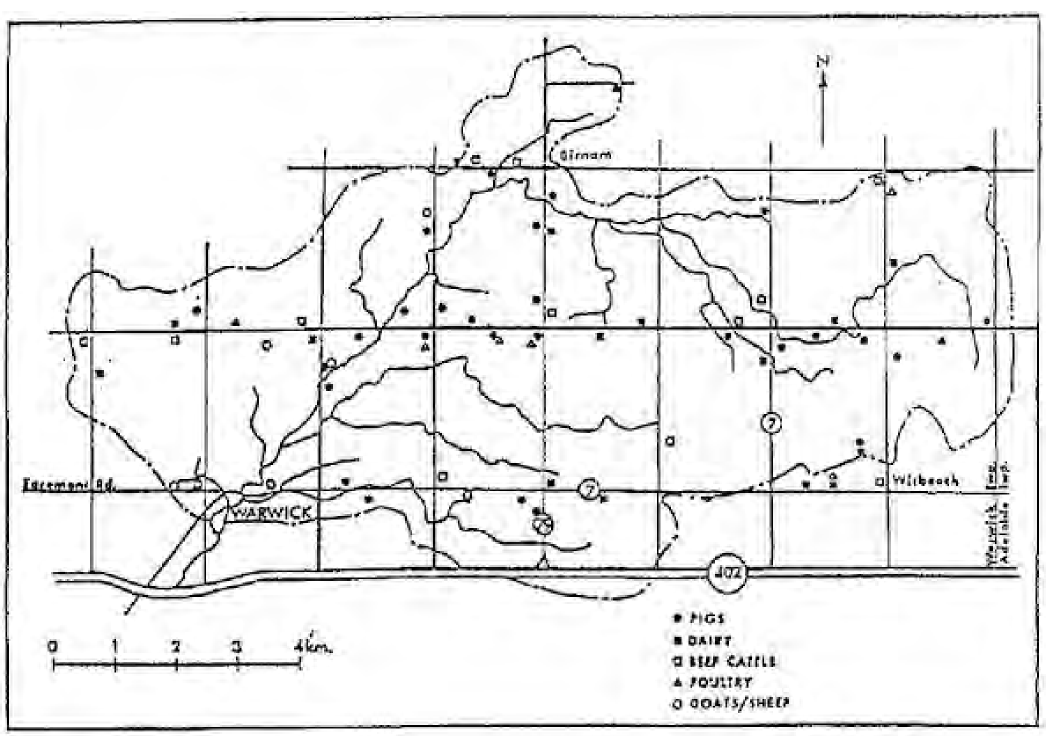

Figure 2b: Location of livestock farms in the Bear Creek watershed.

Perth Clay and Huron Clay soils predominate in this area although some loam soils are present as well. The topography of the land in this watershed and Lambton County in general is quite flat.

Bear Creek discharges into the reservoir at the Warwick Conservation Area. There have been beach closures in the reservoir routinely over the last several summers due to high fecal coliform levels. In addition, users of the Conservation Area have complained of the poor water quality. Figure 4a illustrates the fecal coliform levels in 1990 and 1991 swimming season at the Warwick Conservation Area beach.

Perch Creek Watershed:

Perch Creek drains a watershed area of 69 km^2 and discharges into Lake Huron at the community of Bright's Grove. Bright's Grove is approximately 10 km east of the City of Sarnia.

The watershed is predominantly agricultural in land use with many small hobby farms intermixed with larger farm operations. The suburban community of Bright's Grove flanks the creek near its outlet to the lake. The topography is relatively flat and the predominant soil types are Brookston Clay and Perth Clay. Figure 3 illustrates the location of the farms types and roads in the watershed.

The longest stretch of public beach between Sarnia and Grand Bend is in the Bright's Grove area. This beach is approximately 3.4 km in length, although only sections are actively used for swimming. Levels of fecal coliforms in the beach water from 1988- 1991 are illustrated in Figure 4b. There have been beach closures due to high fecal coliform levels over the last several summers.

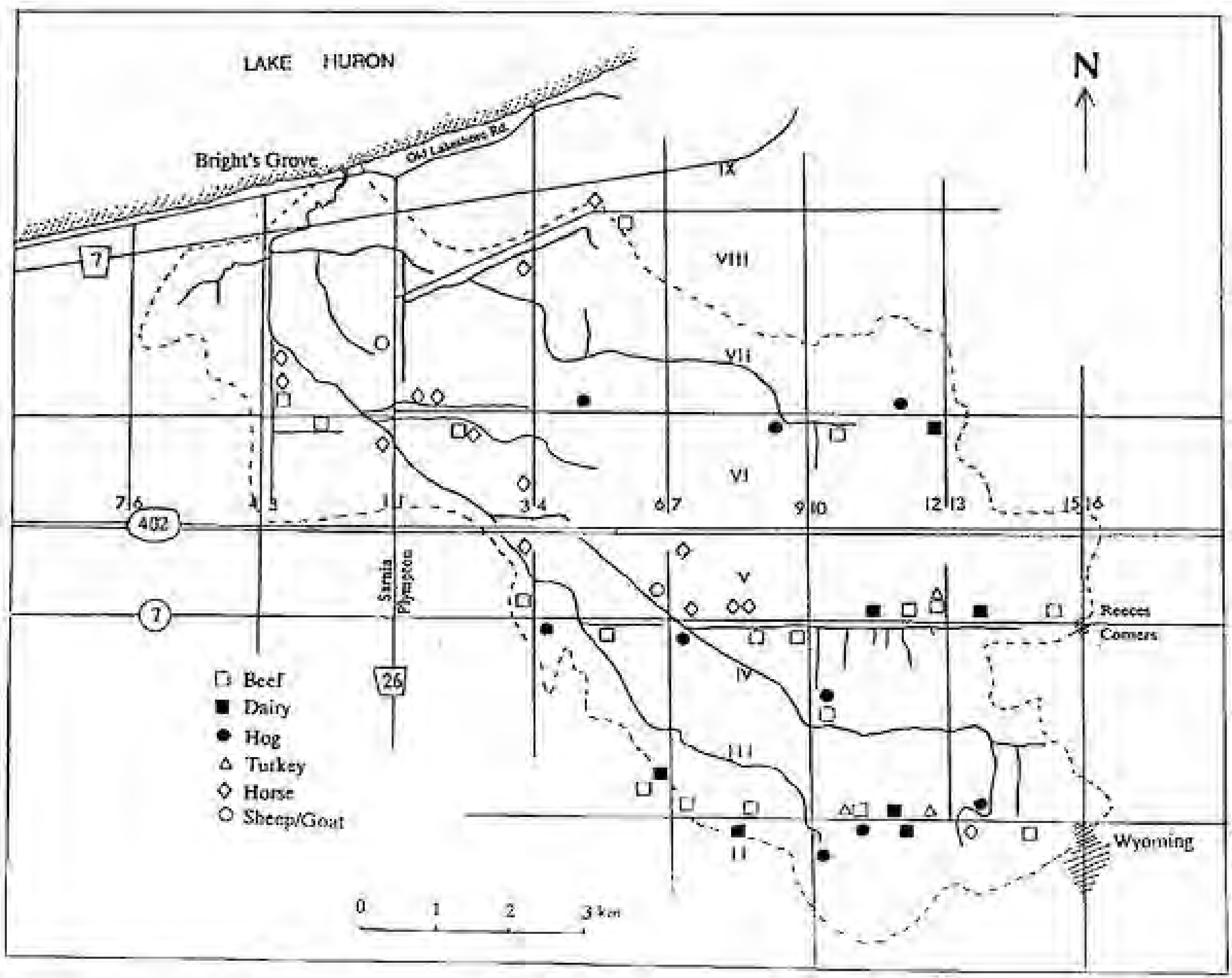

Figure 3: The Perch Creek Watershed

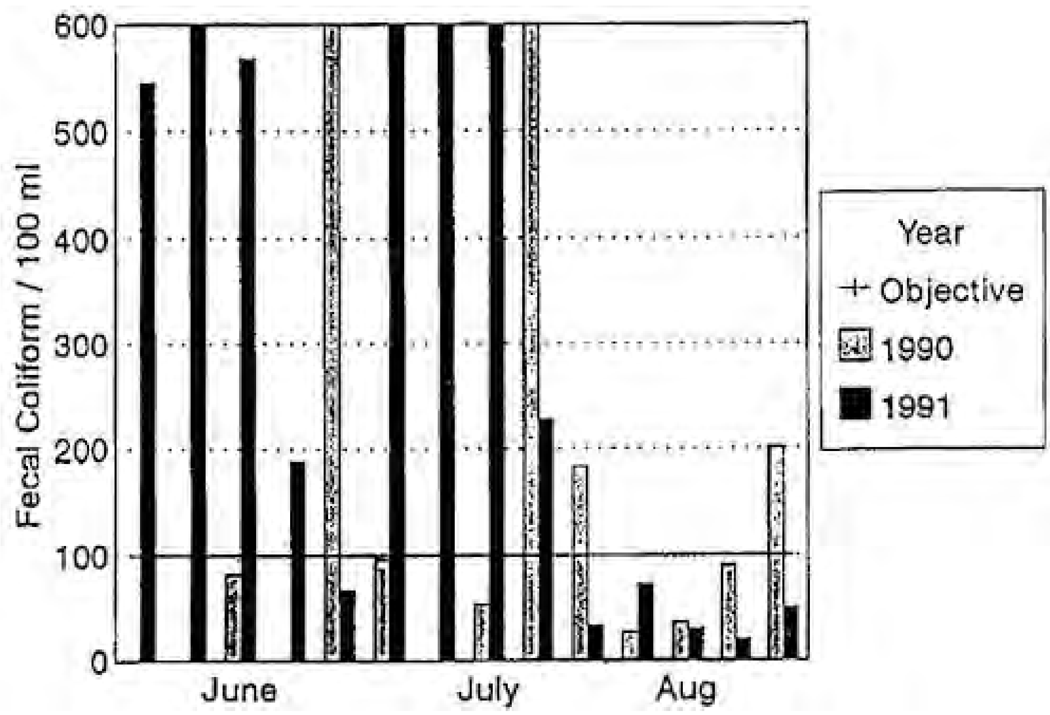

Fig. 4a: Warwick Beach - Fecal coliform levels, 1990-1991

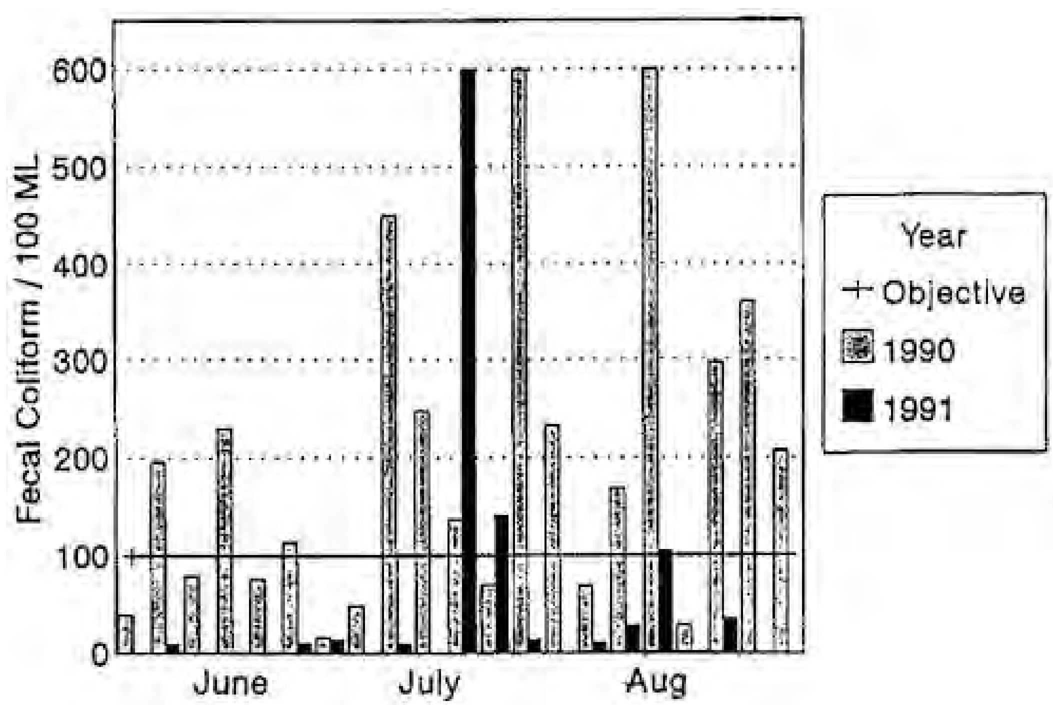

Fig. 4b: Bright's Grove Beach - Fecal coliform levels, 1990-1991

CHAPTER 2

METHODS

2.1 INFORMATION COLLECTION

To complete the CURB Model, information was required on watershed size, length of watercourse, water quality, creek volume discharge, number of farms and homes, and information about individual farms. The following sections summarize the manner in which this information was collected.

Watershed mapping:

The watershed boundaries of Bear Creek and Perch Creek were delineated using township drainage maps at a scale of 1:10,000. Topographic maps (1:25,000 and 1:50,000) in combination with ground truthing were used to distinguish the open watercourse and drains from buried drains. A digital planimeter was used to measure the area of the watersheds and a digital map-meter was used to obtain the length of the open watercourses and other linear measurements.

The buildings marked on the topographic maps were identified by visual examination from a drive-by. Cash crop and livestock farms were distinguished visually as well by noting the presence/absence of manure storages, pasture, fencing, animals, and basic barn shape. The farmer surveys verified many of these assumptions.

Farmer surveys:

A questionnaire was prepared to obtain specific information on farm type, number of livestock, manure management, crops, tiling, etc. The names of the livestock farmers was taken from the mailboxes and the tax assessment roll. The mailing addresses and phone numbers were then obtained from the phone book.

Letters of introduction were sent to the livestock farmers explaining the study and indicating they would soon receive a call from our staff. A copy of the letter and questionnaire is included in Appendix A. The farmers were then called and a time arranged to meet with them in their homes to go over the questionnaire in person. Approximately 30 to 90 minutes were spent with each farmer going over the questionnaire and discussing other related topics. Their confidentiality was assured.

In several cases, the farmer could not be contacted at home and so the questionnaire was dropped off in their mailboxes. Only a few replied by mail. Lastly, the information on each farm was entered into the CURB Model using a LOTUS 1-2-3 spreadsheet.

Water Sampling:

Water samples were collected from the beaches and the watercourses weekly during the course of this study (approximately one year). Eight stations were chosen in the Perch Creek watershed for sampling. They included two beach sites and six creek/tributary sites. Bear Creek was not sampled as vigorously since it had been studied in previous years and good data was available.

Two bottles were filled at each site; one bottle to be tested for bacteria and the other for chemicals (nutrients). The water samples were sent to the MOE lab in London for analysis. The results were mailed back to the SCRCA office and entered onto computer using a LOTUS 1-2-3 spreadsheet.

Flow Readings:

To determine stream discharge and flow rate, a hand-held flow meter was used with a pygmy meter attachment suitable for shallow creeks (minimum depth 10 cm.). Staff set up the equipment at the mouth of the creeks several times a year to obtain a flow reading. During the dry summer months, it was not always possible to read a flow. The results are listed in Appendix B.

CHAPTER 3

CURB ALGORITHMS

3.1 CURB MODEL HISTORY

At the start of the rural beaches strategy program in 1988 it was decided that a standardized mathematical model was needed to quantify all potential pollution sources contributing to beach closures. A workshop was organized to discuss various model approaches with representatives from the MOE and Conservation Authorities.

The Pollution from Livestock Operations Predictor (PLOP) produced earlier by Ecologistics Limited in 1988 under contract from the MOE was examined. It was designed to model phosphorus loadings on an individual farm basis and used American data. Changes to PLOP were necessary to make it workable at a watershed scale, to incorporate Ontario data, and to model fecal coliform loadings.

A meeting was held in Kempenfelt in 1988 to develop a CURB Model suitable for use by Conservation Authorities. Most Conservation Authorities took this preliminary CURB model and altered it to some degree to suit local conditions.

SCRCA Modifications:

In 1989, the SCRCA decided to utilize the model developed by the Maitland Valley Conservation Authority (MVCA, 1989). This model utilized a fairly simple farm-by-farm approach and contained detailed explanations of the algorithms. The SCRCA watersheds were small enough to make this approach feasible.

Following further scrutiny, literature review and discussions with various agencies and the Steering Committee, several changes were made. For example, recent experiments on manure spreading and subsurface tile contamination by the Ausable-Bayfield Conservation Authority (ABCA, 1991) provided the information necessary to write an algorithm to account for subsurface tile pollution from manure spreading.

Changes to the preliminary model and reasons for these changes are explained under each formula. Since the SCRCA beaches are closed due to elevated fecal coliform bacteria levels, only the bacterial model was used. Other conservation authorities have used the phosphorus model as well in response to algae problems. This CURB Plan contains slightly different algorithms than the attached report for the Highland Creek and Coldstream Watersheds. The latter report was produced a year before this one and so there was time to re-think some of the formulas.

3.2 BACKGROUND TO ALGORITHMS

An algorithm is a "procedural model for complicated calculations" (Collins English Dictionary, 1981). Each algorithm in this CURB Model is based on a series of assumptions in combination with actual experimental data. Recent studies by conservation authorities, MOE, OMAF and other agencies have greatly added to our understanding of this complex problem.

The number of fecal coliforms found in manure and in the aquatic environment are extremely large and so are written as a number with an exponent. For example, one million fecal coliforms (1,000,000) is written as 1.0 E+6 (1.0 times 10 to the exponent 6) in this report.

There are eleven major sources of rural water pollution for which algorithms have been written. Detailed descriptions of each formula is contained in Appendix B, Algorithms 1 to 7 were calculated on a farm-by-farm basis and the remainder were tabulated on a watershed average. The following is a summary of the formulas.

