Catfish Creek And Kettle Creek
Clean Up Rural Beaches
(Curb) Plan

Prepared by
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March 1994

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 individual agencies.

FOREWORD

This report is one of a series produced under the Provincial Rural Beaches Program. The objective of the program was 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 provincial rural beaches.

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 present 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) Inadequate manure management practices,
4) Direct discharge of milkhouse wastes,
5) Contaminated field tile systems, and
6) Faulty septic systems.

The impact upon beaches 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 and Energy's (MOEE) Water Resources Branch formulated the Provincial Rural Beaches Strategy Program. Directed by the Provincial Rural Beaches Planning and Advisory Committee, it included representatives from Ministry of Environment and Energy (MOEE), Ministry of Agriculture, Food and Rural Affairs (OMAFRA), and Ministry of Natural Resources (MNR).

With financial and technical assistance from the MOEE, local Conservation Authorities carried out studies under the direction of a local technical steering committee. Chaired by an MOEE regional staff, the committees typically included representation from OMAFRA, MNR, the Medical Officer of Health, Conservation Authority, the local federation of Agriculture, and a local farmer. The chairs of the local committees assured communication between all the projects by participating on the Provincial Committee.

The primary objective of each local study was 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 mathematical modelling techniques.

Recommended actions 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 MOEE funded and undertaken by various Conservation Authorities to improve our understanding of bacterial and nutrient dynamics:

1) *in-situ* bacterial survival studies determined longevity: in watercourses, offshore of beaches, in sediments, and in milkhouse washwater tiles.
2) Biotracer studies determined the speed and nature of travel for bacteria introduced into a watercourse.
3) A liquid manure spreading study examined bacterial movements through the soil column and exiting field tile drains.
4) A target sub-basin study evaluated the effectiveness of comprehensive remedial measure upon a watershed.

Numerous demonstration 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:

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The material presented in this report, both quantitative and qualitative, does not necessarily reflect the position, policies and/or management priorities of any of the individual agencies involved and/or named herein.

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EXECUTIVE SUMMARY

In response to the increasing numbers of beach closures in the early 1980's, the Ontario Ministry the of Environment (MOE) initiated the Provincial Rural Beaches Management Strategy Program in 1985.

The CURB (Clean Up Rural Beaches) Plan report is a document outlining the remedial projects required to improve water quality in the Catfish Creek and Kettle Creek Conservation Authorities Watersheds. Water pollution resulting from various agricultural and urban related sources has lead to beach closures in recent years. This has resulted in the impairment of the recreational potential of beaches at Springwater Reservoir, Port Bruce, Port Stanley, and Dalewood Reservoir.

The CURB Plan is based on extensive farm practice inventories, septic system inventories, water quality data, and pollution delivery capabilities. Landowner questionnaires were conducted at 152 rural residents to determine farming practices and domestic septic system conditions in the two watersheds. A water monitoring study was undertaken which included collection of over 550 water samples for bacterial and chemical analysis, and flow monitoring of tributaries using flow meters.

The information gathered through the two year research stage was used in the development of the Catfish Creek and Kettle Creek Conservation Authorities' CURB Plan. The plan includes algorithms, predictions, remedial costs, implementation strategies and recommendations. Mathematical models were used to estimate the number of bacteria which enter the creeks and beaches from various rural land uses in these watersheds.

In Catfish Creek, the septic systems are the largest contributor with 41% of the total load. Livestock access accounts for 26% and manure spreading 21% of the total load. Feedlot/manure pile runoff and milkhouse washwater only account for 3% and 2% respectively.

In the Kettle Creek Watershed the largest contributor to water quality impairment is livestock access (42%), followed by septic system failure (27%), and urban runoff (13.1%). Milkhouse washwater and manure stack/barnyard are only 3% of the problem in the watershed.

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.

If all remedial projects eligible for CURB assistance, were completed in the Catfish Creek and Kettle Creek Watersheds, 5.1 million would be required from MOEE in grant assistance.

1.0 INTRODUCTION

The Kettle Creek Conservation Authority and the Catfish Creek Conservation Authority watersheds are located adjacent to each other on the north shore of Lake Erie (Figure 1.1). The major urban areas are St. Thomas in the Kettle Creek watershed and Aylmer in the Catfish Creek watershed.

Both watersheds empty into Lake Erie, which is where the two major beaches for the watersheds are located. There are also beaches at different conservation areas in the watersheds.

The two Conservation Authorities have entered into a joint Clean Up Rural Beaches Study beginning in 1992. This joint study focuses on surface water quality within the watersheds and is funded by the Ministry of Environment and Energy under the Provincial Rural Beaches Program. The program began because of the increase in the number of beach closures due to high bacteria levels in the early 1980's. These elevated levels can cause minor skin, nose, ear, eye, and throat infections as well as stomach ailments. A local steering committee directs the study and is made up of representatives from the Ministry of the Environment, Ontario Ministry of Agriculture and Food, Ministry of Natural Resources, Elgin-St. Thomas Health Unit, a representative of the Farming Community, Drainage Superintendent, and both Conservation Authorities.

Both Conservation Authorities are concerned with the water quality in the watersheds and it was determined that a study to identify and priorities the sources of pollution in the watersheds was needed. From this study, the measures needed to improve water quality could be identified. This report is the final CURB Plan which is based on a two year study phase.