1. <u>MILKHOUSE WASTE LOADING:</u>
   Conc. x Vol/day x # days x Delivery (Growth)

2. <u>LIVESTOCK ACCESS LOAD:</u>
   Conc./Defec x EAU x Prob. Defec x # events/day x # animals x # days

3. <u>FEEDLOT/BARNYARD RUNOFF LOAD:</u>
   Conc. x Area x Runoff Factor x # days x Delivery

4. MANURE STACK RUNOFF LOAD:
Conc. x Area x Runoff Factor x # days x Delivery

5. MANURE SPREADING - OVERLAND RUNOFF LOAD:
Vol. x conc. on field x field die-off x Critical Zone x Delivery

6. MANURE SPREADING - SUBSURFACE RUNOFF LOAD:
Vol. x conc. on field x Delivery to tiles

7. SEPTIC FAILURE LOAD:
Conc. x Vol/home/day x # homes x # days x Failure Rate x Delivery

8. MANURE SPILLS LOAD:
Conc. x Volume x # spills/year

9. PASTURE RUNOFF LOAD:
Conc. x precipitation x % runoff x area x Critical Zone

10. SEWAGE TREATMENT PLANT DISCHARGE LOAD:
Conc. x Volume of Discharge

11. URBAN NON-POINT SOURCES LOAD:
Concentration/hectare x urban area

Vol	= Volume
EAU	= Equivalent Animal Units
Conc./Defec.	= Concentration of f. coliforms per defecation
Prob.Defec.	= Probability of Defecation
Conc.	= Concentration of f. coliforms per unit of water

CHAPTER 4

RESULTS

4.1 SURVEY RESULTS Bear Creek:

Of the 52 livestock farmers In the watershed, 43 were given the questionnaire in person, 5 were completed over the phone and 1 was returned by mail. Contact could not be made with the last 3 farmers and so assumptions about the type and size of the operation was derived from visual observations of the barn and barnyard areas and comments from neighbours. In general, there was excellent cooperation from the farming community. Several of the interviews had been completed in 1988 as part of an earlier water quality study.

Twenty four of the 52 livestock farmers raised pigs, 14 kept beef cattle and 10 housed daily cows. Table 4 lists the remainder of farm types. Twenty-one farmers dealt solely with solid manure (stackable), another 23 dealt with liquid manure (most of the hog farmers), and the last 8 farms had both types stored separately. Total yearly manure production for the watershed was calculated to be 400,794 cubic meters. This amount of manure would fill 80 football fields 1 meter deep.

Perch Creek:

Of the 49 livestock farmers in the watershed, 14 were interviewed in person, one over the phone, and 7 were completed by mail. Information about the remaining 27 farms (mostly horse farms) was derived from visual observations of the barnyards. Almost half of the farms were small scale hobby farms. In fact, 23 farms had fewer than 5 horses or 7 beef cattle or 10 goats or sheep. The remaining 26 farms were medium to large scale operations.

Out of 49 farms, 38 dealt exclusively with solid stackable manure, another 9 handled only Liquid manure in tanks and the remaining two had both types stored separately. The total volume of manure produced in this watershed was 88,399 m^3. This would almost fill 18 football fields 1 meter deep with manure.

Table 2 summarizes the number of farms with water pollution problems as identified by staff or predicted by the model. Appendix B lists additional information on livestock numbers and manure production.

4.2 CURB MODEL RESULTS

Tables 3a and 3b list the results of the CURB model calculations for Bear Creek. Table 3a lists the fecal coLiform loadings attributed to each pollution source and differentiates overland and subsurface contamination. Table 3b summarizes and ranks the information. Tables 4a and 4b list the results of the CURB model calculations for Perch Creek.

Figures 5 and 6 depict the summarized data in pie diagrams to illustrate the percentage contribution of each source over the spring and summer period.

Table 2. Summary of farm operations in each watershed

	Bear Creek (#)	Perch Creek (#)
Livestock Farms	52	49
Small Scale Hobby Farms	6	23
Med-Large scale farms	46	26
Septic Systems (Total #)	183	231
Failing systems	55	69
Livestock Access Sites	5	4
Total length (m)	1684	1900
Animals with access	280	498
Milkhouse Wash Water (Dairy Farms)	9	7
Farms with treatment systems	2	1
Farms with no treatment	7	6
Feedlot/Exercise Yards	15	12
Feedlots without containment	14	10
Manure Stacks	23	32
Stacks without containment	23	32
Manure Spreading		
Farmers who spread	48	47
Farmers who spread liquid	31	
Farmers who spread solid	29	40
Volume of manure spread (m^3)	396,786	58,005
Volume of liquid spread (m^3)	362,372	31,880
Volume of solid spread (m^3)	34,414	26,125
Pasture Land Farms with pasture	23	35
Area of pasture (ha.)	177	193
Communal Sewage Treatment Plant	0	1
Urban Non-point Sources (ha.)	24	100

Table 3(a). Fecal coliform loadings to Bear Creek

Source	Loading Spr+Sum ($x 10^{10}$)	Loading Fal+Win ($x 10^{10}$)	Loading Yearly ($x 10^{10}$)
Septic System	4509	4509	9017
Access	1561	0	10101
Spreading			
overland	74	97	170
by tile	958	539	1497
Feedlot			
overland	274	274	547
by tile	9	9	18
Milkhouse	108	108	217
Stack			
overland	9	9	18
by tile	81	81	163
Pasture Runoff	74	0	74
Urban Non-Point	37	37	74
Spills	1	0	1

Table 3(b). Pasturerized and ranked F. Coliform loadings to Bear Creek

Spring + Summer	F. Colif ($x 10^{10}$)	Fall + Winter	F. Colif ($x 10^{10}$)
1. Septic	4509	1. Septic	4509
2. Access	1561	2. Spreading	636
3. Spreading	1032	3. Feedlot+Stack	372
4. Feedlot + Stack	373	4. Milkhouse	108
5. Milkhouse	108	5. Urban	37
6. Pasture	74	6. Spills	0
7. Urban	37	7. Pasture	0
8. Spills	1	8. Access	0
Total	7695	Total	5662

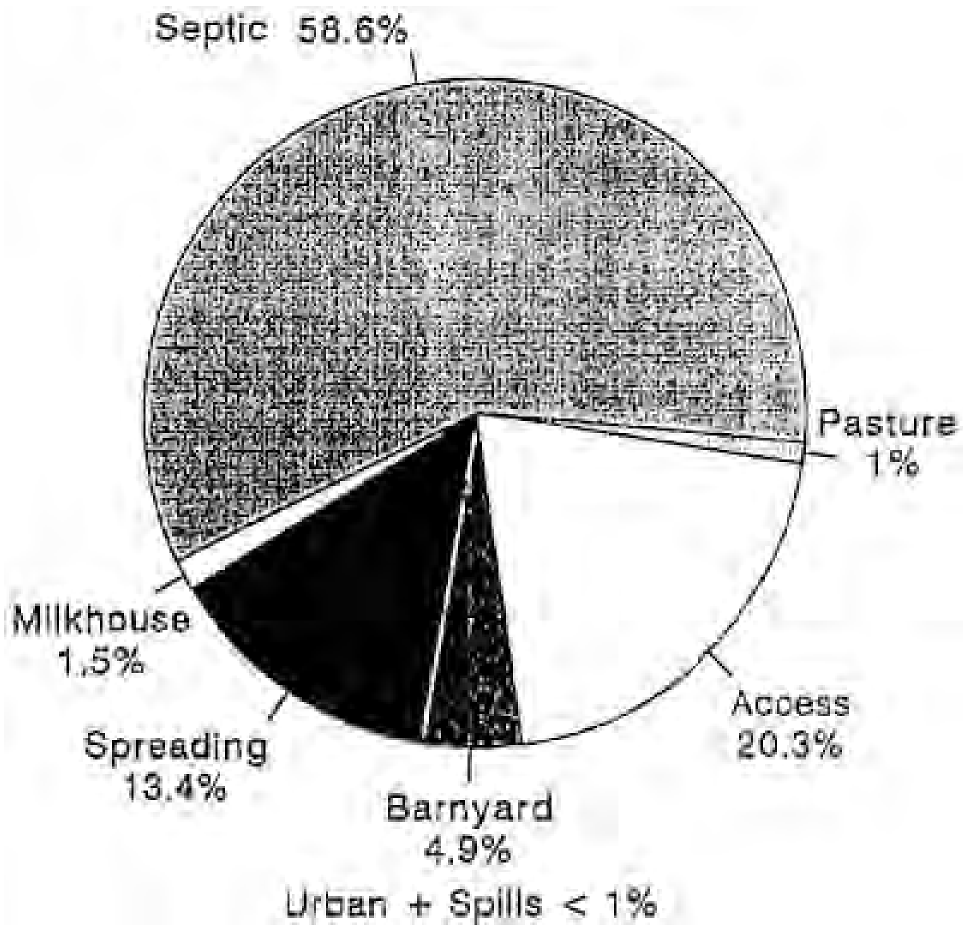

Fig. 5: Fecal coliform loadings to Bear Creek: Spring and Summer

Table 4(a). Fecal coliform loadings to Perch Creek

Source	Loading Spr+Sum (x 10^{10})	Loading Fal+Win (x 10^{10})	Loading Yearly (x 10^{10})
Septic System	4742	4742	9474
Cattle Access	1244	0	1244
Urban Non-Point	233	233	465
Spreading Total			
- overland portion	47	38	85
- by tile portion	59	0	115
Pasture Runoff	89	0	89
Milkhouse Wash Water	48	48	96
Sewage Lagoons	25	25	50
Stack Total			
- overland	4	4	8
- by tile	4	4	8
Feedlot Total			
- overland	0	0	0
- by tile	6	6	12

Table 4(b). Summarized and Ranked F. coliform loadings to Perch Creek

Spring and Summer	F. Coliform (x 10^{10})	Fall and Winter	F. Coliform (x 10^{10})
1. Septic	4742	1. Septic	4742
2. Access	1.244	2. Urban	233
3. Urban	233	3. Spreading	94
4. Spreading	106	4. Milkhouse	48
5. Pasture	89	5. STP	25
6. Milkhouse	48	6. Stack+Feedlot	14
7. STP	25	7. Spills	0
8. Stack+Feedlot	14	8. Access	0
9. Spills	0	9. Pasture	0
Total	6501	Total	5156

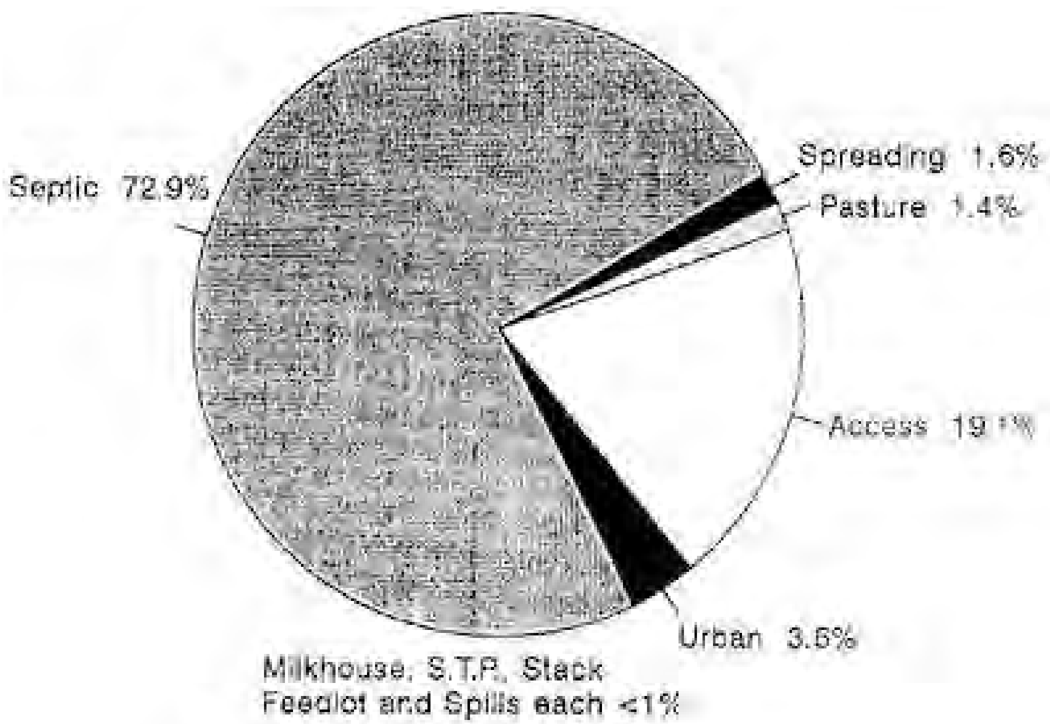

Fig. 6: Fecal coliform loadings to Perch Creek: Spring and Summer

CHAPTER 5

BACTERIAL TRANSPORT AND SURVIVAL TO BEACHES

To determine how many of the bacteria which enter the creek survive to the beach, several factors need to be considered. Bacteria are killed when exposed to sunlight, cold and competition. Theoretically, the longer they remain in the creek, the more die-off will occur. The time spent travelling in the creek is dependent upon the flow conditions. The following formula is utilized:

$$N_t = N_o \times 10^{-kt}$$

where: N_t = number of bacteria reaching the beach or creek mouth per season
N_o = number of bacteria delivered to the stream per season
10^{-kt} = die-off rate, where:
k = decay rate for that season
t = travel time in days for baseflow and event flow conditions

Continuous and Event Discharges:

Sources of fecal coliform pollution are divided into two categories: continuous discharges and event or pulse discharges. This is important to note since this determines the flow conditions under which the bacteria travel. Continuous discharge loadings are those sources that contribute bacteria to a watercourse on a daily basis or regardless of weather conditions. Continuous pollution sources include:

- milkhouse wash water discharges
- livestock access
- tile contamination from liquid manure spreading
- manure spills
- septic system discharges
- sewage treatment discharges

Pulse discharges, on the other hand, only contribute bacteria during a precipitation or storm event. These sources include:

- runoff from feedlots
- runoff from manure stacks
- surface runoff from manure spreading
- urban stormwater runoff
- pasture runoff

5.1 DECAY RATE (k)

Studies carried out by a number of Conservation Authorities on decay rates of fecal coliform bacteria suspended in the water column and in the sediments show a variety of results. It appears that the decay rates vary with temperature, pH and nutrient levels.

Because of the variability in the data, the results from all of the studies were pooled and an average taken (Young, pers. comm.). Table 5 lists the decay rates of fecal coliform bacteria in the water column.

Table 5. Seasonal fecal coliform die-off rates in logs/day

Spring	0.26	Spring + Summer = 0.30
Summer	0.35	
Fall	0.26	Fall + Winter = 0.23
Winter	0.20	

5.2 TRAVEL TIMES (t)

Travel time to creek mouth:

The travel time is the amount of time that it takes fecal coliform bacteria to reach the mouth of the creek from its source of input. It was assumed that all sources were evenly distributed throughout the watershed and so travel times were estimated from the mid-point of the watershed. This was derived by measuring the longest stretch watercourse (mouth to headwaters) and dividing that length in half. In Bear Creek, the midpoint is 9 km from the mouth and in Perch Creek it is 8 km away.

Travel times were calculated for both watersheds for baseflow and storm or event precipitation conditions using the flow readings taken during the year. The flow readings which were obtained are listed in Appendix B. The data is limited due to weather (eg. no flow) and time constraints.

It was estimated that the creeks would be in a high flow condition 52 days a year. This is based on the CURB Model assumption that rainfall events occur once every 14 days (26 days a year) and confirmed with the Sarnia Weather Office data in Appendix B. For simplicity it was assumed that the creeks swell and travel quickly during these precipitation days and the day after and then resume baseflow speeds.

Table 6 lists the stream discharge and travel times. In the Bear Creek watershed, it takes less than a day to travel from the mid-point to the creek mouth during baseflow conditions. In Perch Creek, it takes slightly more than a day. In high flow conditions, travel times for both watersheds are well under a day.

Travel time to beaches:

The travel time from the mouth of the creeks to the swimming beach is different for the two watersheds. Bear Creek empties into the Warwick Reservoir at its north end and travels south for about 400 hundred meters to the beach area near the dam outlet (Figure 7). The reservoir has an average depth of 1 meter and has a surface area of 6.6 hectares (16 acres). This translates to approximately 64,800 cubic meters of water in the reservoir.

Table 6. Stream flow, travel times and die-off rates

	Bear Creek	Perch Creek**
Discharge Rate *		
Event flow	0.39 m^3 /sec	0.38 m^3/sec
Base flow	0.09 m^3/sec	0.08 m^3/sec
Discharge in litres (spring + summer)		
Event flow days (26 days)	1.05 E+9	8.54 E+8
Base flow days (157 days)	1.55 E+9	1.02 E+9
Total days (183)	2.60 m^3/sec	1.95 E+9
Creek Velocity		
Event flow	32 km/day	28 km/day
Base flow	16 km/day	6 km/day
Midpoint	9 km	8 km
Decay Rate (k)	0.3 logs/day	0.3 logs/day
Travel Time (t) to creek mouth		
Event flow	0.3 days	0.3 days
Base flow	0.6 days	1.3 days
Travel Time (t) from mouth to beach		
Event flow	3 - 4 days	1 - 2 days
Base flow	6 - 7 days	1 - 2 days
Die-off rate (10^{-kt}) to creek mouth		
Event flow	0.81	0.81
Base flow	0.66	0.41
Die-off rate (10^{-kt}) from mouth to beach		
Event flow	0.09	0.36
Base flow	0.01	0.36

* Discharge rates taken from averages of data in Appendix D

** Flow readings for Bear Creek taken at Highway 7 in Warwick Village and Perch Creek at new Lakeshore Rd.

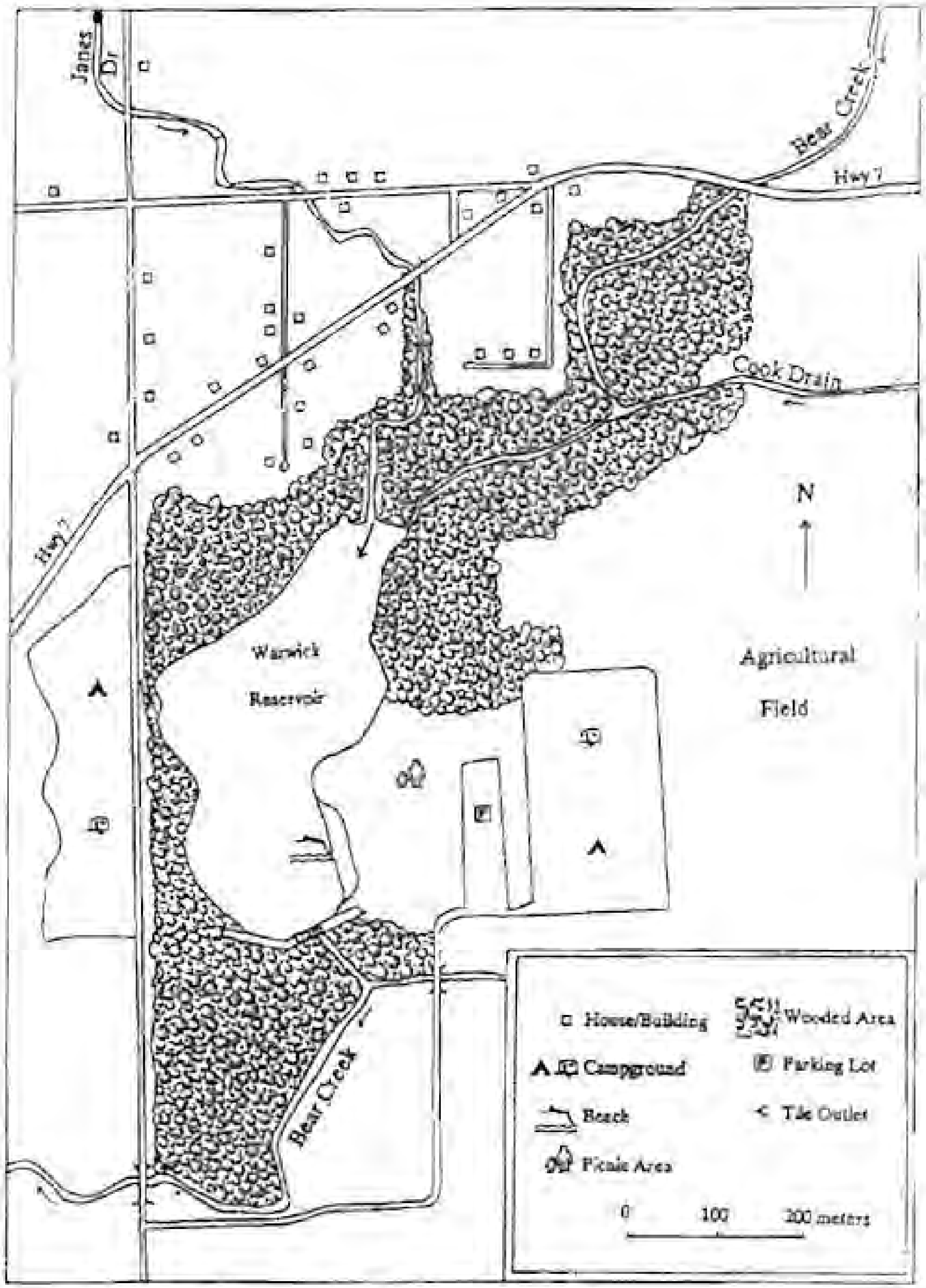

Figure 7: Warwick Conservation Area Reservoir and Beach

Using an average discharge rate of 0.104 m^3/sec from Bear Creek and the two small drains which enter the reservoir independently of Bear Creek (8986 m^3/day), it would take about 6 to 7 days to fill it up if it were empty during baseflow conditions. Therefore, by extrapolation, it was assumed that bacteria would die-off for 6 - 7 days before reaching the beach. During high flow situations, it was estimated that the creek water would reach the beach in 3 to 4 days.

Perch Creek outlets into lake Huron at Bright's Grove. A seawall extends the banks of the creek an additional 20 meters into the lake. Lake and creek water mix within this mouth area. Figure 8 illustrates the location of the public beaches along this stretch of shoreline and the more actively used sections. It was assumed 1 to 2 days would pass before the creek water could move down to the Bright's Grove beach areas. This is dependent upon lake currents.

Bacterial survival in bottom sediments:

While bacteria are travelling in the creek, some will attach themselves to suspended solids and settle down to the creek bed sediments. Some will die and others will thrive in the sediments. Nutrient rich organic sediments like a marsh bottom tend to enhance the survival of bacteria (LSRCA) whereas nutrient poor sandy sediments do not (UTRCA, 1989). The UTRCA also found that almost complete die-off occurred in experimental sediment chambers placed in the Fanshawe Reservoir.

The rate at which bacteria fall out of the water column and settle to the bottom is unknown and so it is impossible to model at this point. This continual process of settling and die-off would affect all bacteria equally, regardless of source. Therefore, this does not alter the overall percentage contribution from the various sources to the beach.

However, it is still important to recognize the potential implications of bacteria in the sediments. Swimmers can stir up this stored bank of bacteria in the sediments and re-contaminate the swimming water. The relatively clean, nutrient-poor sandy sediments at Bright's Grove beach on Lake Huron may not enhance bacterial survival. In fact, bacteria levels at this beach tend to stay low until July. This is well after swimmers have stirred up the sediments.

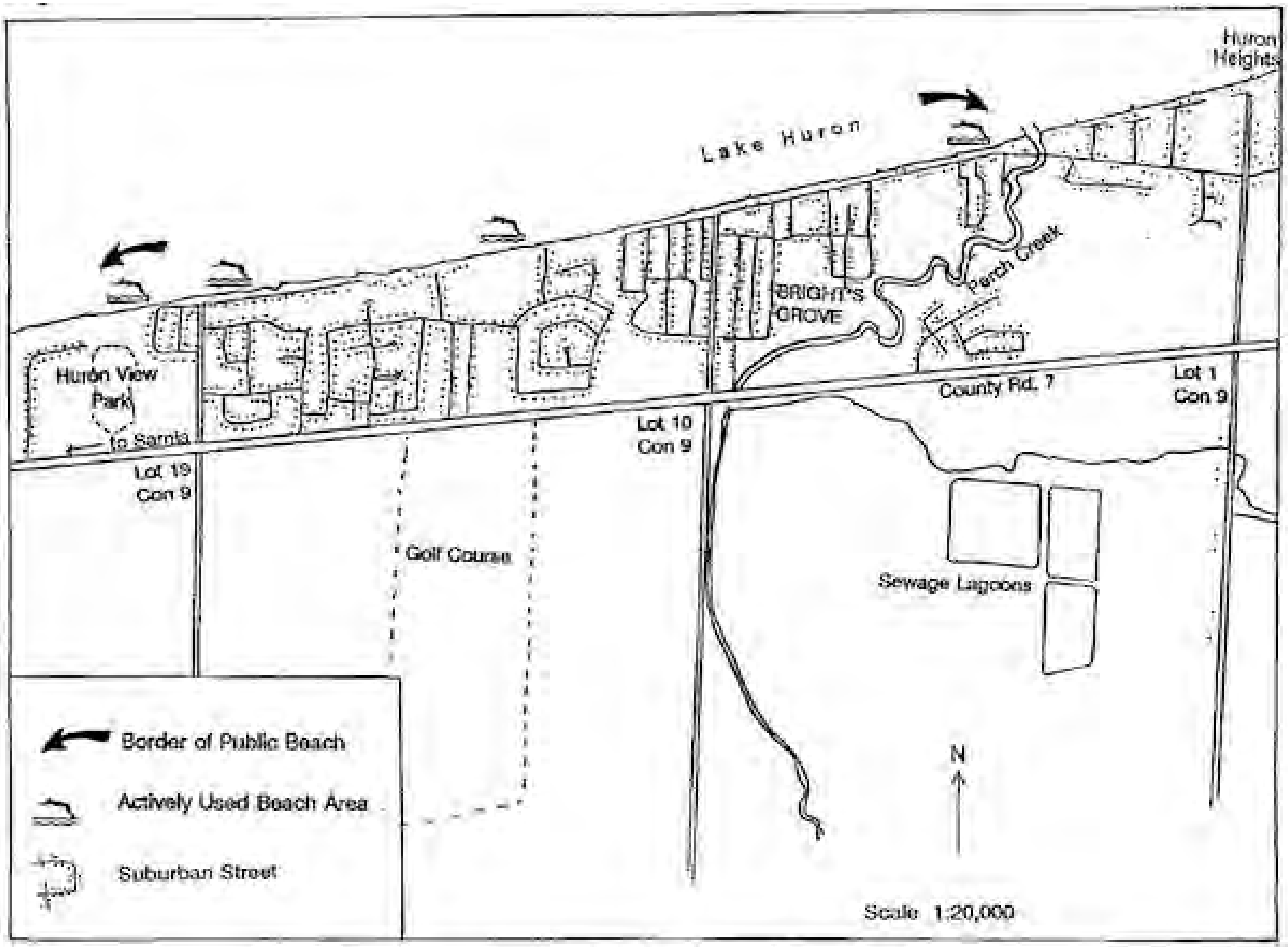

Figure 8: Public beach between Huron View Park and Bright's Grove

On the other hand, the soft clay sediments in the man-made Warwick reservoir are likely more nutrient rich and may encourage the survival of bacteria. Fecal coliform levels at this beach tend to be high throughout the swimming season. Re-contamination of the water column from the sediments is a possibility. Poor water quality from the inflowing Bear Creek is probably still the predominant factor in beach closures.

5.3 LOADINGS TO THE MOUTH AND BEACH

The loadings for each source taken from Tables 3 and 4 were multiplied by the appropriate die-off rates taken from Table 6. Continuous sources of pollution were broken down into the percentage which travel on base flow days (86% of time) and event flow days (14% of time). The results are tabulated in Appendix E and summarized in Tables 7a and 7b. The calculations were done for the spring and summer data since this is the time period of most concern for swimming. It is also the time of year when all pollution sources would be contributing (eg. access). Fall and winter results would be quite similar.

There is a significant reduction in fecal coliform loadings predicted from Bear Creek to the Warwick beach (7694 E+10 to 559 E+10) because of the long residence time of the water in the reservoir. There is less die-off predicted in the Perch Creek/Bright's Grove area (6501 E+10 to 1133 E+10) since the travel time to the beach is estimated at only 1 to 2 days versus 6 to 7 days in the Warwick reservoir.

In both watersheds, the continuous sources of bacterial pollution (eg. septic, spreading, access, etc.) are a much larger contributor of bacteria than pulse sources (eg. manure runoff). At Warwick Beach the ratio is about 4:1 of continuous to pulse and at Brights Grove Beach it is about 2:1 (Appendix E). However, on a loading per day basis, more fecal coliforms travel during event (rain) conditions because all sources are potentially contributing. Since there are only 26 event flow days per season (assumed) compared to 157 baseflow days, baseflow days contribute larger loads overall.

Table 7a. Fecal coliform loadings to Bear creek mouth and Warwick beach, spring and summer.

	to Creek (fc x 10^{10})	to Mouth (fc x 10^{10})	to Beach (fc x 10^{10})
Septic	4509	3070	328
Access	1561	1063	113
Spreading	1032	703	74
Feedlot/Stack	372	301	28
Milkhouse	108	73	8
Pasture	74	60	5
Urban	37	30	3
Spills	1	0	0
TOTAL	7694	5300	559

Table 7b. Fecal coliform loadings to Perch Creek Mouth and Brights Grove Beach, spring and summer.

	to Creek (fc x 10^{10})	to Mouth (fc x 10^{10})	to Beach (fc x 10^{10}))
Septic	4742	2210	796
Access	1244	580	209
Urban	233	189	68
Spreading	106	49	17
Pasture	89	72	26
Milkhouse	48	23	8
STP	25	12	4
Feedlot/Stack	14	12	5
TOTAL	6501	3147	1133

5.4 VALIDATION

It is important to determine this CURB model's accuracy in predicting bacterial concentrations in the creeks and beaches. This model attempts to assimilate an enormous amount of information using somewhat limited data and knowledge concerning bacterial dynamics in the environment. An exact correlation with the real world is not expected.

One method of comparing model projections with actual sample results, is to convert the predicted loading (# f. coliforms) into a concentration (# f. coliforms/litre). This is done by dividing the model loading values by the number of litres of water the creek discharges per year or season.

Flow readings taken during baseflow and event flow conditions were converted into daily discharge volumes. Under baseflow conditions approximately 9,840,000 litres per day are discharged into the Warwick Reservoir from Bear Creek and its tributaries. This translates to 0.155 E+10 litres/season. Under event flow (rain) conditions, approximately 40,440,000 litres/day pass through, which translates to 0.105 E+ 10 litres per season. In Perch Creek, approximately 6,480,000 litres/day are discharged to Lake Huron under baseflow conditions. Under event flow conditions, 32,832,000 litres/day or 0.085 litres/season are discharged.

In the case of Warwick beach, the reservoir Is largely filled with creek water and so creek volumes were used to assess beach concentration figures. Since Bright's Grove beach is open to Lake Huron, a volume could not be estimated. An arbitrary figure of 10 times the creek discharge was used to approximate the actual concentration figures. The results are listed in Table 8.

As Table 8 illustrates, the concentrations predicted by the CURB model are plus or minus one order of magnitude of the actual sample concentrations for both watersheds. The model predicted average fecal coliform concentrations at the mouth of Bear Creek of 2,038/100 ml whereas average spring and summer levels in 1988 and 1992 were measured at 697 fc/100 ml. The model's prediction of event flow levels were extremely close to the measured concentrations (1,150 versus 1,264/100 ml). However, the model overestimated the baseflow concentrations by almost an order of magnitude (2,640 vs. 411/100 ml).

At Warwick Beach, the model's prediction of average concentrations was quite close to the actual values (215 versus 340/100 ml). However, the model underestimated the event flow levels by an order of magnitude and overestimated the baseflow concentrations by almost an order of magnitude.

The model's predictions at Perch Creek were much closer to the actual sample results. The overall average predicted was 1,683 fecal coliforms/100 ml compared to the measured average of 1,068/100 ml. Baseflow levels were overestimated by 2 times and the event flow were only slightly overestimated. At Brights Grove Beach, a true comparison cannot be made since the volumes are unknown. A dilution of 10 times brings the predicted concentration figures quite close.

It must be noted that actual fecal coliform concentrations in the water samples vary substantially from one week to the next. The levels vary from year to year as well. The data presented in Appendix E shows that pollution levels were higher in Bear Creek in 1988 than in 1992.

Although the actual sample results showed higher concentrations under event flow conditions, on average, this is by no means an absolute. Weekly samples give a good idea of water quality, but they cannot show all of the variation and extremes. One or two high values can substantially alter the overall average. The first flush of a storm can generate very high levels as tiles are flushed out into the creeks but samples taken at the end of a storm may be more diluted. In contrast, the model predicted lower concentrations during event flow conditions due to the dilution effect and the fact that the biggest contributors (eg. septic, access and spreading) occur continuously and the pulse sources (runoff) are relatively small impacts in comparison.

Table 8. Fecal coliform concentrations: model vs. actual

	Load (fc x E10)	Water* Volume (litres x E10)	Predicted Conc. (fc/100 ml)	Actual** Conc. (fc/100 ml)
Bear Creek Mouth	5,300	0.260	2,038	697
Base flow	4,092	0.155	2,640	411
Event flow	1,208	0.105	1,150	1,264
Warwick Beach	559	0.260	215	340
Base flow	450	0.155	290	68
Event flow	109	0.105	104	1,698
Perch Creek Mouth	3,147	0.187	1,683	1,068
Base flow	2,174	0.102	2,131	1,098
Event flow	973	0.085	1,145	838
Bright's Grove Beach	1,133	1.870*	61	90
Base flow	782	1.020*	77	89
Event flow	351	0.850*	41	93

* Volume of lake water diluting the creek water Is unknown; Arbitrarily assume 10 times the creek volume is added.

** Actual concentrations:
for Bear Creek and Warwick = average of 1988 and 1992 samples,
for Perch Creek and Br. Grove = average of 1991 and 1992 samples + Brigh'ts Grove.

CHAPTER 6

REMEDIATION COSTS AND STRATEGY

The approximate number of pollution sources in need of repair is listed in Table 9. For many sources, the construction of a structure will reduce pollution, but for others a change in management is required. A description of how the costs were derived follows. The total cost for the watershed is summarized in Table 10.

6.1 ESTIMATION OF COSTS

Septic System Repair or Replacement

The average cost of a new septic system installed on clay soils is approximately $12,000. This was based on estimates obtained from contractors over the phone. The MOE now requires raised beds on clay soils and this greatly adds to the cost of a traditional septic system. Clay soils dominate in the Bear Creek and Perch Creek watersheds. The watershed cost of replacing each of the suspected faulty septic systems was determined by multiplying the total number of sites by $12,000.

Fencing Cattle out of Creek

The cost of a cattle fencing project can vary greatly depending upon whether the project involves simply fencing one side of a creek or fencing both sides of a creek and installing a water pump and culvert crossing. A list of costs associated with a fencing project, including culverts and alternate watering devices is listed in Appendix F.

The average cost of a conventional fence (page wire, barb wire or electric) is $1.20 per meter for materials only. A specialty, high tensile fence costs approximately $4.20 per meter including installation (the installation is required for the guarantee). If half of the farmers chose one or the other, the average cost per watershed would be $ 2.70/meter. It was assumed that most farmers would choose to fence both sides of the creek.