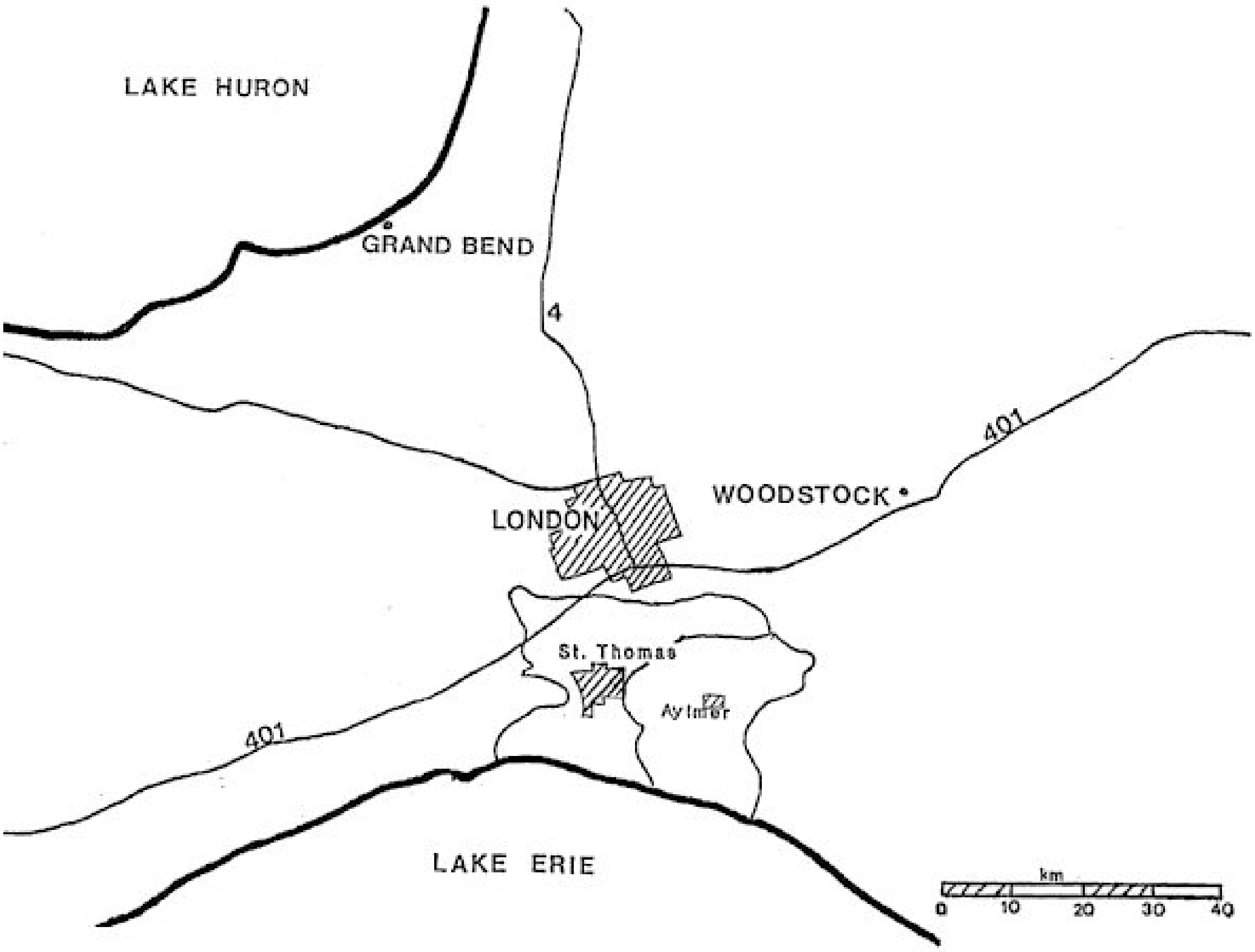

FIGURE 1.1: Location of CCCA and KCCA

1.1 GOALS AND OBJECTIVES

The goal of the Clean Up Rural Beaches Program as set out by the Ministry of Environment and Energy is for Conservation Authorities to be able to restore and maintain acceptable water quality in watersheds with rural beaches through the guidance of the CURB Plan. In order to do this a measurable improvement in water quality is necessary within the targeted watersheds.

During the 10 year program, $57 million will be allocated towards the CURB Program. Eight Authorities that are presently in the Implementation Stage have determined that it will take an estimated $65 million to implement effective measures within their Authorities, therefore, it is clear that most Authorities will be underfunded (Hayman, 1992).

Because of this potential underfunding, it is necessary that the Conservation Authorities set realistic goals in determining how to best achieve improved water quality. The Kettle Creek and Catfish Creek Conservation Authorities would like to achieve measurable results with the least amount of funding. This will be accomplished through a systematic implementation of the program, on priority areas in each Authority's CURB watersheds. The Kettle Creek and Catfish Creek CURB Plan includes the following goals and objectives for the study phase to facilitate this idea.

GOAL:

1. Confirm and establish the extent of faecal and phosphorus contamination by rural point/non-point sources in the Kettle and Catfish Creek watersheds and provide recommendations for implementation and remedial works.

OBJECTIVES:

1. A monitoring and data collection program throughout both watersheds to establish and isolate priority areas of faecal and phosphorus contributions.

2. Provide information and educational materials to the rural community on the goals of the CURB Program and how the community can participate.

3. Provide recommendations within a Final Report, at the end of a two year Study Phase, which will identify projects in each watershed directed toward reducing phosphorus and faecal loading and possibly other major sources of water degradation. The importance of selecting subwatersheds in each Authority for systematic prioritized funding, if warranted, will be emphasised.

1.2 STUDY AREA

The study area is outlined in Figure 1.2. A few of the smaller watersheds were not included in the study area because they did not impact on the beaches. These watersheds are on the east side of the Catfish Creek and impact more on Port Burwell than on Port Brace because of the littoral drift of Lake Erie. The beaches are very important to the local economies of Port Stanley and Port Bruce. Both the beaches at Port Stanley and the beach at Port Bruce attract tourists in the summer. This tourist population is a major source of revenue for the villages.

Kettle Creek watershed

The Kettle Creek CURB watershed is located in the area regulated by the Kettle Creek Conservation Authority and accounts for the majority of the land in the Authority. The watershed drains about 520 km^2 of land. The primary land use in the watershed is agricultural, with mixed farming predominate in the northern half of the watershed.

The two beaches in Port Stanley are Little Beach and Main Beach. These beaches were closed for the first time in 1992, but there has always been some concern about water quality and the beaches are monitored closely every year. Garbage from the Kettle Creek has also been found on the beaches.

As well as the beaches of Port Stanley at the mouth of the Kettle Creek, there are other areas of concern as well. Dalewood Reservoir is located just north of the city of St. Thomas and is part of the Dalewood Conservation Area. Though the Reservoir has not been used for swimming since the 1970's, there is interest in improving the water quality and reopening the Reservoir for swimming. The Reservoir was closed for swimming because of the high bacteria counts and sediment coming downstream which degraded the water quality.

Catfish Creek watershed

The Catfish Creek CURB watershed drains the 355 km^2 area regulated by the Catfish Creek Conservation Authority and accounts for 71 % of the area within the Authority. Here the primary land use is agriculture, with mixed farming in the northern half of the watershed and primarily cash cropping in the south.

The two important beaches within the Catfish watershed are Port Bruce Provincial Park and the Springwater Day Use Area Beach near Aylmer. The beach in Port Brace is located along the Lake Erie shore and is used by many visitors and seasonal residents of trailer parks in the village. The beach at Springwater Conservation Area is used by both local residents and conservation area campers for many recreational activities.

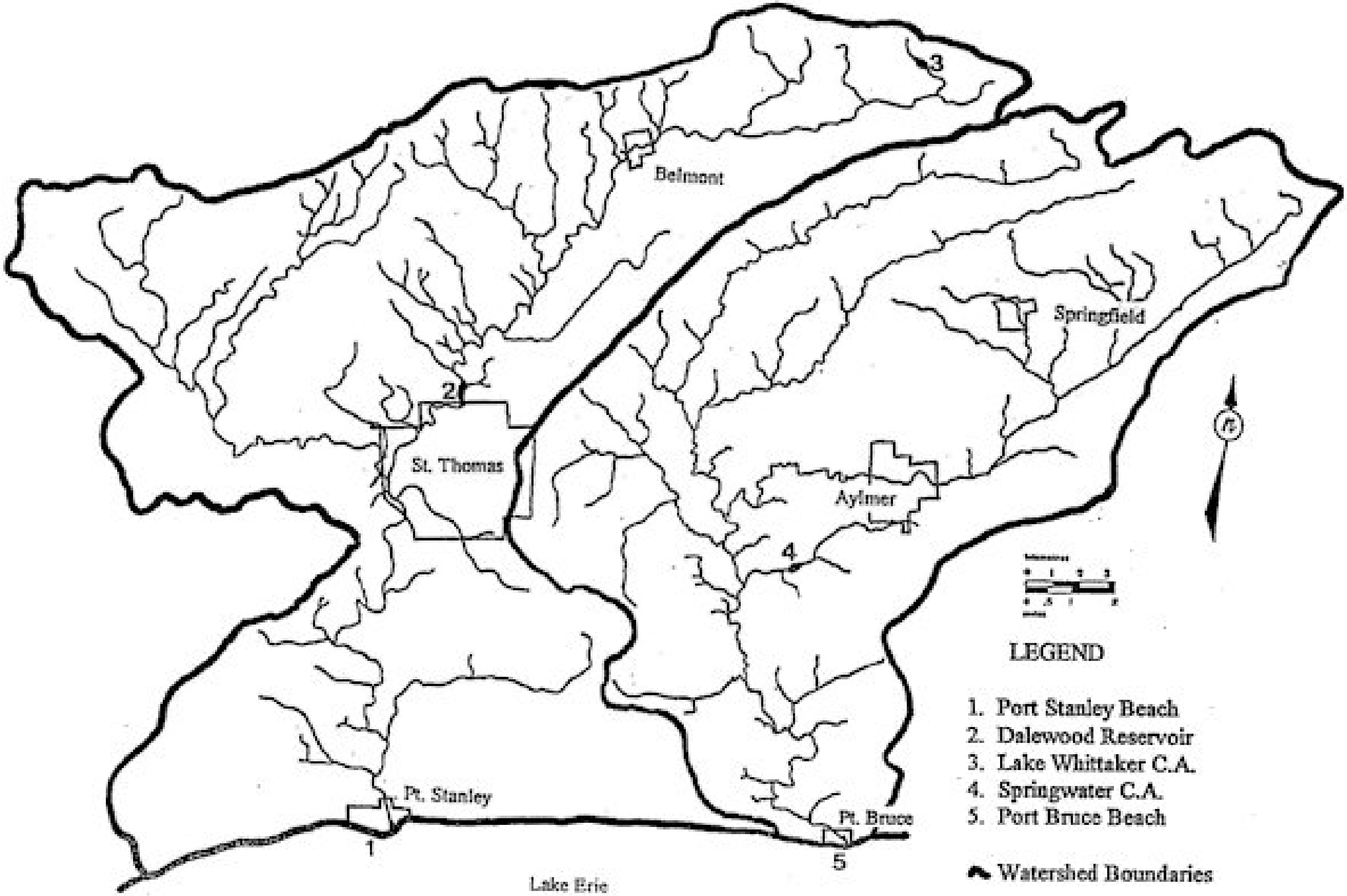

FIGURE 1.2: CURB Study Area

1.3 PUBLIC RELATIONS

The television commercial for the CURB Program prepared by the Ministry of Environment and Energy raised considerable interest within the agricultural community in the watersheds. Information was sent on request to people interested in further information. As well, a few site visits were made to examine potential projects and to offer some suggestions on how to prepare for the Implementation Phase.

A display was created on the Curb Program and appeared at the Elgin County Plowing Match-Agrivision in 1992 and 1993. An information sheet for landowners on the Program was created and made available to the public at various public events. Presentations on the CURB Program were made at the Kettle Creek Conservation Authority's Fall Tour. Articles on the CURB Program were published in the Annual Reports of both Authorities, which were distributed to every watershed household.

One newspaper article on the CURB Program appeared in a local paper informing the public about the program. The newspaper article appear in Appendix F.

2.0 WATER SAMPLING SUMMARY

2.1 WATER SAMPLING

Water sampling was conducted to not only track rural water quality problems in the watersheds, but also to try to account for the urban influences within the watersheds. There are many small communities in the watersheds that could be impacting on the creeks because only St. Thomas, Port Stanley, Belmont and Aylmer have municipal treatment for their waste. The other villages are on septic systems, many of which are probably very old.

In order to compare water quality during wet and dry periods, the rainfall events were monitored and recorded so that the samples could be identified as either being taken during wet or dry weather.

There were eleven water sampling sites in 1993 that were chosen for the Catfish Creek. Figure 2.1 indicates these sites. Sites CL1 and CL2 were sampled on alternate weeks.

There were seven weekly water sampling sites chosen in the Kettle Creek Conservation Authority. Figure 2.2 indicates these sites.

Water samples were collected at each station from June 10 to the end of October. Bacterial analysis and chemical analysis was completed at the London Ministry of Environment and Energy laboratory. A total of 300 samples were analysed at MOEE for the parameters that are outlined below. The Elgin-St. Thomas Health Unit also analysed two samples weekly for bacteria parameters. The following specific parameters were analysed:

BACTERIAL AND CHEMICAL PARAMETERS STUDIED

Bacterial	Chemical
Faecal Streptococci	Suspended solids
Pseudomonas aeruginosa	Nitrogen as free ammonia
Escherichia coli (*E. coli*)	Nitrate
	Nitrite
	Total Kjeldahl
	Total phosphorus
	Dissolved phosphorus
	pH
	Conductivity
	Chloride

Temperature and dissolved oxygen levels were also measured for each site at time of sampling.