Material costs for a cross-over (culvert, backfill, and erosion protection) and an alternate watering device (mechanical nose pump, hose) and seeding amount to approximately $1800 per site. Again, this does not include the costs of installation or

Table 9. Pollution sources needing remediation

	Bear Creek (# repairs)	Perch Creek (# repairs)
Structural Measures Required		
Septic Systems Replacement/Repair		
Faulty systems	55	69
Fencing Livestock		
Access sites	5	4
Total length (m)	1684	1900
Milkhouse Treatment System		
Farms with no treatment	8	6
Containment for Feedlot + Stack Runoff		
Feedlots contributing	4	1
Feedlots + stacks contributing	6	1
Manure stacks contributing	1	11
Sewage Treat. Plant Improvements	0	1
Manure Pits		
Farms with <6 months storage	14	5
Urban Non-Point Runoff		
Urban centres	1	1
Storm sewer drainage (ha.)	23	100
Remediation through management, not structures		
Manure Spills	<1	<1
Manure Spreading	31	11
Farmers who spread liquid (#)		
Pasture Land		
Farms with pasture	23	35
Average pasture size (ha.)	8	6

engineering. An installed culvert can cost $4000 or more. It was assumed that half of the sites require such work.

Assuming one half of the farmers choose the cheaper, self-installed method and the other half choose the installed fence, the average cost would be $2.70/meter. This cost was multiplied by the total length of the watercourse (both sides) needing fencing in each watershed.

Milkhouse Wash Water Treatment Systems

Milkhouse waste water can be treated in a sediment tank treatment trench system or stored in a concrete pit and then land spread. The latter can be used in combination with Liquid manure or runoff storages as well which is more cost-effective.

The Treatment Trench system costs approximately $4,000 to install (Harold House pers. comm., Don Hilborn pers. comm.). This system is being examined by the UTRCA for effectiveness.

In order to estimate the size of a concrete pit to hold only wash water, the daily water usage per farm per day was multiplied by 240 days. In the Bear Creek watershed, an average pit would need to hold 219 m^3 (7730 ft^3) over 240 days. In Perch Creek, an average pit would need to hold of 115 m^3 (4060 ft^3) of wash water. The cost of an open concrete tank in this small size range is approximately $1.22/$ft^3$ (Appendix E). Accordingly, the 219 m^3 tank would cost approximately $9400. The 115 m^3 tank would cost $5000.

Runoff Containment for Feedlots and Manure Stacks

Ideally, runoff containment structures should consist of a paved pad enclosed by three concrete walls (4 ft. high or 1.22 meters) and a tank to catch the liquids. Concrete pads cost about $21.60/$m^2$ and walls cost $82/$m^3$ (Appendix F.). However, for economic reasons, many farmers construct earthen berms in place of vertical concrete walls. The cost is low, generally the fee for a back-hoe operator for a few hours time.

Most farmers choose a concrete circular in ground tank with vertical walls. A common size is 30 x 10 feet at a cost of $8600. A list of costs for manure storages is listed in Appendix F. To obtain an average cost for a pad, an average feedlot/stack area was used and multiplied by $21.60. Costs are given for the both the walled and un-walled designs in Table 10.

Liquid Manure Pits / Tanks

Undersized liquid manure storages may lead to over-spreading or untimely spreading. This, in turn, leads to overland runoff and subsurface tile contamination. Manure storages were priced for those farms with less than 6 months of storage since they may be at most risk of over-spreading. All farms had some liquid manure storage and so only needed an additional pit to hold the extra months of manure.

Information obtained from an earlier study of Bear Creek (SCRCA, 1989) revealed that of 15 farmers with liquid manure, 12 needed additional storage to meet the 240 day requirement. On average, farmers needed storage for an additional 30,000 ft^3 each. A concrete circular pit with dimensions of 60 x 12 feet would hold 34,000 ft^3. An open pit at $0.43/$ft^3$ would cost approximately $16,000. These costs were multiplied by the number of farms needing additional storage and the results are listed in Table 10. A pit 60 x 12 feet would need approximately 188 feet (57.5 meters) of safety fence. At a cost of $42.60/meter, the cost per pit is $2500.

Sewage Treatment Plant Improvements

To reduce bacteria levels in the Bright's Grove Sewage Lagoons, the facility would need to either construct an Ultra-violet (UV) Light Sterilization System, or chlorinate and de-chlorinate the water. At the present time, only facilities which discharge continuously (i.e. larger urban plants) use these methods to reduce bacteria.

An Ultra-Violet Light Sterilization System would cost approximately $350,000 to install assuming hydro is available at the plant. A chlorination system would be more costly. The UV System reduces bacterial concentration in the discharge water to below 100 fc/100 ml of water (Rick Turnbull, MOE, pers. comm.).

Today's environmental standards are tougher than they were when the Bright's Grove Lagoons were installed. If the facility were to expand, MOE would likely force the plant to convert to a mechanical plant. The cost of this would be approximately $5 million. Lagoons cost approximately one-third less to install than mechanical plants. It is unlikely that a sewage lagoon would be constructed to service the small village of Warwick. Individual septic systems will likely remain the only alternative for some time.

Storm Sewer / Urban Drainage Improvements

There are several designs which engineers now use to improve storm water quality in urban and suburban areas. These are termed Best Management Practice (BMPs). Best Management Practices usually involve one of the following designs: Extended Detention Pond, Wet Pond, Infiltration Trench, Infiltration Basin, Porous Pavement, 'Water Quality Inlet, Filter Strip, and Grassed Swale.

There is limited information of the effectiveness of most of these designs in removing bacteria (see Appendix F). However, there is information on the Infiltration Trench, Infiltration Basin and Porous Pavement which indicates they can remove 60 - 100% of the incoming bacteria (Schueler, 1987). Weil's article (1991) summarizes the use of wet pond in rural/urban watersheds. Good results (96% removal) were found if water is treated in a batch flow mode versus only 53% removal in a continuous flow mode.

There are site specific limitations to using any of these designs. Design selection would need to take into account slope, water table, soil depth, space, etc. The most limiting factor is often money. Schueler (1987) explains that construction costs for different BMP options can vary substantially depending on the methods and materials used as well as certain economies-of-scale. An engineering consulting firm was contacted to determine some average dollar figures for these designs. Only values for infiltration basins were available.

Table 10. Total watershed cost of remediation work.

	Bear Creek ($)	Perch Creek ($)
Septic System Replacements		
Raised beds	660,000	828,000
Fencing Livestock		
Fencing one side	4,600	3,900
Fencing both sides + culvert	18,100	14,900
Milkhouse Treatment		
Treatment Trench System	28,000	24,000
Open concrete pit	32,800	15,000
Closed concrete pit	72,000	33,000
Runoff Containment		
Earthen curbing		
Feedlot containment	36,500	0
Feedlots with stacks	96,700	12,000
Stack containment	3,900	36,700
Concrete walls		
Feedlot containment	46,300	0
Feedlots with stacks	128,800	16,700
Stack containment	5,800	49,900
Liquid Manure Pits		
Open concrete tank + fence	257,600	92,000
Covered concrete tank	394,800	141,000
STP Improvements		
UV Light treatment system	0	350,000
Mechanical Plant	0	5,000,000
Urban Runoff		
Infiltration Trench	200,000	2,000,000
Total (least expensive)	1,255,800	3,337,600
Total (most expensive)	1,551,790	8,095,800

6.2 COST-EFFECTIVENESS OF REMEDIAL MEASURES

To determine the cost-effectiveness of each of the remedial measures the total watershed cost for each source was divided by the number of fecal coliforms contributed from that source. Tables 11 and 12 List the cost of removing 10 billion fecal coliforms from each source taking into account the effectiveness of the remediation in removing bacteria from the watercourse.

In the case of constructing liquid manure pits, an effectiveness of 20% was chosen since proper storage does not prevent most of the pollution which results from manure spreading. Application rates may still be too high for soil and moisture conditions. However, with adequate storage, the farmer is more likely to spread wisely. It is hoped that with continued research, recommendations will be available to farmers regarding how and when to spread to minimize tile contamination.

Similarly, in the case of Sewage Treatment Plants, UV lights and mechanical plants reduce bacteria, but do not eliminate it altogether. An arbitrary effectiveness rating of 80% was chosen for UV light and 90% for mechanical plants.

In the case of urban stormwater, an effectiveness rating of 70% was chosen since not all of the water can be treated during large storms. All other structures were assumed to remove all of the bacteria providing they are correctly built and maintained.

Results:

The most cost-effective measure to reduce bacteria in both watersheds is livestock fencing. Fencing only one side of the creek is the cheapest at $3 per 10 billion fecal coliforms, but this does not account for the loss of pasture land or the willingness of farmers to retire the land. The most realistic scenario is to fence both sides and supply a cross-over and an alternate water supply. This will cost approximately $12 to remove 10 billion bacteria.

The second most cost-effective measure is the replacement of septic systems. In both watersheds, this would cost less than $90 per 10 billion bacteria.

In Bear Creek, barnyard runoff containment and milkhouse washwater treatment can both be cost effective at under $400/10 billion fecal coliforms. In Perch Creek, millkhouse treatment is cost-effective but manure runoff is not due to the small size of the farms and the economies of scale. Liquid manure tanks are less cost effective at over $600/10 billion f. coliforms since they do not completely eliminate tile contamination from manure spreading.

The least cost-effective measures are urban stormwater treatment and sewage treatment plant improvements. These are expensive, capital-intensive projects considering the relatively small bacterial loading they contribute in these areas If the CURB Grant is given to correct each problem and the maximum grant rate given, the total CURB allocation to Bear Creek would be approximately $500,000 and $424,000 for Perch Creek.

Table 11. Cost-effectiveness of remedial measures in the Bear Creek watershed

Remedial Structure	FC Load (x 10^{10})	% of FC removed	Total Cost ($)	$ to remove 10 billion F. coliform
Livestock Access				
1. Fence one side	1561	100	4,600	3
2. Fence both sides + culvert, etc.	1561	100	18,100	12
Septic Systems				
1. Tank + raised bed	9107	100	660,000	79
Barnyard Runoff				
1. Pad, curb + tank	746	100	137,100	184
2. Pad, walls + tank	746	100	180,900	243
Milkhouse Washwater				
1. Treatment trench	217	100	28,000	129
2. Open concrete tank	217	100	75,200	347
3. Closed concrete tank	217	100	105,000	484
Liquid Manure Pit				
1. Open concrete tank + safety fence	1667*	20	220,000	660
2. Closed concrete tank	1677*	20	394,800	1186
Urban Stormwater				
1. Infiltration trench	74	75	200,000	3571

* There is no loading for liquid manure pits so the manure spreading load is used instead since spreading practices are related to storage availability.

Table 12. Cost-effectiveness of remedial measures in the Perch Creek watershed

Remedial Structure	FC Load (x 10^{10})	% of FC removed	Total Cost ($)	$ to remove 10 billion F. coliform
Livestock Access				
1. Fence one side	1244	100	3,900	3
2. Fence both sides + culvert, etc.	1244	100	14,900	12
Septic Systems				
1. Tank + raised bed	9474	100	828,000	87
Manure Runoff				
1. Pad, curb + tank	27	100	48,700	1,800
2. Pad, walls + tank	27	100	30,000	313
Milkhouse Washwater				
1. Treatment trench				
2. Open concrete tank	96	100	15,800	165
3. Closed concrete tank	96	100	33,000	344
Manure Pit				
1. Open concrete tank + safety fence	200	20	92,000	2,300
2. Closed concrete tank	200	20	141,000	3,525
Urban Stormwater				
1. Infiltration trench	465	75	2,000,000	5,730
Sewage Treatment Plant				
1. UV Light Disinfection	50	80	350,000	8,750
2. Mechanical Plant	50	90	5,000,000	111,111

* There is no loading for liquid manure pits sot the manure spreading load is used instead since spreading practices are related to storage availability.

6.3 IMPLEMENTATION STRATEGY

Efforts to clean-up surface water pollution problems in these watersheds will be greatly aided by the Ministry of the Environment's new CURB Implementation Grant Program which commenced in the 1991. Rural landowners will be eligible for grant money for projects which improve water quality in designated CURB watersheds. Conservation Authorities with completed CURB Plans will be able to offer the grant for a 5 year period.

The SCRCA will offer the CURB Implementation Grant to these landowners in 1992. A local multi-agency Steering Committee will be set up to review and prioritize applications. Within the guidelines of this voluntary program, the committee will target the grant to those sources which contribute the most bacteria and are the cheapest to repair as outlined in Tables 11 and 12. This is a voluntary incentive program and so complete control in the landowners who remediate is not possible. Urban runoff and Sewage Treatment Plant problems are not addressed under this particular grant program.

Bear Creek Watershed

According to the CURB Model, average fecal coliform levels at Warwick beach are 215/100 ml. To reduce the bacteria to the Health Unit standard for swimming of 100/100 ml, at least a 53% reduction in fecal conforms at the beach is needed. To achieve swimming quality standards at the creek mouth, a much larger reduction is needed.

Theoretically, any combination of sources could be repaired at varying levels to arrive at this total watershed reduction. However, because the reduction required is so large, it Is obvious that repairs are needed foremost from the largest contributing sources. These include septic systems, cattle access and contamination from liquid manure spreading practices. Together, these account for 92% of the bacterial loadings.

One can simulate remediation and monitor the outcome by deleting sources from the CURB Model Spreadsheet. For simplicity, the total loads for each source were summarized and the average fecal conform concentration in the creek and at the beach were computed. Then for interest sake, various sources were eliminated to see what the resultant change in loadings and concentrations would be. Table 13 lists the results of various manipulations on the average concentrations. Baseflow concentrations will be slightly higher and event flow slightly lower than the average given.

The model predicts that if all of the septic problems were removed, the average fecal coliform concentration at Warwick Beach would be 89/100 ml, although baseflow conditions would be slightly higher. By eliminating just access sites or just feedlot/stack runoff problems, the concentrations would still be over swimming guidelines. In fact, by correcting all access, feedlot/stack, milkhouse and spreading problems together, the average fecal coliform levels would still be 129/100 ml. Thus, a certain percentage of the septic problems will need to be repaired to achieve swimming standards at the beach.

Perch Creek Watershed

According to the CURB Model, fecal coliform levels at Perch Creek mouth during baseflow conditions f. coliform levels are projected to average 2131/100 ml and 1,145/100 ml during event conditions which is quite close to the actual measured values. To reduce creek levels to 100/100 ml a 90 to 95% reduction is required.

Although the overall average fecal coliform levels at Bright's Grove Beach are predicted and shown to be under 100/100 ml, it is the sporadic peaks in bacteria 1-3 times per season which close the beach. There is no good correlation between creek flow, lake conditions and pollution levels. Reductions are thus still needed overall to reduce these peaks.

As in the case of Bear Creek, the most cost-effective measures to reduce bacteria are cattle access restriction and septic system repairs. Milkhouse wash water treatment was also cost-effective. Septic and access problems together account for 92% of spring and summer f. coliform loadings. If these were repaired, fecal conform levels at the creek mouth would be 136/100 ml and substantially lower at the beach.

As in Bear Creek, repairing the access, feedlots, stacks, milkhouses and spreading problems together would not reduce levels in the creek enough to meet swimming standards. Repairs to the faulty septic systems are essential if the creek is ever to substantially improve.

Table 13a. Projected f. coliform concentrations after remediation in the Bear Creek watershed

Sources Repaired	Conc. at Creek mouth	Conc. at Beach
None	2039	215
All septic	858	89
All access	1630	171
All feedlots/stacks	1923	205
All milkhouse	2011	212
All spreading	1769	186
All septic + access	449	45
All access, feed/stack, milkhouse + spreading	1216	129

Table 13b. Projected f. coliform concentrations after remediation in the Perch Creek watershed

Sources Repaired	Conc. at Creek Mouth	Conc. at Beach
None	1209	44
All septics	359	13
All access	986	34
All feedlots/stacks	1204	43
All milkhouses	1200	43
All spreading	1190	43
All septics and access	136	5
All access, feedlots, stacks milkhouses and spreading	954	34

6.4 DISCUSSION

It is unlikely that remediation will proceed in the fashion described above, of course. Some landowners will jump at the opportunity to repair a problem with a grant incentive, while others will remain skeptical or still find the costs too high. Any repair which improves local water quality will always be encouraged, not only because of the improvements at that particular site, but also because of the positive message it sends to other landowners. Ultimately all pollution sources should be eventually corrected but the final decision rests with the landowners themselves.

Solutions to tile contamination from manure spreading need to be researched. Solutions will likely involve management changes involving working the ground beforehand, selecting dry days to spread, spreading more thinly and increasing storage to allow for these changes. The large volume of liquid manure produced in the Bear Creek watershed and the large percentage of the problem it represents, highlights the importance of this issue.

Manure spills do not comprise a large portion of the overall loading to the beaches although they can have serious consequences immediately after they occur. Adequate storage for liquid manure is an obvious solution as well diligence when spreading. The more farmers who deal with liquid manure or convert to liquid systems, the greater the overall risk of a mechanical breakdown when spreading or around the tank. The fines farmers receive if convicted of a spill should be re-examined so they encourage farmers to correct the problem and not repeat the action. For example, fines should be large enough to deter second time offenders. A percentage of the fine could be put into a contingency fund and used to correct the problem on the farm.

Septic system malfunctions are predicted to be the single largest source of bacteria to these beaches. Solutions to this problem are paramount. Offering landowners a grant towards their repair is an excellent start. Other creative solutions may be required as well. For example, new designs and other forms of household sewage disposal systems should be explored and tested in southern Ontario. Landowners should be encouraged and/or forced to pump their tanks every 3 years to ensure the continued functioning of these systems. This could be accomplished through a by-law or a permit system.

In summary, there are numerous sources of fecal conform pollution to our rural beaches and ideally all of them should be repaired. The challenge is to clean up the largest contributors for the least amount of dollars. The CURB Implementation Grant offers an excellent incentive to do just that.