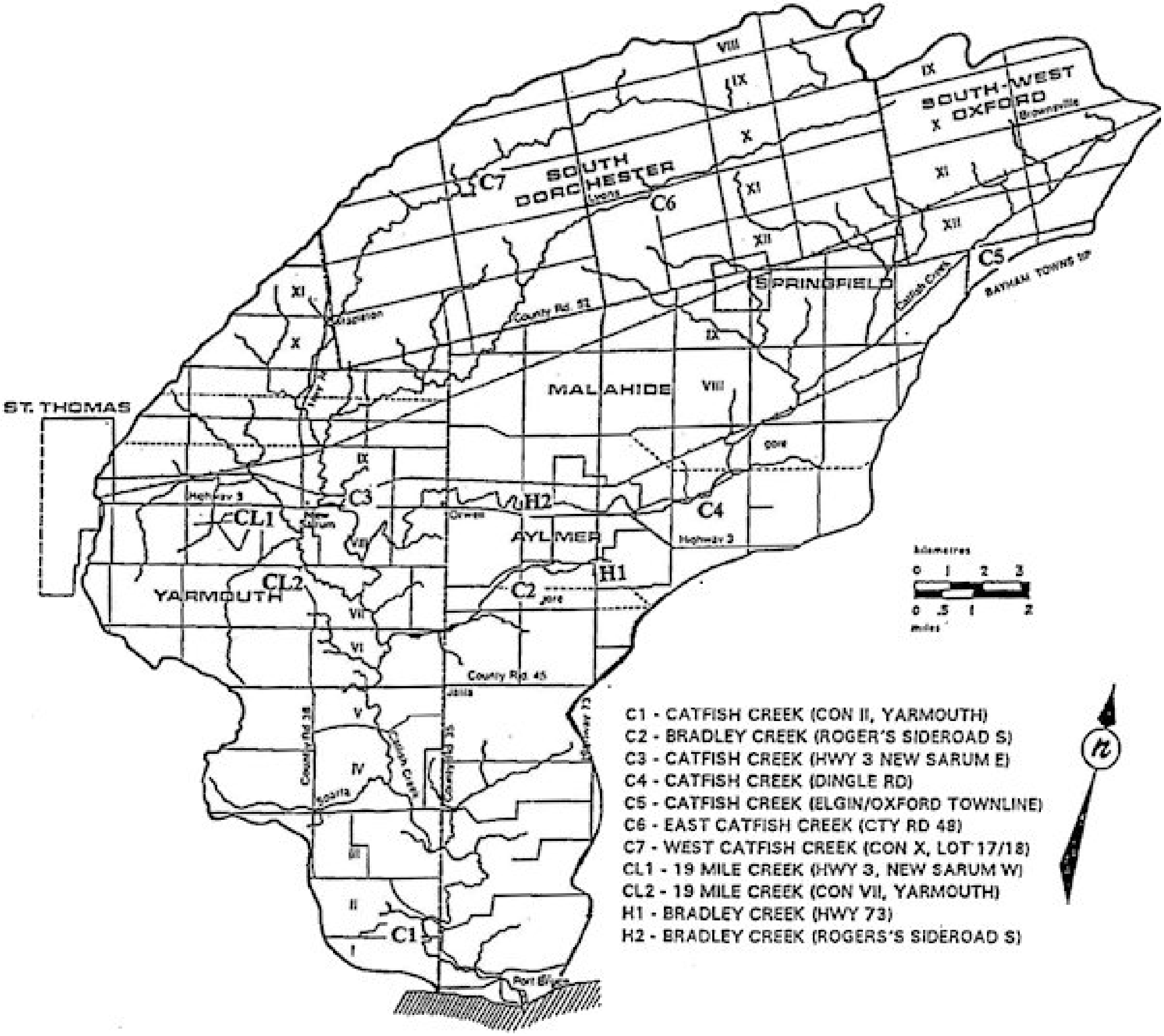

FIGURE 2.1: Location Of Watershed Sampling Points Catfish Creek Watershed

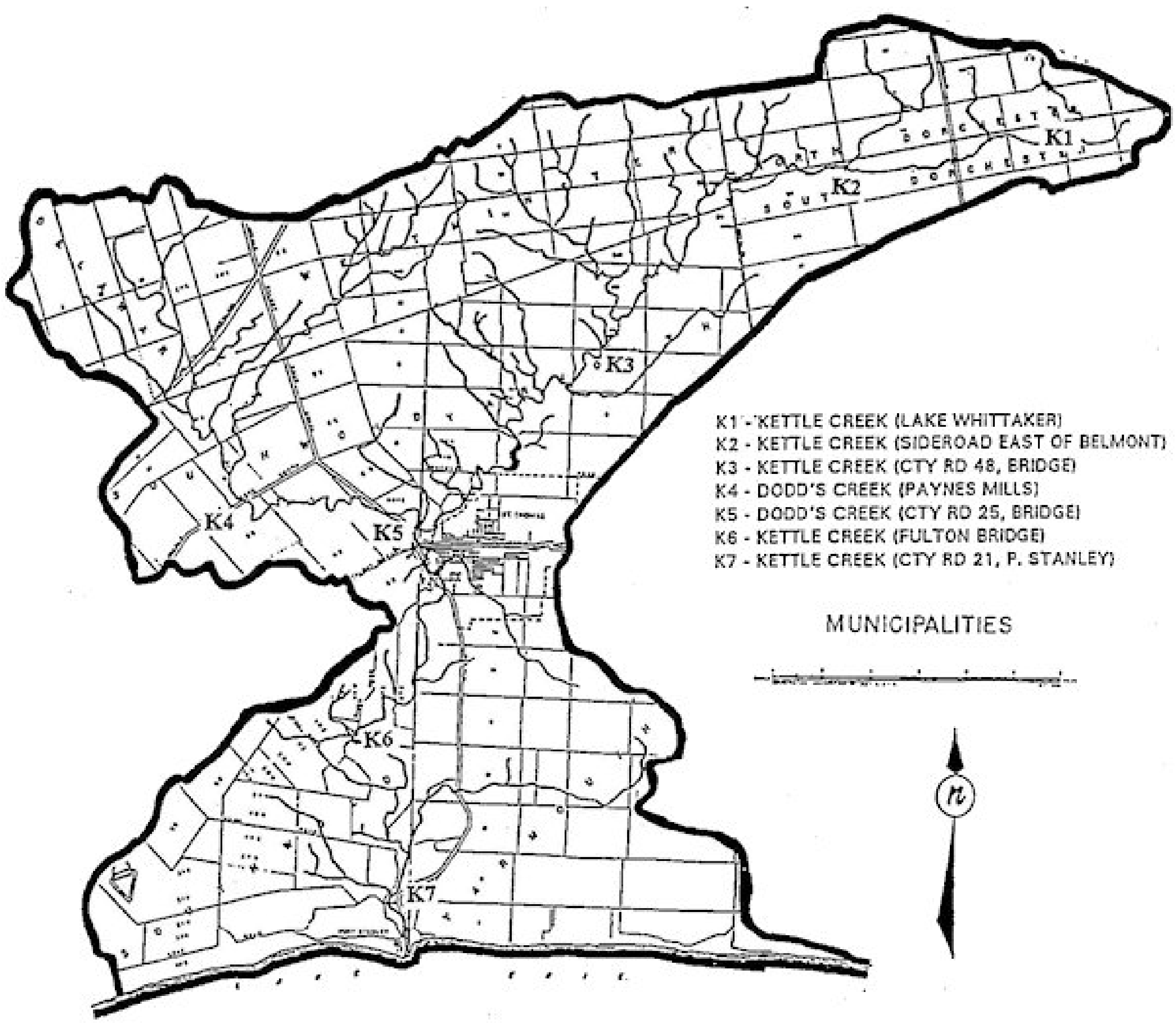

FIGURE 2.2: Location Of Watershed Sampling Points Kettle Creek Watershed

Bacterial indicators

Water that is polluted with human or animal waste can be a serious health hazard to both humans and livestock. Humans run the risk of nose, throat, ear and *eye* infections as well as stomach complaints. Livestock can be exposed to a number of diseases through poor water quality. Bacterial indicators indicate the presence of pathogenic organisms of human or animal origin and that soil and faecal contamination have occurred. These pathogens include bacteria, viruses and protozoa which are easily spread in water. The bacterial indicators for this study are (Margaret Steel, CCCA & KCCA 1992):

1. Faecal Streptococci

Faecal Streptococci is generally found in the alimentary tract of warm blooded animals They are indicative of sanitary waste and/or faecal contamination from warm blooded animals Although present in large numbers in faeces, they are less abundant than coliform in human faeces and thus are a less sensitive indicator.

2. *Escherichia Coliform (E. coli*)

E. coli is the predominant species found in the large intestine and is most directly related to faecal pollution. Once released to the environment, this bacteria can only grow in faeces. *E coli* is primarily an indicator organism for the presence of more virulent organisms. The Public Health Unit uses this bacteria to determine whether a beach will be posted for public swimming.

The MOEE guideline for *E. coli* is less than 100 per 100 ml for water to be safe for swimming.

3. *Pseudomonas aeruginosa*

These organisms are primarily found in sewage. Pseudomonas is the major cause of earaches and skin infections and is noted for its resistance to antibiotics.

The MOEE guideline for Pseudomonas is only 4 organisms per 100 ml.

Chemical Indicators

1. Suspended Solids

Suspended solids can transport significant quantities of organic and inorganic trace elements. They can originate from soil erosion, sewage treatment plant effluents, municipal storm drains, and industrial discharges.

2. Nitrogen

a) Nitrogen as Free Ammonia

Ammonia nitrogen is found in fertilizers, cleaning solvents, livestock wastes, household wastewater and industrial discharges. It is rather short lived in surface waters, but can be toxic to freshwater aquatic life.

b) Nitrate and Nitrite

Nitrate is the end product of the stabilization of organic nitrogen which occurs primarily through aerobic processes. Nitrate is usually present in trace amounts in surface waters. However, high levels of nitrate will contribute to the eutrophication process.

Nitrite is the intermediate oxidation product of ammonia and is also an intermediate form in the denitrification process from nitrate to nitrogen gas. High concentrations of nitrite are indicative of the presence of industrial effluent.

Cattle, young animals and children can convert nitrate to nitrite and can develop methaemoglobinaemia (blue baby syndrome).

c) Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen (TKN) is a measure of the total nitrogenous matter present including nitrate and nitrite. The concentration of Total Kjeldahl Nitrogen minus the ammonia concentration gives a measure of the organic nitrogen present. Eutrophication may occur if TKN is found in excessive amounts. Sources of TKN include manure, sewage, industrial waste treatment effluent and normal biological activities.

3. Total and Dissolved Phosphorus

Phosphorus is a primary nutrient for plant and animal life. Sources of phosphorus are untreated and treated sewage, industrial wastes, agricultural practices, and urban drainage. Excess phosphorus promotes excessive aquatic plant growth which, upon decay, depletes oxygen in lakes and streams. This can result in fish kills and the death of other aquatic life.

The MOEE guideline for phosphorus is 0.03 mg/L to prevent excessive plant growth.

4. pH

pH is an index of the acidity or alkalinity of the water. It is important in determining the appropriate treatment of water supplies. Both acidic and alkaline water may cause eye irritation, therefore the pH of recreational waters should be in the range of 6.5 to 8.5.

5. Conductivity

Conductivity provides a measurement of the electrolytic properties of water. It is an excellent indicator of water quality changes since it is relatively sensitive to variations in dissolved solids concentrations. A standard temperature of 25 degrees Celsius is used when presenting the results.

6. Chlorides

The largest sources of chlorides are from domestic sewage effluent, municipal storm drains, road salting and industrial waste. The level of chlorides should not exceed .002 mg/L according to the Provincial Water Quality Objectives put out by the Ministry of the Environment.

7. Temperature

The water temperature directly affects the solubility of gases and biological and chemical reaction rates.

8. Dissolved Oxygen

Dissolved Oxygen originates either by direct interchange from the atmosphere or from photosynthesis of aquatic plants. The higher the level of dissolved oxygen in the water, the more satisfactory the conditions are for fish and other aquatic species.

2.2 1993 WATER SAMPLING RESULTS

For the purposes of the CURB Plan the main parameter which must be addressed is the bacteria loadings to the watercourses and beach areas. The bacteria and chemical results during base and high flows are outlined in Appendix A.

Faecal Streptococci

Faecal streptococci levels are elevated in the northern half of the watershed likely due to increased livestock farming operations. There was a huge jump in high flow levels at site C6 in the Catfish Creek watershed. From visual observations this increase would likely be caused by a point source polluter. For both watersheds, levels increased significantly during high flow events.

Pseudomonas aeruginosa

Appendix A shows Pseudomonas levels for both watersheds. There was a wide fluctuation in the levels of Pseudomonas measured in the Kettle Creek for each site, especially during high flow sampling. The Catfish samples show a wide fluctuation in levels between sites and shows the different contributions of each tributary.

Escherichia Coliform

E. coli levels in the creeks rose and fell with rainfall events. However, for most sites levels during low rainfall periods remained above the MOEE Provincial Water Quality Objective of 100 *E. coli* /100 ml. Though the guidelines are set for swimming areas, it is clear that even with dilution the high bacteria numbers in the creeks are affecting the beaches downstream. The number of days the beaches were closed is proof of this (Section 2.3).

On average the bacteria levels in the Catfish Creek watershed were higher than those in the Kettle Creek watershed for the upper branches. Rainfall levels influence the numbers of bacteria in the watercourses since there are a lot of runoff pollutants such as manure runoff from fields, barnyards and manure piles as well as urban runoff influence. There was usually a correlation between rainfall and *E. coli*. Figures 2.3 to 2.6 illustrate the geometric average *E. coli* levels during Base and Event Flows (rain events) at the different water sampling locations in the CURB Study Areas.

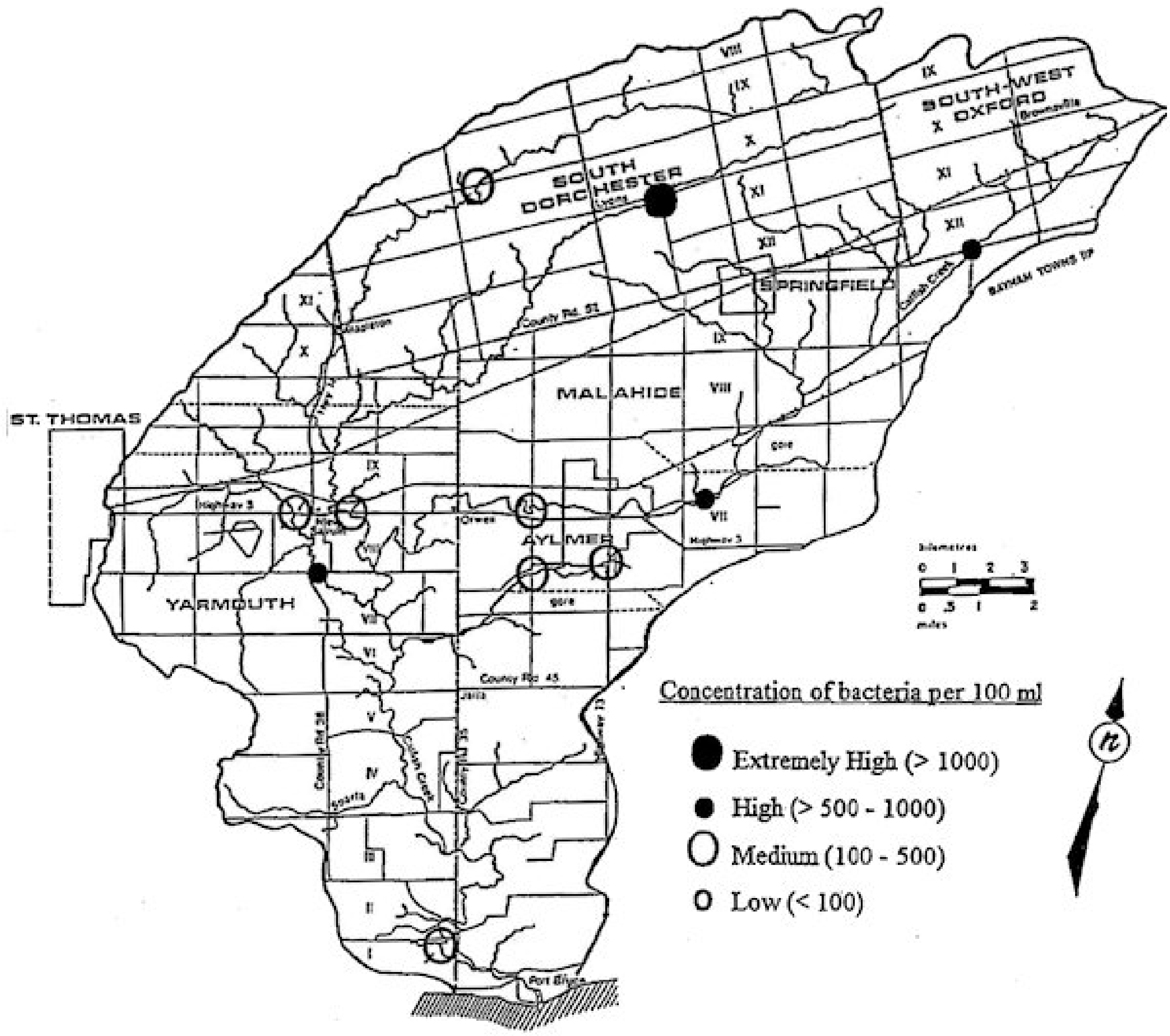

FIGURE 2.3: CATFISH CREEK CURB WATERSHED

Concentration of Escherichia Coliform during Base Flows (1993)