CHAPTER 7

ADDITIONAL WATERSHEDS IMPACTING BEACHES

There are several creeks outside of the CURB areas which discharge directly into Lake Huron and the St. Clair River and may be polluting beaches there. The creek systems are listed in Table 15 and their locations are illustrated in Figure 9. There is interest in including these watersheds within the CURB Program from the local communities and municipal governments.

7.1 LAKE HURON SHORELINE

There are four creeks which empty into Lake Huron between Sarnia and the northern boundary of the SCRCA. These include the Hickory, Aberarder, Patterson and Pulse Creeks. Lake currents have no fixed direction in the summer months and so creek discharge may affect beaches both to east and west of the mouth (D. Sawyer, pers. comm.)

Summer students hired under the Environmental Youth Corps Program in the summer of 1992 sampled these creeks weekly and mapped the livestock farms in each watershed. The sample results and maps are included in Appendix G. They appear to be fairly similar in watershed size, topography, soil type, and land use (predominantly agricultural) to the neighbouring Highland and Perch Creek watersheds which have been studied under the CURB Program. The levels of fecal coliforms in these neighbouring creeks are quite similar, showing the same rise and fall in levels over the spring and summer seasons.

The entire Lake Huron waterfront is used for swimming and water sports. Most of the beachfront is privately owned although there are several public access points. In fact, the private beaches of Hillsboro, Gallimere, Invercairn and others are used more heavily than the public beaches. A resident reported that there are approximately 150 residents and their guests using the Hillsboro Beach each summer day.

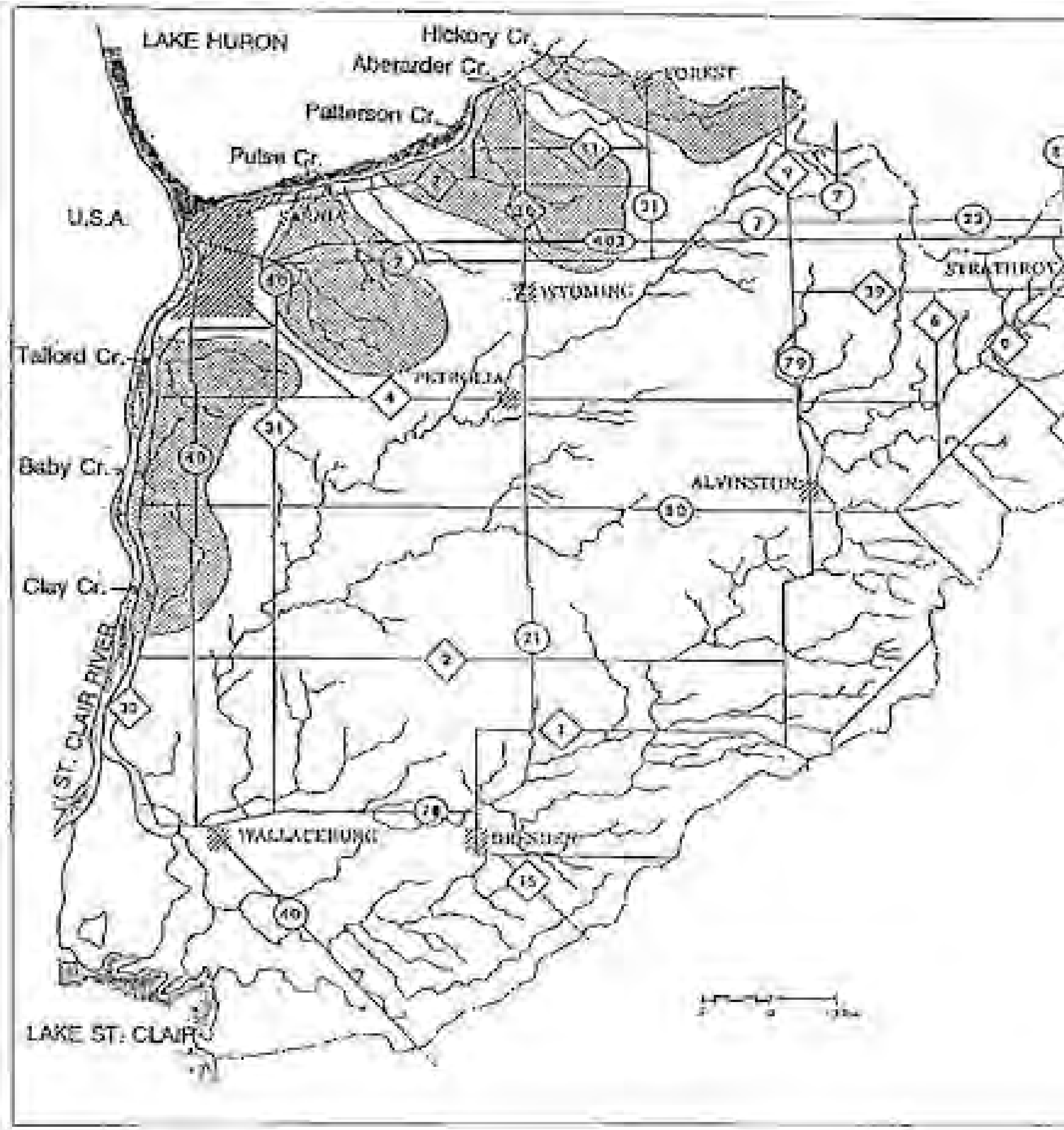

Figure 9.
Additional Shoreline Watersheds within the SCRCA

Table 14. Additional Watersheds Outside of CURB

WATERSHED	AREA (km^2)	DISTANCE TO BEACH
Lake Huron Area		
Hickory Creek	77	adjacent to Hillsboro Beach
Aberarder Creek	48	adjacent to Highland Glen C.A.
Patterson Creek	84	near Pointview Subdivision
Pulse Creek	155	adjacent to Bright's Grove/Sarnia
St. Clair River Area		
Talfourd Creek	10	12 km to Willow Park
Baby Creek	5	4 km to Willow Park and. 5 km to Seager Park
Clay Creek	5	2 km to Cundick Park and 5 km to Reagan Park

In 1991, the Hillsboro Beach Association requested that MOE study the Hickory Creek watershed and its impact of the beach area. They believe the creek may be responsible for the poor water quality which has led to a number of reports of ear infections, intestinal disorders and sickness associated with bacterial contamination.

All residents along the Lake Huron shoreline will have to pay $4200 towards the hookup and construction of a communal sewage treatment plant as soon as provincial grant is secured. The ratepayers feel a certain amount of animosity towards this and now feel strongly that the other contributors of water pollution (farmers upstream and Forest STP) must now do their part. The cottage communities will petition strongly for the inclusion of the waterfront creeks in the CURB implementation program (Ralph Coe, pers. comm.).

Bosanquet Township:

Approximately 20 km of Lake Huron shoreline lies between the borders of the SCRCA and ABCA (Ausable-Bayfield Conservation Authority) but is not under the jurisdiction of either. This 130 km^2 triangular piece of land in Bosanquet Township, Lambton County is predominantly rural in landuse.

Approximately seven small creeks drain the area and discharge directly into Lake Huron. Swimming is popular through much of this shoreline, especially at Ipperwash Beach (public) and Glendale Beach (private). Since the direction of lake currents varies, these creeks could impact beaches in the SCRCA and ABCA watersheds.

7.2 ST. CLAIR RIVER WATERFRONT

There are three creeks which drain directly into the St. Clair River and may impact the beaches in this area. These include the Talfourd Creek, Baby Creek, and Clay Creek. The St. Clair Parkway Commission operates several waterfront parks in this area and all have experienced beach closures in recent years. River currents flow in a southerly direction towards Lake St. Clair. Table 15 lists their location relative to the creeks. Information on the fecal coliform levels in the creeks is unavailable. The livestock farms were mapped and are included in Appendix G.

7.3 PROPOSED ACTION

The SCRCA proposes that these remaining watersheds which impact shoreline beaches be brought into the CURB Program and a CURB Plan written for them, Landowners in these watersheds should then be eligible for the CURB Implementation Grant the following year, This would amount to approximately 363 additional livestock farms and 1511 homes.

CHAPTER 8

RECOMMENDATIONS

The St. Clair Region Conservation Authority should:

1. Continue to be a lead agency in improving the water quality in its rural watersheds through:

    a. involvement with the Provincial Rural Beaches program of the Ministry of the Environment.

    b. facilitation of the CURB Implementation Grant Program for landowners in the target watersheds.

    c. research into areas related to bacterial pollution from rural land uses.

    d. monitoring water quality changes in watercourses and beaches.

2. Seek solutions to reduce the high bacterial loadings from:

    a. Bear Creek to the 'Warwick reservoir beach by at least 83% over the next five years to meet current Provincial Water Quality Guidelines for safe swimming.

    b. Perch Creek to Lake Huron at Bright's Grove by at least 90% over the next five years to meet current Provincial Water Quality Guidelines for safe swimming.

The provincial government should:

3. Continue to be the lead agency in improving water quality in rural Ontario through:

    a. Landowner incentive programs such as the CURB Implementation Grant Program which is available to people in designated CURB areas to correct on-farm pollution sources and septic system.

b. Research into the sources and solutions to various rural pollution sources including the behaviour and transport of bacteria in the natural environment and on the environmental rate of manure application.

4. Make CURB grant money available to landowners in watersheds along Lake Huron and the St. Clair River.

5. Research new designs of septic systems or other forms of household sewage disposal, especially for use on heavy clay soils.

6. Include a minimum acreage requirement on the certificate of compliance for new livestock farms or livestock barn expansions to ensure an adequate landbase for manure application.

7. Investigate methods of using fines from manure spills in a manner which encourages farmers to correct the problem and not repeat the action such as putting fine money into a contingency fund which must be used to repair the problem.

Rural landowners should:

8. Control pollution sources on their properties including the household and barnyard areas.

9. Replace or upgrade existing septic systems to meet the Ontario Regulation 37-81 of the Environmental Protection Act and ensure the septic tank is routinely pumped.

10. develop a manure management plan regarding the storage, placement, timing and rate of application to prevent contamination of surface and ground waters.

Municipalities should:

11. pass a by-law stating that a landowner must have the septic system pumped at least every three years or make it part of a Permit System.

12. be encouraged to use Section 83(1) of the Drainage Act to eliminate some sources of bacterial pollution.

13. include a minimum acreage requirement on the Certificate of Compliance and Building Permit for new livestock farms or livestock barn expansions to ensure adequate landbase for manure application.

Health Units / MOE should:

14. obtain information on all septic systems installed before 1974 to bring their records up to date

15. undertake a plan to identify inadequate septic systems in the SCRCA watersheds

16. issue permits for septic tanks on a three year basis, renewing the permit if the tank is cleaned out or adding the cost to the individual's taxes if it is not

Government and Farm Organizations should work together to:

17. educate rural landowners about the serious threat of faulty septic systems to beach waters and watercourses.

18. educate farmers about methods to avoid pollution from manure.

19. increase awareness in the watershed about the sources of bacteria in swimming waters through pamphlets, information days, workshops, etc.

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APPENDICES

Appendix A(i)

ST. CLAIR REGION CONSERVATION AUTHORITY
205 Mill Pond Crescent, Strathroy, Ontario, N7G 3P9 519-245-3710

February 7, 1992.

MEMORANDUM TO: All livestock farmers in the Perch Creek Watershed

As you may be aware, the St. Clair Region Conservation Authority has been conducting a study on the water quality of Perch Creek which empties into Lake Huron at Bright's Grove. This study is in cooperation with the Ontario Federation of Agriculture and the Ministry of the Environment. The purpose of the study is to identify the possible sources of pollution which have led to beach closures, fish kills and other complaints from landowners in this area.

Our results to date indicate that our drains and creeks are carriers of soil, nutrients, and bacteria in concentrations that impair water quality and present a potential risk to livestock and people. To the farmer, this reflects a logs of productivity of the land. A government grant will be available for farmers this spring to correct operations which have been identified as potential problems in this watershed.

Since the problems and solutions to water pollution affect everyone in the community, we will be attempting to contact all landowners over the next few weeks. We hope that you will be willing to meet with our Water Quality Technician, Cathy Quinlan, at a convenient time to you to answer a brief questionnaire. This should only take 15-20 minutes of your time. We think it is very important to obtain your views and concerns and to discuss the types of activities (farming or otherwise) which may or may not be contributing to water pollution in the area. All of the information will be confidential.

You will probably be receiving a phone call from Cathy within the next few weeks. We appreciate your cooperation and look forward to meeting with you.

Yours truly,

Donald Craig
Manager of Conservation Services

Appendix A(ii).

ST. CLAIR REGION CONSERVATION AUTHORITY

205 Mill Pond Crescent, Strathroy, Ontario, N7G 3P9 519 ● 245 ● 3710

WATER QUALITY QUESTIONNAIRE

Name ______________________________ Date _____________
Mailing ________________________________ Phone _____________
Address ________________________________
Cash Crop ____ Livestock _____
Lot(s) _______________ Concession(s) ____________ Size _____________
_______________ ____________ _____________

SECTION I. CROPS AND DRAINAGE

Total farm acres _________________

Crops#	of Acres	Acres Tiled	Random(%)	Systematic (%)
_______	_______	_________	___________	_____________
_______	_______	_________	___________	_____________
_______	_______	_________	___________	_____________
_______	_______	_________	___________	_____________

SECTION 2. SIZE OF OPERATION

Livestock		Total head per year	
dairy	calves ______	heifers ______	milking cows ______
beef	cow ______	calf ______	yearlings ______
	slaughter steers	______	
swine	sows litter ______	weaners ______	feeders ________
	boars ______		
chicken	broiler _______	laying _________	breeder _________
turkey	broilers _______	breeders + toms _________	
horses	_______		
sheep	_______		
other	_______		

SECTION 3. TYPE OF MANURE AND MANURE MANAGEMENT

SOLID MANURE

Manure stored: inside _______ outside ________ on pad ______
in feedlot _____ On ground _____
Pad dimensions ______________________________
How often do you scrape pad? ______________________
Are there walls around stack? yes ____ no ____
Is there runoff containment? no _____ yes ____
If yes, type? pond _____ tank _____ capacity ___________
dimensions _____________________
How close is the nearest tile or open ditch? __________________

LIOUID MANURE

Covered tank _____ Open tank ______ Earthen pit ______
Dimensions ________________ capacity ________________
How close is the nearest tile or open ditch? ______________________

SECTION 4. MANURE APPLICATION.

Type of spreader box _____ liquid tanker ______ injection________
irrigation ______ other ___________________________
Custom operator? yes _____ no ____

	Time of application	# of acres	application rate	crop or residue in field?
spring	______	_______	_________	____________
summer	______	_______	_________	____________
fall	______	_______	_________	____________
winter	______	_______	_________	____________

Is the land tilled before spreading? yes ____ no _____
Is manure worked in afterwards? yes ____ no _____
How soon afterwards? ____
Type of soil: sand _____ clay _____ loam ______
Do you have your soil analyzed? yes ____ no _____
How often? ______________________________________

SECTION 5. LIVESTOCK WATERING

Do livestock water in stream/ditch? yes _____ no _____
If yes, number and type of animals: ___________________________________
Is access to stream: unlimited ______ limited _______
If limited, describe (ramps, pumps, bridges, etc. ___________________________________
____

Do animals have to cross stream to get to barn? yes ____ no _____
days/yr. pastured _________ % of day pastured ___________________
Length of streambank accessible to animals: ____________________________
Size of pasture ____________________________

SECTION 6. FEEDLOT/CEMENT YARD/EXERCISE YARD

Number of type of animals using feedlot/yard: _____________________________
Dimensions _____________________________________

Is the yard roofed? Yes _____ No _______ Partly ______
Is the yard paved? Yes _____ No _______ Partly _______
Is it eavestroughed? yes _____ No _______

Are there retaining walls? yes ______ no _____
Is there runoff containment? no ______ yes ______
If yes, describe: pond _____ tank ______ other ______

What is the distance to nearest tile or ditch? _______________________
Number of months in use ___________________________
Hours per day used ____________________________

Number of cleanouts per year ___________________

SECTION 7. DAIRY

Type of system: pipeline _____ parlour ______
where does wash water go? septic tank ______ holding tank ______
lagoon _____ manure storage system ______ tile drain ______
trench ______ other ______

Volume of washwater/milking ___________________ gals/day
Number of cycles/day ____________________
Is the water from the first rinse fed to calves? yes _____ no ______

SECTION 8. HOUSEHOLD SEPTIC SYSTEM

Is there a septic system for the house? Yes _____ No ______
Age of system ___________________
Is grey water (eg. from dishwashers, washing machines, etc.) hooked to septic tank?
Yes ____ No _____ Don't know _____
Have you had problems with backups, ponding of water, etc.? yes ____ no _____
describe ____
____
How often is it pumped out? ____________________
How close is the nearest tile drain? _______________

SECTION 9. GENERAL QUESTIONS

Have you updated or changed your farm/farming practices within the past 5 years?
yes _____ no _____
describe ____
____
Are you considering any changes? yes _____ no ____________
describe ____
What do you feel is the best way to clean up water pollution in rural areas?
1) provide farmers with more information ______
2) provide farmers with more grant money ______
3) prosecute offenders harder and more often _____
4) other _____________________________________

What are the 2 best sources of information to you concerning farm management?
____ farm newspaper/magazine _____ fact sheets
____ government staff _____ demonstrations/seminars
____ neighbours
____ equipment dealers _____ other

Do you ever swim at the beach at Brights Grove?

yes _____ no _____ If no, why not? ______________________________

____

Have you ever fished near Brights Grove in Lake Huron or Perch/Cow Creek?