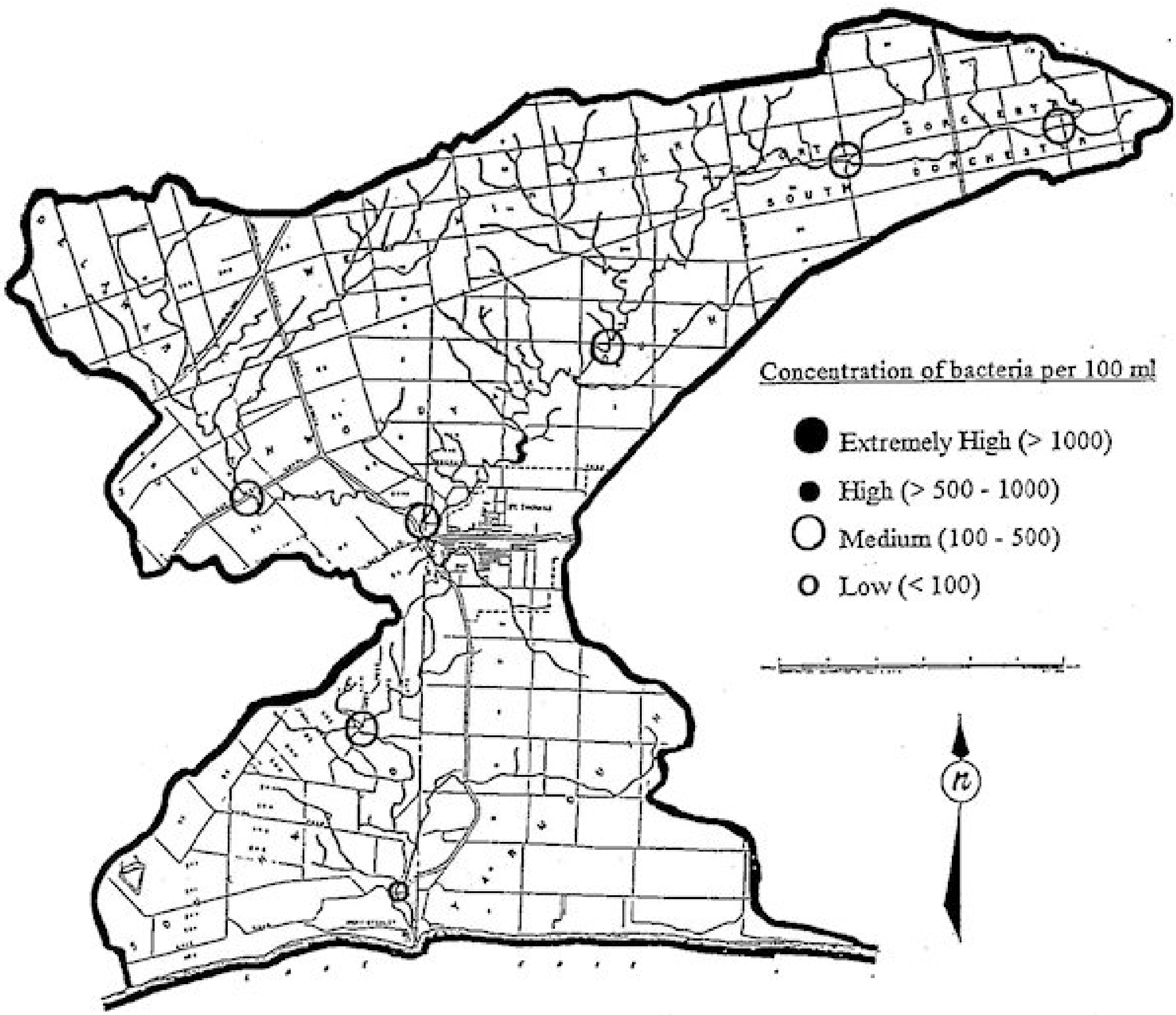

FIGURE 2.4: KETTLE CREEK CURB WATERSHED

Concentration of Escherichia Coliform during Base Flows (1993)

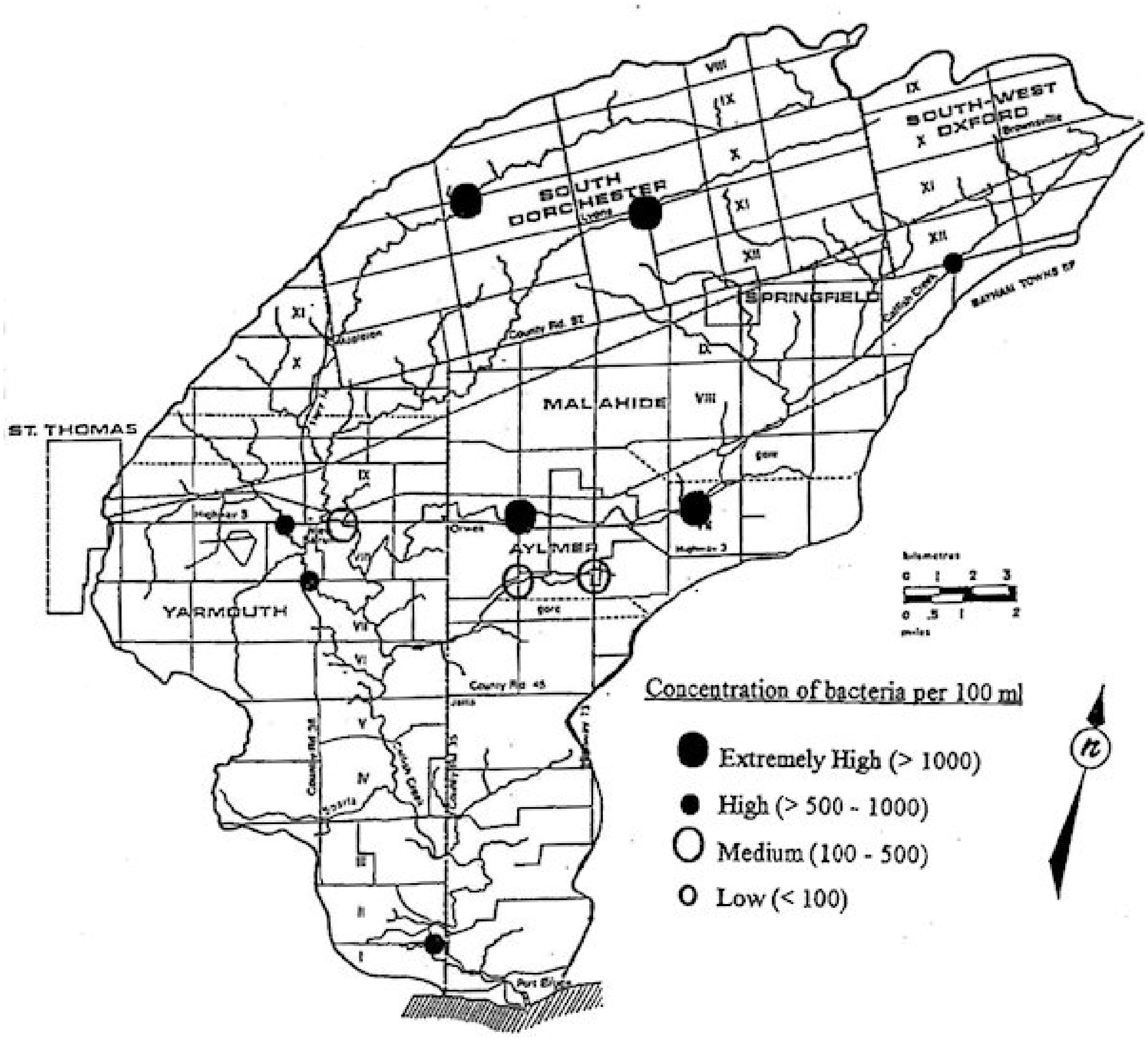

FIGURE 2.5: CATFISH CREEK CURB WATERSHED

Concentration of Escherichia Coliform during Event Flows (1993)