Yes _____ no _____

If yes, what do you catch? ____

____

Miscellaneous Comments

____

____

____

APPENDIX B

FLOW READINGS

CREEK	DATE	DISCHARGE (m^3/sec)	AREA (m^2)	VELOCITY (m/sec)	WEATHER
Bear	29 Aug 89	0.018	0.190	0.1	dry summer
	04 Oct 89	0.025	0.371	0.1	avg fail
	05 Apr 91	0.439	0.961	0.5	wet spring
	10 May 91	0.179	0.271	0.7	avg spring
	28 Jun 91	0.081	0.389	0.2	avg summer
	07 Oct 91	0.021	0.400	0.1	dry fall
	29 Oct 91	0.081	0.572	0.1	wet fall
	07 Jan 92	0.652	1.596	0.4	wet winter
Perch	05 Apr 91	0.249	1.158	0.2	wet spring
	10 May 91	0.147	2.270	0.1	avg spring
	28 Jun 91	too slow			avg summer
	07 Oct 91	0.003	0.044	4.1	dry fall
	07 Jan 92	0.511	1.253	0.4	wet winter

- Bear Creek measured at Egremont Rd in Warwick Village.
- Perch Creek measured at New Lakeshore Rd, Bright's Grove.

Appendix B (ii)

ALGORITHMS

The following are abbreviations used in the CURB algorithms which follow:

conc =	concentration
prob =	probability
EAU =	Equivalent Animal Units
# =	number
f.colif =	fecal coliforms
defec =	defecation
vol =	volume
% =	percent

1) MILKHOUSE WASH WATER ALGORITHM

This formula estimates the number of fecal coliform bacteria delivered to a watercourse each year through the discharge of untreated milkhouse washwater. The loading is calculated for each dairy farm where no treatment system exists as indicated in the farmer surveys. In the Perch Creek watershed, survey data was not available for most of the dairy farms. It was assumed that 78% of the farms had no treatment as was found in Bear Creek.

Milkhouse = Vol / day x conc. x growth x days

Example = 400 x 2000 x 500 x 365

1. The volume of washwater in litres used per day was taken from the survey data. For those dairy farmers where actual figures were not known, survey averages were used.

2. The concentration of fecal coliforms in the wash water entering the milkhouse drain was assumed to be 2000/litre. This is based on samples taken by UTRCA (1989).

3. The growth of bacteria in the tile was found to be 50,000%. Sampling results from the UTRCA (1989) indicate that bacteria multiply by 50,000% in the tiles as a result of the rich food source that the milk substrate provides. Therefore, by the time the washwater reaches the tile outlet at the watercourse, there are 50,000% more fecal coliforms than there were when it entered the barn drain. This was calculated as a loading, not a concentration, and therefore water volume at the end of pipe does not need to be factored in.

4. The number of days of discharge was 365 days for a year-round operation.

2) CATTLE ACCESS LOAD ALGORITHM

This formula estimates the number of fecal coliform bacteria delivered to a watercourse from cattle or other livestock defecating directly into the stream.

Access = conc/defec x EAU x prob. x events/day x # animals x # days

Example = 8.9 E+8 x 1.62 x 0.18 x 2.5 x 30 x 183

1. The concentration of 8.9 E+8 fecal coliforms per defecation was assumed for a 454 kg (1000 pound) steer (MVCA, 1989).

2. The EAU's for manure production for each animal type is given in Appendix C. For example, the EAU for a steer is 1.00 but for a dairy cow is 1.62 since it is a larger animal and produces more manure.

3. Demal (1982) found that the probability of an animal defecating in the stream was 18%.

4. Demal (1982) also found that animals enter the watercourse 2.5 times per day on average.

5. The number of animals with access was taken from the survey data.

6. The number of days with access was taken from the survey data or assumed to be 183 days (May 1 to November 1) where survey data was not obtained.

3) FEEDLOT/EXERCISE YARD RUNOFF ALGORITHM

This algorithm estimates the number of fecal coliform bacteria delivered to a watercourse as a result of runoff from feedlots and exercise yards. Overland runoff was calculated for those yards located within the critical zone (150 meters of an open watercourse). **Ten percent of all remaining feedlot/yards were assumed to contribute bacteria through the underground tiles which are laid around or near the barnyards** (SCRCA, Steering Committee, 1990). This is a new addition to the CURB Plans.

Feedlots = conc. x Area x Runoff Factor x # days x delivery

Example = 7.5 E+8 x 200 x 0.005 x 365 x 0.80

1. The concentration of fecal coliform bacteria in one cubic meter of runoff from feedlots was found to be 7.5 E+8 or 75,000/100 ml. This was an average compiled from several samples taken by the Ausable Bayfield Conservation Authority (ABCA, 1989).

2. The area of yard in square meters was taken from survey data or a visual estimate.

3. The Runoff Factor of 0.005/day was taken from OMAF's Agricultural Pollution Control Manual.

4. The number of days the feedlot is exposed to rain and runoff was assumed to be 365 days unless otherwise stated in the survey.

5. The delivery of this bacteria to the nearby stream is assumed to be 80%. Thus it is assumed 20% is absorbed into the ground or trapped in vegetation along the way to the creek or tile (MVCA, 1989).

4) MANURE STACK RUNOFF ALGORITHM

This formula estimates the number of fecal coliform bacteria which enter a watercourse yearly from manure stack runoff. All manure stacks located within the critical zone (150 meters of an open watercourse) were assumed to contribute bacterial pollution through surface runoff. **Ten percent of all remaining farms were assumed to contribute runoff pollution through the subsurface tiling and catchbasins around the barn areas.** This is a new addition to the CURB formulas.

The MVCA model contained complex calculations **to** estimate the actual size and shape of the stack dome and to account for the number of scrapings/week. This was replaced with a simpler calculation since only the rainwater landing on the pad will be contaminated by the manure, regardless of stack shape or height. Manure is usually always present on the pad regardless of how often it is scraped and so this calculation was eliminated. In addition, the average concentration of fecal coliforms in manure stack runoff was obtained through actual water samples and this accounts for a variety of stack management practices.

Stack = conc. x area x runoff factor x # days x delivery

Example = 7.5 E+8 x 30 x 0.005 x 365 x 0.8

1. A concentration of 7.5 E+8 fecal coliforms per cubic meter or 75,000/100 ml was assumed for manure stack runoff (ABCA, 1989). This is an average concentration based on several samples collected by the ABCA (1989).

2. The area of the pad or ground the stack sits upon was taken from survey data or an average size of 50 m^2 (7 m x 7 m) was assumed.

3. The runoff factor of 0.005/day was taken from OMAF's Agricultural Pollution Control Manual.

4. The number of days the stack is exposed to rain and runoff was assumed to be 365 unless otherwise stated in the survey.

5. The delivery of 80% was assumed (MVCA, 1989). The remaining 20% is absorbed or trapped by vegetation on the way to the creek.

5) MANURE SPREADING ALGORITHM

This formula estimates the number of fecal coliforms delivered to a watercourse as a result of manure being spread on the land. There are three separate formulas to account for overland runoff from solid manure, overland runoff from liquid manure, and subsurface tile contamination from liquid manure spreading.

Loadings for the Fall + Winter spreading season were calculated separately from Spring + Summer season loadings. This was done so that the die-off rates for the different seasons could be applied separately. In addition it allowed the data to be viewed separately during the beach season and during the winter.

a) Overland loading from liquid manure spreading

This formula estimates the number of fecal coliform bacteria delivered to the creek from surface runoff from a field spread with liquid manure. It is calculated separately from solid manure because there is now information on the fecal coliform concentration of liquid manure spread onto the land which is more accurate than approximating a storage die-off rate. There is no such figure for solid manure and so a storage die-off value was needed in a separate formula.

Liquid manure spreading (overland loading): = Volume x % spread/season x conc. on-field x field die-off x critical zone x delivery

Example = 1000 x 0.5 x 8.4 E+9 x 0.1 x 0.21 x 0.01

1. The volume of liquid manure produced in cubic meters per year was calculated as follows:

   Volume = # head x daily manure production x # days
   Example = 300 x 0.0071 x 365

   - number of head of livestock taken from survey data
   - daily manure production values in m^3/animal/day were taken from Appendix C
   - assume 365 days per year if livestock are confined, 183 days if the animals are in pasture during the growing season.

2. The percentage of liquid manure spread in each season was taken from the survey data. If data was not available, it was assumed that half was spread in the spring + summer and the other half in the fall + winter.

3. The fecal coliform concentration per cubic meter of manure spread onto a field was extrapolated from data collected by ABCA (see Appendix C).

4. Field die-off would occur between the time of spreading and a runoff event. The formula used to calculate this is: 10^{-kt} where:

   k = constant of 0.066
   t = time (in days) between significant rainfall events is 15 days (see Appendix D)

   This figure likely underestimates the dieoff but more accurate figures are not available at this time.

5. The critical zone (land within 150 meters of an open watercourse) covers 21% of Bear Creek's watershed area and 24% of Perch Creek's. Assuming that manure is spread evenly over the watercourse, 21% (and 24% respectively) of the manure would fall in the critical zone and have the potential to runoff.

6. The delivery was assumed to be 1 %. in other words, it was assumed that 1% of all of the manure spread in the critical zone would runoff into the nearby watercourse.

5b) Overland loading from solid manure spreading

This formula estimates the number of fecal coliform bacteria delivered to the watercourse as a result of surface runoff from solid manure spread on the land.

Solid Manure Spreading (Overland Loading):
= Volume spread x conc. x storage die-off x field die-off x critical zone x delivery

Ex. = 2.3 E+16 x 0.01 x 0.1 x 0.21 x 0.01

1. The volume spread was calculated as follows:
   = # animals x daily manure production x #x % spread/season
   - # animals taken from survey data
   - daily manure production values (see Appendix C)
   - # days assumed to be 365 if confined, 183 if pastured
   - % spread in each season taken from survey data or assumed to be 50% if no survey data available

2. The number of fecal coliforms per cubic meter of fresh manure taken from Appendix C.

3. Storage die-off is assumed to be 2 orders of magnitude based on an average storage time (Kress and Gifford, 198)

4. Field die-off would occur between the time of spreading and a rainfall or winter thaw event. The formula used to calculate this is: 10^{-kt}, where,
   k = constant of 0.066 (Ecologistics, 1988)
   t = time (in days) between rainfall events (15 days)

   This formula likely underestimates the die-off but more accurate figures are not available at this time.

5. The critical zone (land within 150 meters of an open watercourse) covers 21% of Bear Creek's watershed area and 24% of Perch Creek's. Assuming that manure is spread evenly over the watercourse, 21% (and 24% respectively) of the manure would fall in the critical zone and have the potential to runoff.

6. The delivery was assumed to be 1%. In other words, it was assumed that 1% of all of the manure spread in the critical zone would runoff into the nearby watercourse.

5c) Subsurface loading from liquid manure spreading

This new CURB formula developed by the author utilizes the results of a two year study by the ABCA on subsurface tile contamination from liquid manure spreading. A variety of soil types were tested under varying moisture conditions.

Tile contamination is known to occur in the SCRCA watersheds as well according to the farmers. A one-day experiment was conducted to validate this claim. The results are listed in Appendix D.

Liquid manure spreading (Subsurface tile loading):
= Volume x % spread / season x conc. (on-field) x delivery

Example = 1000 x 0.5 x 8.4 E+9 x 0.005

1. The volume of manure produced in cubic meters per year was calculated as follows: Volume = # head x daily manure production x # days

   - number of head of livestock taken from survey data
   - daily manure production values in m^3/animal/day were taken from Appendix C
   - 365 days per year if confined, 183 if in summer pasture

2. The percentage of manure spread in each season was taken from the survey data. If data was not available, it was assumed that half was spread in the spring + summer and the other half in the fall + winter.

3. The fecal coliform concentration per cubic meter of manure spread onto a field was taken from data collected by ABCA (1991). It represents the average concentration of manure collected in a pan on the field immediately after spreading. The results are listed in Appendix C.

4. The delivery from the field to the tiles was determined to be 0.5% on average. This was based on the data collected by the ABCA in their manure spreading and infiltration studies carried out in 1990 and 1991. This was the delivery within the first 24 hours after spreading or the first day the tiles flowed after spreading.

6) PASTURE LAND RUNOFF LOAD

This new CURB algorithm was produced by the author to estimate the number of fecal coliforms delivered to the watercourse from surface runoff from grazed pasture lands during the spring and summer months. Since almost half of the farms pasture some animals, this amounts to a lot of manure previously unaccounted for in the model.

It is estimated that approximately 4555 m^3 of manure is deposited onto pasture lands throughout the Bear Creek watershed per pasture season, representing 1% of total watershed manure production. In Perch Creek, about 25,763 m^3 (4.8 E+16) of manure is deposited onto pasture lands, representing 29% of total manure production.

Pasture = area x precip x % runoff x conc. x crit zone x die-off

Example = 40000 x 0.4 x 0.04 x 5.0 E9 x 0.21 x 0.10

1. The number of square meters of pasture was taken from the survey response.

2. The precipitation for the spring and summer months is approximately 0.4 meters (400 mm) for Warwick and Plympton Townships.

3. It was assumed that 40% of the precipitation landing on a pasture runs off. Most is absorbed or evaporated. This was extrapolated from precipitation versus actual measured stream discharge data compiled in the Strathroy watershed. The watershed is largely agricultural with clay soils, like the CURB watersheds, and so similar conditions were assumed.

4. The average fecal coliform concentration running off a fresh cowpie on a pasture was assumed to be 50,000/100 ml (5.0 E9/m^3). This was extrapolated from experiments conducted on standard cowpies using rainfall simulation by Kress and Gifford, 1984). There is very little data on actual water taken from pastures.

5. It was assumed that only pastures located in the critical zone would contribute bacteria from overland runoff. Tile contamination is unlikely since pasture lands are rarely tiled. The critical zone covers 21% of the Bear Creek watershed and 24% of Perch Creek. It was assumed that pasture land is evenly distributed over the watercourse and so 21 and 24% of the total pasture acreage was contributing. In reality it may be higher since pastures tend to be located in floodplain areas.

6. It was assumed 90% of the bacteria would die-off along the way to the creek.

7) SEPTIC SYSTEM FAILURE ALGORITHM

This algorithm estimates the total number of fecal coliform bacteria which enter the watercourse each year as a result of faulty septic system hook-ups. Malfunctioning septic systems are a common occurrence in Ontario, especially on the impermeable clay soils.

Septic = conc. x vol/home/day x # days x # homes x failure rate x delivery
Example = 1 .0 E+7 x 900 x 365 x 183 x 0.30 x 0.50

1. A concentration of 1.0 E+7 fecal coliform per litre of effluent or 1,000,000/100 ml at the tile outlet was based on samples taken by various Conservation Authorities (MVCA, 1989).

2. A total volume (consumption) of 300 litres/person/day was assumed (Steering Committee, 1990). Appendix D lists water usage in Lambton Co. towns for comparison. In Warwick Township the average number of people per household is three and in Plympton Twp it is 2.5 (MMA, 1991). This converts to 900 and 750 litres/home/day respectively.

3. Permanent residences were assumed to be contributing for 365 days a year.

4. The number of homes (including schools and businesses) in the watershed were counted on topographic maps combined with field checks. The total was 183 for the Bear Creek and 231 for the Perch Creek watershed.

5. A failure rate of 30% was assumed. In other words, 30% of all septic systems were assumed to be faulty or have illegal by-passes (Steering Committee, 1990).

6. Of the polluting systems, it was assumed that 50% of the total water consumption was reaching the tile outlet and watercourse (Steering Committee, 1990). In other words, the septic systems did treat at least half of the water volume.

8) URBAN NON-POINT ALGORITHM

This formula estimates the total number of fecal coliform bacteria delivered to the watercourse from urban runoff and storm sewers. The Police Village of Warwick is the only urban area in the Bear Creek watershed. Portions of Bright's Grove lie within with the Perch Creek watershed.

URBAN = Conc. / ha. x Urban area (ha.)
Example = 3.1 E+10 x 24

1. The average concentration of urban runoff in low density centres (less than 50 people per hectare) was found to be 3.1 E+10 fecal coliforms per hectare (Marsalek et al, 1985, Marsalek, 1978).

2. The size of the Police Village of Warwick was estimated from aerial photographs using a digitizer. It is approximately 24 hectares in size. Bright's Grove area of impact was estimated at 150 hectares (City of Sarnia Engineering Dept.).

9) SEWAGE TREATMENT PLANT DISCHARGE ALGORITHM

There is no Sewage Treatment Plant (STP) in the Bear Creek Watershed. The suburban community of Bright's Grove is serviced by the Bright's Grove Sewage Lagoons. The lagoons are discharged into Deer Creek which empties into Perch Creek at County Road 7, a short distance from the beach. Treated water from the lagoons is usually discharged twice a year although in 1991 it occurred three times.

There are no plans to greatly increase the capacity of the lagoons or the number of homes hooked up to it. There are future plans, however, to improve the effluent quality through aeration and phosphorus removal.

STP LOADING = Concentration x Volume
Example =1.93 E+6 x 128,695

1. Using water quality results obtained from MOE Sarnia, the geometric mean concentration of fecal coliforms in the effluent water was 193/100 ml or 1,930,000/m^3 (Appendix D).

2. Data on the volume of water discharged is not usually recorded. However, in May of 1989 the discharge was reported as 128,695 m^3. This is assumed to represent an average amount per discharge. There are two discharges per year.

10) MANURE SPILL ALGORITHM

This algorithm accounts for the total annual fecal coliform load to the watercourse from manure Information was obtained from the Ministry of the Environment in Sarnia regarding the frequency of manure spills in the Bear Creek and Perch Creek watersheds.

The Ministry in Sarnia receives two or three manure spill reports a year in the Bear Creek area and less than one in Perch Creek. Most of these 'spills' were actually tile contamination resulting from manure spreading. The manure spreading algorithm accounts for this contribution. Spills caused by other factors such as manure irrigation equipment failure and overflowing tanks account for only about 10% of those reported.

Spills = volume / spill x concentration x # spills / year

Example = 22,750 x 5.86 E+7 x 0.3

1. The volumes of each spill are not recorded or known. It was assumed that an average spill would deliver 22,750 litres (5,000 gallons) to the watercourse (MVCA, 1989). This is the equivalent size of a liquid tanker of manure. Other CURB models used 20,000 gallons since they were incorporating contamination from manure spreading as well as other spills.

2. The majority of spills are of swine manure. Samples collected of manure on fields immediately after application were pooled (Appendix C). The geometric mean concentration of fecal coliforms is 5,860,000/100 ml (5.86 E+7/litre).

3. Spills from equipment failure and deliberate discharge account for approximately 10% of reported spills and reported spills amount to about 3 a year in the Bear Creek area (Vandenheuvel, pers. comm. 1992). Therefore: 3 spills x 10% = 0.3. This is the equivalent of one-third of a spill per year. In Perch Creek, there have been no recent reports of spills so this algorithm was not used.

APPENDIX B (iii)

Livestock farms in the Bear and Perch Creek watersheds

Type of Livestock	BEAR CREEK No. of farms	BEAR CREEK Total # head	PERCH CREEK No. of farms	PERCH CREEK Total # head
Pig	27	21,760	11	4,245
Beef	14	1,009	16	3,316
Dairy	10	1,140	7	448
Chickens	5	45,105	3	898
Sheep/Goat	5	179	2	20
Horse	5	21	17	104
Turkey	2	25,500	1	20,000

Volume of manure produced per year

Manure Type	Bear Creek (m^3)	Perch Creek (m^3)
Liquid	362,372	32,659
Solid	34,707	55,740
Total	400,794	88,399

APPENDIX B (iv)
Storm and Precipitation Patterns, Sarnia Airport

Month	No. of storms measuring at least 10 mm	No. of storms measuring at least 20 mm	Monthly Precipitation 1991 (mm)	Monthly Precipitation 30 Year Normal (mm)
Jan	1	0	40.2	52.4
Feb	1	0	32.8	45.3
Mar	1	0	56.2	61.9
Apr	1	0	65.7	80.6
May	4	1	92.9	69.2
Jun	2	1	46.4	81.1
Jul	3	0	73.4	65.8
Aug	1	0	51.8	55.3
Sep	1	0	18.0	68.2
Oct	4	2	130.4	59.9
Nov	2	1	63.6	77.6
Dec	1	1	54.8	81.6
Total	22	5	726.8	798.9

Source: Monthly Meteorological Summary, Environment Canada

Seasonal Precipitation Distribution for Sarnia

Season	% of Annual Precipitation
Spring	27
Summer	25
Fall	26
Winter	22

APPENDIX C (i)

AVERAGE FECAL COLIFORM DENSITIES IN FRESH ANIMAL FECES

Animal Type	F. coliform per gram	F. coliform per m^3
Cattle	5.0×10^{5}	5.0×10^{11}
Swine	1.0×10^{7}	1.0×10^{11}
Chickens	9.9×10^{7}	9.9×10^{13}
Sheep	1.6×10^{7}	1.6×10^{13}
Horses	8.7×10^{4}	8.7×10^{10}

* Provided by Mike Young, MOE, Toronto, based on a collection of samples.

APPENDIX C (ii)

EQUIVALENT ANIMAL UNITS (EAU)

Animal Type	Weight (kg)	EAU P	EAU FC
BEEF			
Beef Cow	455	1.04	1.04
Slaughter Steer	455	1.00	1.00
Yearly Beef	365	0.78	0.71
Beef Calf	180	0,53	0.48
DAIRY			
Dairy Cow	-	1.50	1.62
Dairy Heifer	318	0.75	0.71
Dairy Calf	136	0.46	0.36
SWINE			
Sow/Boar	-	0.60	-
Feeder Pig	22-99	0.40	-
SHEEP	45	0.17	0.02
TURKEY	5	0,03	0.03
CHICKEN/DUCK	2	0.02	-
HORSE	455	1.20	0.013

NOTE: P = phosphorus, FC Fecal coliforms

SOURCE: Ecologistics, 1988.

APPENDIX C (iii)

MANURE PRODUCTION PER DAY BY ANIMAL TYPE

ANIMAL TYPE	PRODUCTION m^3/day
Beef or Dairy	
Calf (6-15 mo.)	0.0170
Juvenile (15-24 mo.)	0.0227
Beef cows (550 kg.)	0.0340
Dairy cows - free stall	0.0581
Dairy cows - tie stall	0.0616
Swine	
Weaners	0.0023
Feeders	0.0071
Sows + litters	0.1700
Poultry	
Chickens - broilers	0.0001
Turkeys - broilers	0.0003
Turkeys - breeders + toms	0.0007
Sheep	0.0042
Horses	0.0566

Source: OMAF Factsheet 1983, Agdex 400/721. "Sizing of Manure Storages". Adapted from Canadian Farm Building Code, 1977.

Note: Liquid manure volumes include dilution water. Solid manure volumes include bedding.

APPENDIX C (iv)

ST. CLAIR REGION CONSERVATION AUTHORITY
TILE CONTAMINATION EXPERIMENT

DATE: 10 December 1991
LOCATION: Warwick Township
MANURE TYPE: Liquid hog
SOIL CONDITIONS: wet, clay
APPLICATION: by irrigation gun
RATE: 5000 gallons/acre

SAMPLING: tile outlet 1 km from property, no open water on property, buried drains only

	1 hour after spreading	3 hours after spreading
fecal coliform	4,000	120,000
fecal streptococci	1,800	119,000
E. coli	3,400	70,000
Pseud. aeruginosa	40	100
Colour	clear	murky
Smell	not strong	manure smell

* all concentrations listed in #/100 ml of water

APPENDIX C (v)

F. COLIFORM CONCENTRATION)OF MANURE IN STORAGE AND ON-FIELD

	On-Field (# fc/100 ml)	Storage Tank (# fc/100 ml)
Dairy, covered tank	8.9 E+6	1.2 E+6
Dairy, covered tank	7.9 E+6	1.4 E+7
Swine, lagoon	2.0 E+5	2.1 E+4
Swine, lagoon	1.1 E+6	2.8 E+5
Swine, lagoon	3.2 E+5	1.3 E+5
Swine, lagoon	2.5 E+6	2.9 E+5
Swine, lagoon	1.5 E+4	1.7 E+4
Swine open tank	1.7 E+5	4.5 E+2
Swine, covered tank	3.4 E+4	4.3 E+3
Swine, covered tank	5.3 E+5	5.3 E+5
Swine, covered tank	3.0 E+6	3.0 E+6
Swine, covered tank	9.6 E+6	1.3 E+7

Source: ABCA, 1991. On-Field samples collected in pans laid on soil during manure irrigation or spreading. Storage Tank samples were collected in tanks before spreading and usually before agitation.

APPENDIX D (I) (ii)

(i) BRIGHT'S GROVE SEWAGE LAGOON DISCHARGES

Year	Date (start)	Duration (days)	Volume (m^3)	Cell #	F. COLIFORM* (#/100 ml)
1989	Oct 2	4	128,695	2+3	510; 10
1989	Oct 24	?	?	?	160
1990	April	8	?	?	40; 28
1990	Oct 15	6	?	?	4000
1991	Mar 14	6	?	1+3	1900; 300; 500
1991	Oct 24	12	?	3	20; 660
Geometric Mean					193

Source: Ministry of the Environment, Sarnia

* 1) F. coliform values - several sample results shown per date

2) Three cell system: #1=6 ha, #2=6 ha., #3=9 ha.

3) Services 1,085 homes or 4,140 people

(ii) Water Usage In Lambton County STP's

STP	Water Usage (L/person/day)
Oil Springs	280
Oil City	300
Brights Grove	339
Forest	380
Dresden	700
Grand Bend	760

* amounts vary depending on presence of metered water, industry, tourism, etc.

APPENDIX D (iii)

POPULATION STATISTICS

Municipality	1988 Pop'n	No. of Houses	# People/ House	Area (ha.)
Plympton	4,860	1,972	2.5	31,947
Wyoming	1,824	688	2.7	212
Sarnia	70,877	29,292	2.4	16,406
Warwick	2,433	801	3.0	29,347
Bear Creek *	550	183	3.0	77
Perch Creek *	578	231	2.5	74

Source: Ministry of Municipal Affairs, 1991 Municipal Directory

* Values extrapolated using number of households counted

APPENDIX E (i)

F. coliform loadings and die-off, spring + summer, Bear Creek

Source	Load at Creek (x E+10)	Die-off Rate	Load at Mouth (x E+10)	Die-off Rate	Load at Beach (x E+10)
Septic-Base	3878	0.66	2559	0.11	282
Event	631	0.81	511	0.09	46
Access-Base	1342	0,66	886	0.11	97
Event	219	0.81	177	0.09	16
Spreading-Base	888	0.66	586	0.11	64
Event	144	0.81	117	0.09	10
Feedlot-Event	283	0.81	229	0.09	21
Milkhouse-Base	93	0.66	61	0.11	7
Event	15	0.81	12	0,09	1
Stack-Event	89	0.81	72	0.09	7
Pasture-Event	74	0.81	60	0.09	5
Urban-Event	37	0.81	30	0.09	3
Spills	1	0.81	1	0.09	0
Totals	7694		5300		559
Base Flow Days	6201		4092		45Q
Event Flow Days	1493		1208		109
Loading per day					
Base Flow days	40		26		3
Event Flow days	57		46		4

Note: Load at Creek taken from Table 3.

Base Flow Days occur 157 days/season (86% of the time);
Event Flow days occur 26 days/season (14% of the time)

APPENDIX E (ii)

F. coliform loadings and die-off, spring + summer, Perch Creek

Source	Load at Creek (fc x E+10)	Die-off Rate	Load at Mouth (fc x E+10)	Die-off Rate	Load at Beach (fc x E+10)
Septic-Base	4078	0.41	1672	0.36	602
Event	664	0.81	638	0.36	194
Access-Base	1070	0.41	439	0.36	158
Event	174	0.81	141	0.36	51
Urban-Event	233	0.81	189	0.36	68
Spreading-Base	91	0.41	37	0.36	13
Event	16	0.81	12	0.36	4
Pasture-Event	89	0.81	72	0.36	26
Milkhouse-Base	41	0.41	17	0.36	6
Event	7	0.81	6	0.36	2
STP-Base	22	0.41	9	0.36	3
Event	3	0.81	3	0.36	1
Stack-Event	8	0.81	7	0.36	3
Feedlot-Event	6	0.81	5	0.36	2
Totals	6501		3147		1133
Base	5302		2174		782
Event	1199		973		351
Per Day Load					
Base	34		14		5
Event	46		37		14

Load at creek taken from Table 4.
Baseflow days = 157 days/season or 86% of time
Event flow days = 26 days/season or 14% of time

APPENDIX E (iii)

F. coliform concentrations versus creek flow patterns

1992 Bear Creek - Sorted By Creek Flow

Date	Flow	Creek F. colif	Beach F. colif
Jul 09	fast	1000	1000
Jul 16	fast	1000	3800
Aug 13	fast/mod	290	294
Jun 06	mod	80	10
Aug 20	mod	90	140
Sep 03	mod	90	70
May 07	mod	100	18
May14	mod	120	40
May 28	mod	148	50
Jul 30	mod	150	14
Jul 02	mod	230	I7
May 21	mod	300	249
Jul 23	mod	300	100
Jun 18	mod	400	81
Aug 06	mod/slow	190	200
Jun 11	slow	116	10
Jun 25	slow	170	20

1991 Perch Creek - Sorted By Creek Flow

Date	Flow	F. colif Creek	F. colif Beach	Lake Condition
May 20	fast	1800	352	calm
May 07	mod	140	10	rolls/wavy
May 14	mod	168	4	calm
Apr 24	mod	210	10	calm
Jul16	mod	1300	4	calm
Jun 11	mod	7900	24	calm
Jul 09	mod	10000	250	rolls/wavy
Aug 27	slow	50	84	calm
Jun 04	slow	100	170	rough
Aug 14	slow	230	16	calm
May 21	slow	230	4	calm
Aug 21	slow	560	16	rolls/wavy
Jul 02	slow	610	16	calm
Aug 07	slow	760	10	calm
Jul23	slow	830	100	rolls/wavy
Jul 30	slow	900	24	rough
Jun 18	slow	1600	170	calm

1988 Bear Creek - Sorted By Creek Flow

Date	Flow	F. Colif
Aug 08	fast	460
Jul 18	fast	700
Sep 07	fast	1800
Aug 15	fast	3600
Jul 04	mod	240
Aug 22	mod	270
Jul 11	mod	270
Jul 25	cad	700
Sep 12	mod	1000
Aug 29	mod	1500
Aug 02	mod	2500
Jun 27	slow	500

1992 Perch Creek - Sorted By Creek Flow

Date	Flow	F. Colif Creek	F. Colif Beach	Lake Conditions
Jun 25	fast	150	4	rolls/wavy
Jun 18	fast	400	1	rolls/wavy
Jul 09	fast/mod	1000	12	rolls/wavy
May 14	mod	84	64	rolls/wavy
Jun 04	mod	250	1	calm
Jul 02	mod	280	16	rolls/wavy
Aug 06	mod	450	12	rolls/wavy
Sep 03	mod	650	40	calm
Aug 13	mod	910	14	rough
Aug 20	mod	1100	10	rolls/wavy
Jul 16	mod	2000	1000	rough
May 21	slow	164	1	calm
Jun 11	slow	200	1	rolls/wavy
May 28	slow	240	1	rough
July 30	slow	470	10	rolls/wavy

APPENDIX F (i)
MATERIAL COSTS (1991)
CATTLE FENCING AROUND WATERCOURSE AND CROSSOVER CONSTRUCTION

ITEM	SUPPLIERS	UNIT SIZE	UNIT COST
<u>Culverts</u>			
Corrugated Steel Pipe	Coldstream Concrete 666-0604	12" x 20'	$120.00
		18" x 20'	$183.00
		20" x 20'	$207.00
		24" x 20'	$242.00
		36" x 20'	$378.00
Plastic Pipe Boss N-12	Coldstream Concrete 666-0604	24" x 20'	$477.20
<u>Backfill</u>			
Gravel Grade A	Alex Newbigging 471-0760	ton	$ 6.75
		cubic meter	$ 6.00
		truck (18 ton)	$122.00
Concrete poured	Red-D-Mix 451-9240	cubic meter	$110.00
			$119.00
Crushed Stone	Matthew's	ton	$ 8.00
		cubic meter	$ 12.00
Filter Cloth	Coldstream Concrete 666-0604	square meter	$ 1.10
<u>Erosion Protection</u>			
GeoWeb	Coldstream Concr.	8' x 20' x 4"	$192.00
	666-0604	8' x 20' x 8"	$336.00
Quarry Stone 6 - 12"	Johnson Brothers 471-3059 Komoka	ton (4-8")	$ 17.00
	Reid Aggregates 336-8584 Sarnia	ton	$ 15.25
	Dallas Trucking 336-8584 Ingersoll	ton	$ 2.95
Cable Concrete	West Lorne Precast 768-1420	4' x 16'	$214.40
<u>Equipment</u>			
Back Hoe Contractor	Tom Mahon 666-0946	per hour	$ 45.00
Jumping Jack Rental	Strathroy Equip. 245-3980	per day	$ 40.00
<u>Watering Devices and Supplies</u>			
Nose Pump Mechanical	Ketchums Guelph) 1-823-8850	standard	$339.00
Plastic Piping 1.25"	TSC Stores 245-2599	100' white	$ 51.00
		100' red	$ 75.00

watering Devices and Supplies (cont'd)			
Electrical Pump	Canadian Tire 245-2703	12 volt	$100-200
Transfer Pump (gas)	TSC Stores 245-2599	3 horse	$349.00
		5 horse	$440.00
Trough Galvanized Steel	TSC Stores 245-2599	4' x 2' x2' (110 gal)	$ 95.00
		6' x 2' x2' (170gal)	$139.00
		8' x 2' x2' (230 gal)	$189.00
Trough Rubber	TSC Stores 245-2599	50 gallon	$109.00
		100 gallon	$134.00
		150 gallon	$189.00
		300 gal	$299.00
Solar Panel	Prometheus Energy (416)660-7868	G100 (10 Watt)	$120.00
		M65 (self-regul)	$675.00
		M75 (need controller)	$620.00
Solar Pump	Prometheus (416)660-7868	Sureflow	$120.00
		Metal pump	$675.00
Battery	Canadian Tire	RV Deep Cycle	$120.00
Seeds and Trees for Buffer Strip			
Forage Seed	Co-op 245-3420.	Tall Fescue	$2.80/kg
		Creeping Red Fescue	$2.05/kg
		Timothy, common	$2.50/kg
		Crown Vetch	
		Trefoil, birdsfoot	
Tree Seedlings	Conservation Authority 245-3710	Application Fee	$10.00
		each tree	$ 0.10
		Plant + spray/tree (subsidies available)	$ 0.35
Fencing - materials only for 1000 meters			
Page Wire	TSC Stores 245-2599	Steel Posts + wiring	$ 640.00
		Cedar Posts + wiring	$2000.00
Barb Wire	TSC Stores 245-2599	Steel Post + strands	$ 370.00
		Cedar Post + strands	$1720.00
Electric	TSC Stores 245-2599	Steel Post + wiring	$ 430.00
		Cedar Post + wiring	$1850.00
Specialty Fences - installed - 1000 meters			
Spider Fence	Common Sense (416)786-2200	Complete /w energizer	$4200.00
High Tensile	Common Sense (416)786-2200	8 wires, posts, etc	$3400-7800

* Solar power can be used to charge electrical fencing too. Only need G100 (100 Watts). Two panels will run 40 acres.