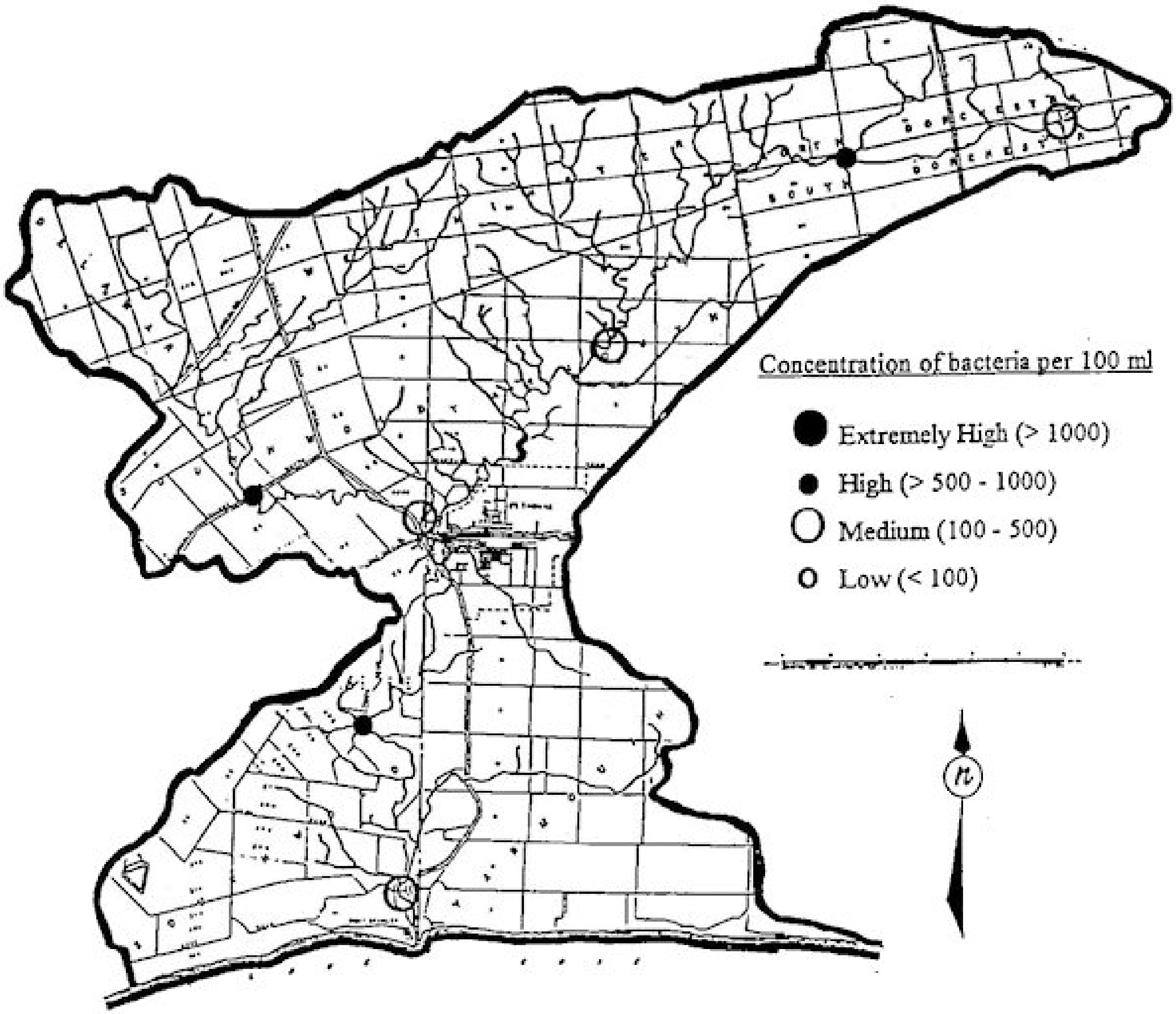

FIGURE 2.6: KETTLE CREEK CURB WATERSHED

Concentration of Escherichia Coliform during Event Flows (1993)

2.3 BEACH CLOSURES

1992 was the first year in many years that the beaches have been closed. Unfortunately there are no water quality records for past years available from the Health Unit (Johnston, 1994).

TABLE 2.1: Beach Postings For Elgin-St. Thomas Health Unit 1992 And 1993 Seasons

YEAR	BEACH LOCATION	# OF DAYS
1992	Port Bruce Beach	5
	Port Stanley - Little Beach	19
	Port Stanley - Main Beach	7
1993	Port Stanley - Main Beach	2

The Springwater Reservoir has not been closed in recent years however, the Elgin-St. Thomas Health Unit monitors it on a weekly basis during the swimming season. Dalewood reservoir counts are extremely high during any storm events (Steele, 1992). The reservoir is not monitored by the Heath Unit since very few people use the area for swimming due the degraded nature of it's water.

3.0 METHODS OF ASSESSMENT

3.1 INTRODUCTION

Faecal pollution delivered to the watercourses from specific sources was calculated separately for each watershed. Agriculture and Urban sources considered were: milkhouse washwater, livestock access, barnyard runoff manure stack runoff, manure spreading, domestic septic systems, urban runoff and sewage treatment plant discharges. Farm surveys were performed to determine the areas of the watershed and types of problems which were most prevalent.

3.2 FARM DATA COLLECTION

Intensive on-site surveys were required to determine whether the practices on livestock farms were contributing to bacterial pollution of surface waters. The large number of livestock operations and time constraints made it impossible to survey all livestock farms in each watershed, given the time parameters of the study.

A methodology was derived to collect pertinent rural landowner information in the most effective manner. The first step in the identification of livestock operations within the watershed was the window survey. The window survey involves;

1. taking the names of livestock farmers off the farm's mailbox,
2. identifying which type of livestock were present,
3. looking for any visible concerns,
4. Identifying the farms proximity to a watercourse.

The mailing address and phone numbers were then obtained from the phone book. Each farm was given an identification number and was placed on a topographic map of the each watershed. From this information the farm was categorised into either "high" or "low" priority based on whether a stream intersected the property.

The farmers were then mailed introductory letter explaining the program and that they would be contacted within. the next few weeks to fill out a confidential questionnaire. The farm questionnaire gathered information on manure management, barnyard/feedlot operation, as well as household and dairy waste water disposal. The questionnaire is shown in Appendix B. The farmers were called to arrange a meeting time at their farm, thirty to sixty minutes was required to fill out the questionnaire and discuss the CURB Program.

In the Catfish Creek CURB Study area 161 livestock farms were identified from the window survey, of which 51 are consider "high" priority. In this watershed, of the "high" priority farms, 65 per cent were surveyed as compared to 16 percent of "low priority" farms. "High" priority farms were surveyed to a greater extent so that a greater accuracy could be derived from the modelling since the farms with great potential for water quality impact were studied. 62 rural landowners were questioned on their household septic system.

In the Kettle Creek CURB Study area there were 166 livestock farms were identified of which 51 are "high" priority. As a percentage breakdown 53 per cent of "high" priority and 21 percent of the "low" priority farms were surveyed. 68 homes in the Kettle Creek CURB study area were studied in regards to their household septic system.

In other CURB studies farms that did not have water intersecting them were assumed to not be polluting an therefore were not studied. However, the questionnaires seem to indicate that the majority of "low" priority farm had some type water quality impairment problem. These are mainly due to municipal open ditches that are not on the topographic maps, or tile drainage carrying such pollutants as milkhouse washwater a great distance to the creeks. Therefore the terms "high" and "low" priority have been dropped from the remainder of the report.

The following is a list of the pertinent information that was gathered from the landowner questionnaire. This information was used in the CURB models to determine bacterial loadings to the watersheds.

TABLE 3.1 Average Farm Statistics Catfish Creek

Average Dairy Farm:

	TOTAL
# Of Dairy Farms	72
# Surveyed	30
Average # Of Cows	43
Average # Of Calves	18
Average # Of Heifers	30
% With Solid Manure	93.3
Average Pad Size (Ha)	0.03
% With Manure Stack <= 150M	47.4
% With Liquid Manure	16.7
% With Feedlots	76.7
Average Feedlots Size (Ha)	0.08
% With Feedlots <= 150M	55.6
% Winter Spreading	30
% With Stream/Ditch On Property	44.8
% Without Milkhouse Disposal	38.5
% With Livestock Access	35.5
Average # Of Cows With Access	17.6
Average # Of Calves With Access	0.6
Average # Of Heifers With Access	20.2
# Of Access Days On Average	190
Average Pasture Size (Ha)	13.3

AVERAGE SWINE FARM:

	TOTAL
# Of Swine Farms	28
# Surveyed	10
Average # Of Farrowing	180
Average # Of Feeders	654
% With Solid Manure	30
Average Pad Size (Ha)	0.008
% With Manure Stack <=150M	12.9
% With Liquid Manure	80
% Winter Spreading	10
% With Stream/Ditch	32.14

AVERAGE BEEF FARM:

	TOTAL
# Of Beef Farms	50
# Surveyed	12
Average # Of Cows	24
Average # Of Calves	15
Average # Of Steers	94
% With Solid Manure	100
Average Pad Size (Ha)	0
% With Manure Stack <= 150M	46.8
% With Feedlots	63.6
Average Feedlots Size (Ha)	0.02
% With Feedlots <= 150M	46.8
% Winter Spreading	18.2
% With Stream/Ditch On Property	32
% With Livestock Access	0
Average # Of Cows With Access	0
Average # Of Calves With Access	0
Average # Of Steers With Access	0
# Of Access Days On Average	0

AVERAGE POULTRY FARM:

	TOTAL
# Of Poultry Farms	6
# Surveyed	2
Average # Of Broilers	15000
Average # Of Layers	0
Average # Of Breeders	0
% With Solid Manure	50
Average Pad Size (Ha)	0
% With Manure Stack <= 150M	0
% Winter Spreading	0
% With Stream/Ditch	16.7