** Prices may vary with different suppliers.

APPENDIX F (ii)

UNIT COST FOR MANURE STORAGES
1991/1992 DOLLARS

Solid Manure Storage

Concrete pad	$21.60/m^2
Concrete walls	$82.00/m^2

Liquid manure storage costs (per cubic meter)

TYPE	SMALL (<340 m^3)	MEDIUM (340-1040 m^3)	LARGE (>1040 m^3)
Covered tank	$55.00	$44.00	$33.00
Open tank	$25.00	$20.00	$13.00
	SMALL (<600 m^3)	MEDIUM (600-2600 m^3)	LARGE (>2600 m^3)
Earthen Pit	$ 6.60	$ 3.60	$ 2.60

Safety fence

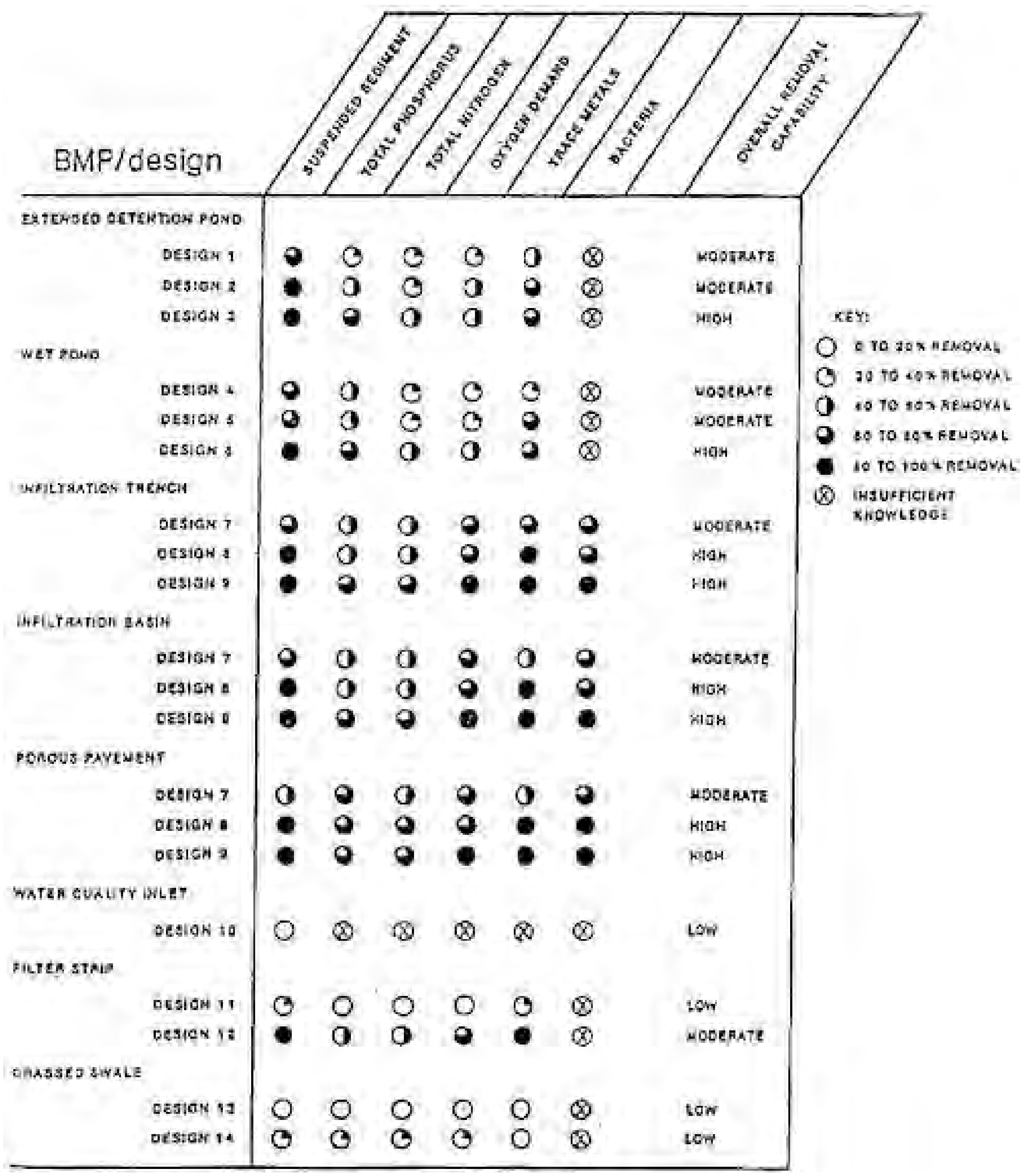
Chain link	$42.60/m

Source: Ron Fleming, Centralia College, Personal Communication.

NOTE: 340 m^3 = 74,800 gallons 1040 m^3 = 228,800 gallons

APPENDIX F (iii)

Comparative Pollutant Removal Of Urban BMP designs



Design 1: First-flush runoff volume detained for 6-12 hours.
Design 2: Runoff volume produced by 1.0 inch, detained 24 hours.
Design 3: As in Design 2, but with shallow marsh in bottom stage.
Design 4: Permanent pool equal to 0.5 inch storage per impervious acre.
Design 5: Permanent pool equal to 2.5 (Vr); where Vr*mean storm runoff.
Design 6: Permanent pool equal to 4.0 (Vr); approx. 2 weeks retention.
Design 7: Facility exfiltrates first-flush; 0.5 inch runoff/imper. acre.
Design 8: Facility exfiltrates one inch runoff volume per imper. acre.
Design 9: Facility exfiltrates all runoff, up to the 2 year design storm.
Design 10: 400 cubic feet wet storage per impervious acre.
Design 11: 20 foot wide turf strip.
Design 12: 100 foot wide forested strip, with level spreader.
Design 13: High slope wales, with no check dams.
Design 14: Low gradient swales, with check dams.

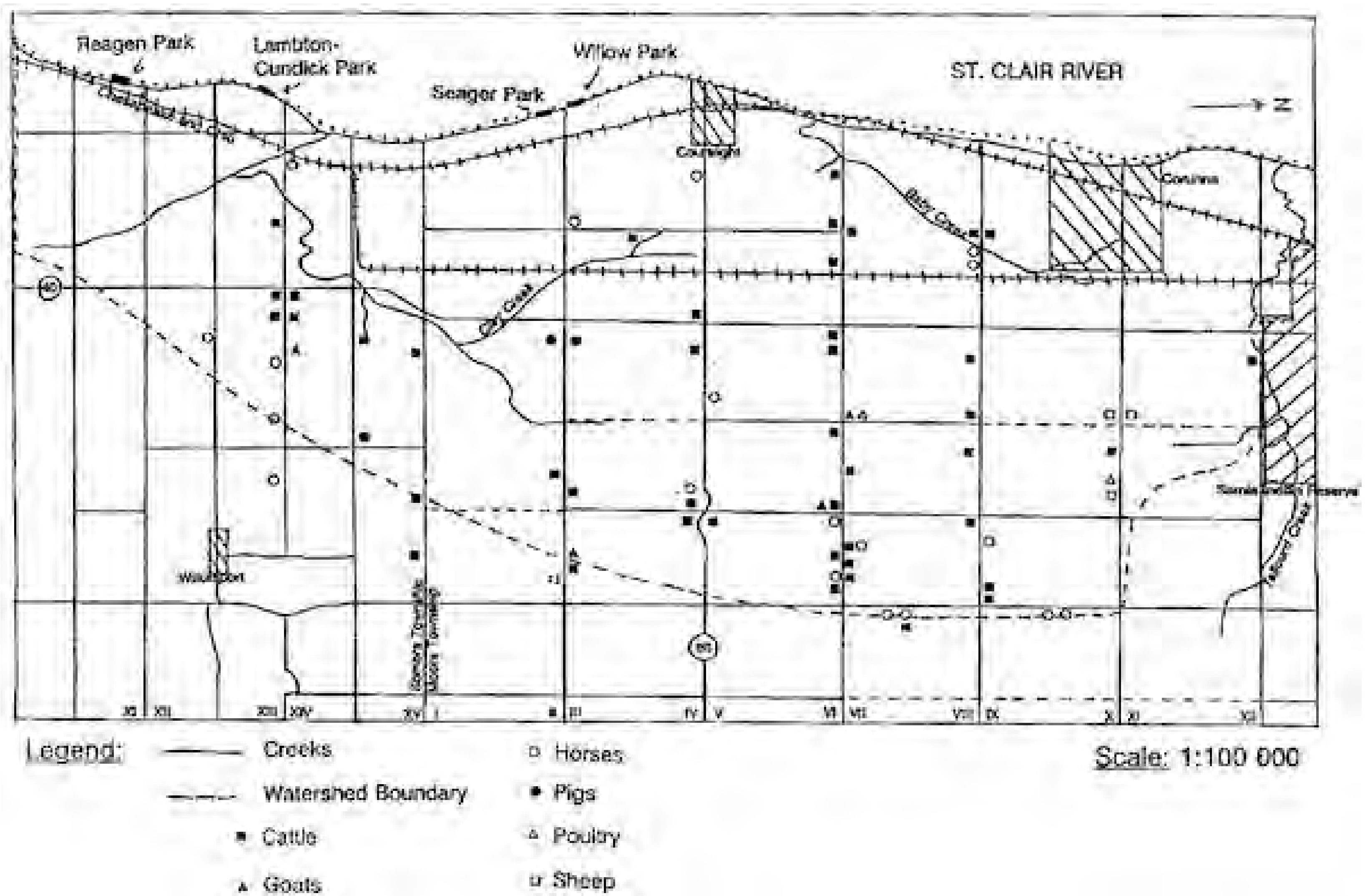
Appendix G (i)

Fecal coliform levels In Lake Huron creeks, 1992 (# fc/100 ml)

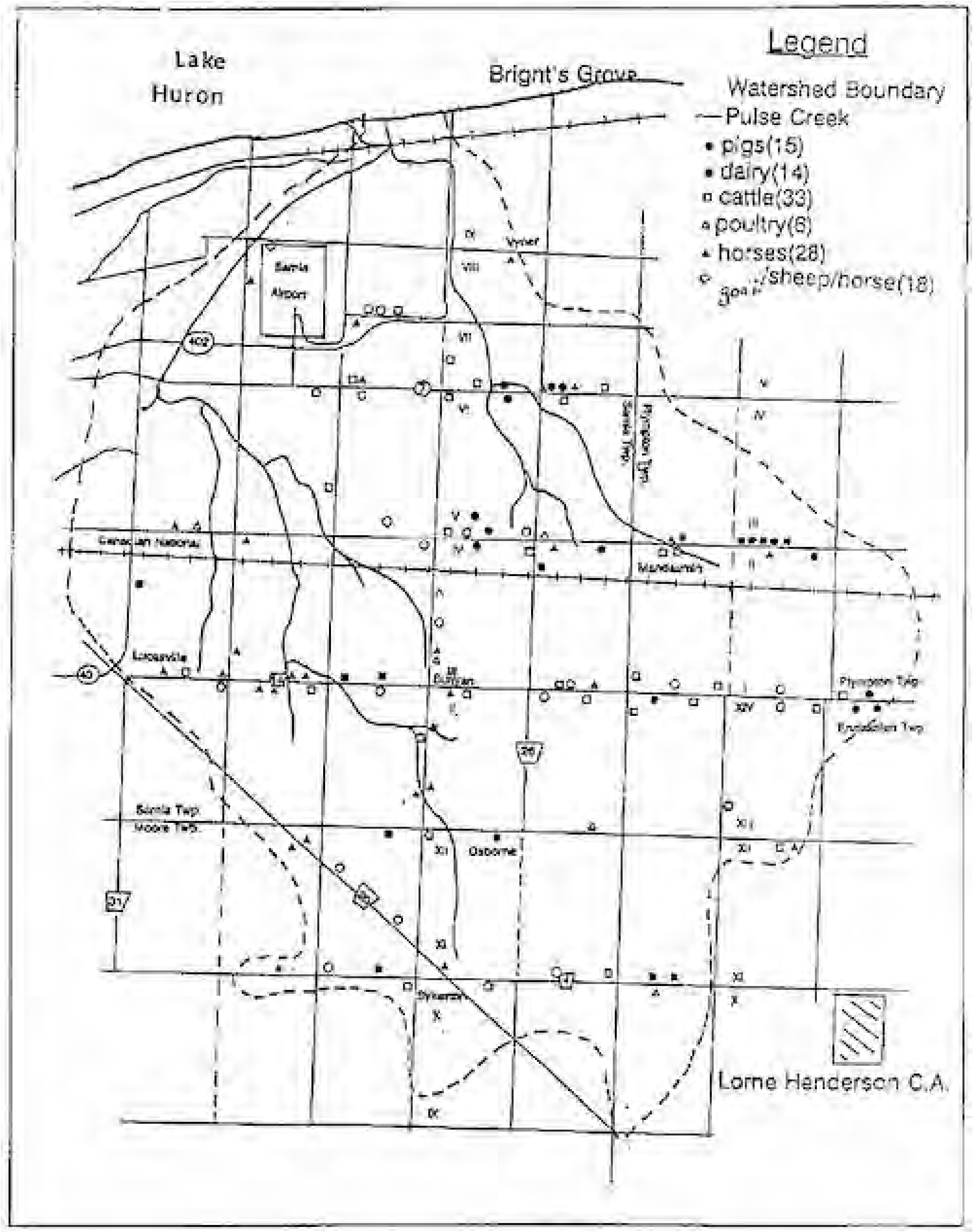
Date	Hickory	Aberarder	Patterson	Pulse	Perch*
07 May	24	20	28	120	4
14 May	16	52	52	290	84
21 May	252	264	144	108	164
28 May	4	108	64	50	240
04 Jun	50	410	30	150	250
11 Jun	80	60	110	180	200
18 Jun	400	400	400	236	400
25 Jun	110	210	80	260	150
02 Jul	120	1000	30	100	230
09 Jul	1000	10000	1000	1000	1000
16 Jul	1500	2500	2500	2800	2000
23 Jul	240	540	800	520	560
30 Jul	140	240	80	500	470
06 Aug	110	190	1000	60	450
13 Aug	210	448	1000	400	910

* Perch Creek - CURB Watershed shown for comparison

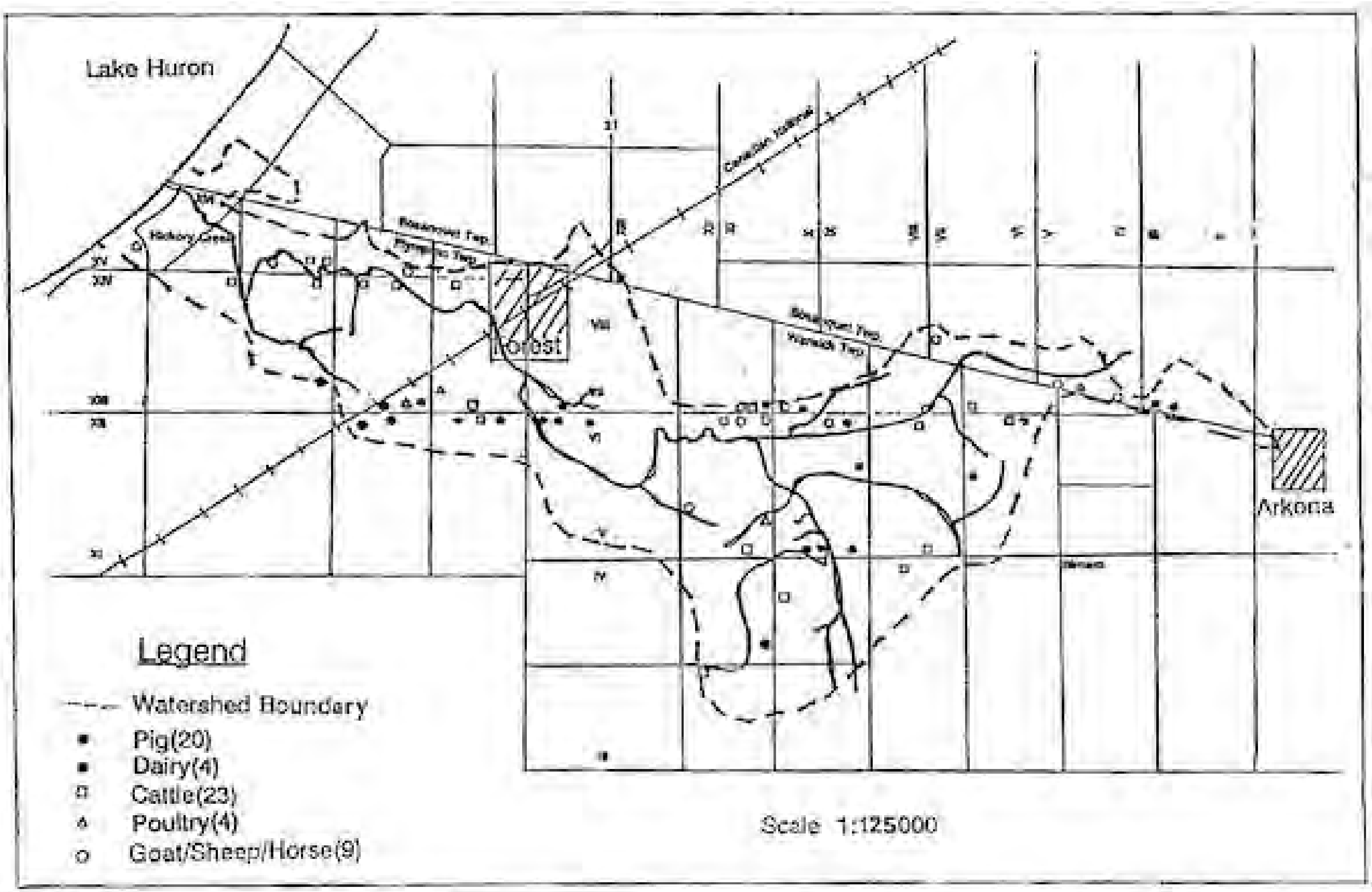
The Baby, Clay and Talfourd Creek Watersheds



The Pulse Creek Watershed



The Hickory Creek Watershed



The Aberarder And Patterson Creek Watersheds