AVERAGE HORSES FARM:

	TOTAL
# Of Horse Farms	33
# Surveyed	3
Average # Of Horses	9
% With Manure Stack <= 150M	0
% Winter Spreading	33.3
% With Stream/Ditch	78.8
% With Livestock Access	0
Average # Of Horses With Access	0
# Of Access Days On Average	0

SEPTIC SYSTEMS:

	TOTAL
# Of Homes	2570
# Of Homes Surveyed	62
% With Faulty Septic Systems	24.2

TABLE 3.2 Average Farm Statistics Kettle Creek

AVERAGE DAIRY FARM:

	TOTAL
# Of Dairy Farms	48
# Surveyed	24
Average # Of Cows	41
Average # Of Calves	24
Average # Of Heifers	29
% With Solid Manure	87.5
Average Pad Size (Ha)	0.02
% With Manure Stack <= 150M	35.2
% With Liquid Manure	16.7
% With Feedlots	70.8
Average Feedlots Size (Ha)	0.06
% With Feedlots <= 150M	45.4
% Winter Spreading	29.2
% With Stream/Ditch On Property	48.6
% Without Milkhouse Disposal	60.3
% With Livestock Access	32.8
Average # Of Cows With Access	14.7
Average # Of Calves With Access	0
Average # Of Heifers With Access	16.7
# Of Access Days On Average	190
Average Pasture Size (Ha)	9.0

AVERAGE SWINE FARM:

	TOTAL
# Of Swine Farms	18
# Surveyed	11
Average # Of Farrowing	98
Average # Of Feeders	501
% With Solid Manure	18.2
Average Pad Size (Ha)	0.04
% With Manure Stack <=150M	4.44
% With Liquid Manure	54.5
% Winter Spreading	18.2
% With Stream/Ditch	35.2

AVERAGE BEEF FARM:

	TOTAL
# Of Beef Farms	73
# Surveyed	23
Average # Of Cows	61
Average # Of Calves	31
Average # Of Steers	56
% With Solid Manure	78.3
Average Pad Size (Ha)	0.01
% With Manure Stack <= 150M	29.1
% With Liquid Manure	4.3
% With Feedlots	73.7
Average Feedlots Size (Ha)	0.11
% With Feedlots <= 150M	29.1
% Winter Spreading	39.1
% With Stream/Ditch On Property	35.2
% With Livestock Access	34.8
Average # Of Cows With Access	30.2
Average # Of Calves With Access	26
Average # Of Steers With Access	32. 8
# Of Access Days On Average	220
Average Pasture Size (Ha)	27.6

AVERAGE POULTRY FARM:

	TOTAL
# Of Poultry Farms	11
# Surveyed	4
Average # Of Broilers	31500
Average # Of Layers	335
Average # Of Breeders	0
% With Solid Manure	75
Average Pad Size (Ha)	0.04
% With Manure Stack <= 150M	45.5
% With Liquid Manure	45.5
% Winter Spreading	75
% With Stream/Ditch	100

AVERAGE HORSE FARM:

	TOTAL
# Of Horse Farms	30
# Surveyed	5
Average # Of Horses	8
% With Manure Stack <= 150M	100
% Winter Spreading	40
% With Stream/Ditch	0
% With Livestock Access	15.6
Average # Of Horses With Access	10
# Of Access Days On Average	180

SEPTIC SYSTEMS:

	TOTAL
# Of Homes	2529
# Of Homes Surveyed	68
% With Faulty Septic Systems	20.6

4.0 CURB MODELLING

4.1 CURB MODEL DEVELOPMENT

In order to produce a Clean Up Rural Beaches (CURB) plan, all potential pollution sources contributing to beaches must be determined and quantified. The model utilized information that was collected from rural landowners in the summer of 1993.

The original CURB model was developed in 1988 by the consulting firm Ecologistics Limited contracted under the Ministry of the Environment. The result was the Pollution from Livestock Operation Predictor (PLOP). This model was based on American data on a site specific basis and only addressed manure stack runoff; barnyard runoff livestock stream access and milkhouse washwater pollution. The CURB model has been adapted by the Clean Up Rural Beaches Programs to better reflect bacterial conditions found within Southern Ontario. Therefore, the present models being used do not resemble the original PLOP model.

Modifications were required to the PLOP model in the Catfish Creek and Kettle Creek CURB study areas. The model for this study was derived from several other CURB programs and adapted to suit these particular watersheds. The model used was developed by the St. Clair Region Conservation Authority (Quinlan 1992) and took into consideration not only those components covered by the PLOP model but other elements such as manure spreading (overland and subsurface runoff), septic system failure, pasture runoff; sewage treatment plants and urban non-point sources.

4.2 CURB ALGORITHMS

To predict the bacteria load to the watersheds and beaches a series of CURB Algorithms were developed. These algorithms are based on a number of assumptions and results of experiments used to create or verify these models. These models are not precise enough to accurately predict the bacterial loading from a site specific evaluation. However, averaged on a watershed basis you will get a reasonably accurate account of the different components that are impacting the streams in the watersheds and hence the beaches.

Following is a list of algorithms used to determine bacterial loadings in the watersheds. The algorithm is stated with an explanation of the mathematical components and any assumptions which were used. in the farm algorithms the mathematical components were averaged from the farm information collected.

MILKHOUSE WASH WATER ALGORITHM

The milkhouse wash water algorithm estimates the total annual faecal coliform delivered to the watercourse as a result of discharge of untreated milkhouse wash water. In the Kettle Creek watershed 60% of Dairy operations have no milkhouse wastewater treatment system. The survey showed that this number is 38.5% in the Catfish Creek watershed.

Load = Conc. x Vol / cow / day x Average Number of Cows x Days x Percent Delivery x Percent Dairy Farms with untreated waste water x Number of Dairy Farms

* The concentration of faecal coliform in the wash water entering the milkhouse drain was assumed to be 2000/litre. (Hayman 1989)
* The volume of washwater was assumed to be 13 litres/cow/day. (Fuller and Foran 1989)
* The average number of cows was taken from the Water Quality Questionnaire.
* The number of days of discharge was assumed to be 365.
* The growth of bacteria in the tile was determined to be 50,000 percent. The bacteria grow in the tiles due to the good food source which the wash water provides. (Hayman 1989)
* Percentage of dairy farms with no treatment system was calculated from the Water Quality Questionnaire.
* Number of Dairy Farms each study area was taken from the Water Quality Questionnaire if interviewed or from window surveys.

LIVESTOCK ACCESS ALGORITHM

The livestock Access Algorithm estimates the total annual faecal coliform delivered to the watercourse as a result of livestock direct defecation into the watercourse.

Load =	**Conc. / defecation x EAU x Probability of defecation x Access events per day x Number of days on pasture x Average number of animals x Percentage of animals with access x Number of farms**

* The concentration of 8.9×10^8 faecal coliform per defecation was assumed for a 454 kg (1000 lbs) steer. (MVCA 1989)
* The Equivalent Animal Units (EAU) are listed in Appendix C. It is a measure of the amount of faecal coliform produced based on the animal's size and type.
* The probability of an animal defecating in the watercourse was assumed to be 0.18. (Dermal 1982)
* The number of access events per day was assumed to be 2.5 on average. (Dermal 1982)
* The number of days on pasture was averaged from the Water Quality Questionnaire.
* Average number of animals was taken from the Water Quality Questionnaire. Each type of animal was put through the formula separately.
* Percentage of each animal type with access to watercourse was taken from the Water Quality Questionnaire.
* Numbers of each type of livestock farms were taken from the Water Quality Questionnaire if interviewed, or from window surveys.

FEEDLOT/EXERCISE YARD RUNOFF ALGORITHM

The feedlot runoff algorithm estimates the total annual faecal coliform delivered to the watercourse as a result of runoff from feedlots and exercise yards within 150 metres of a watercourse.

Load =	**Conc. x Average area x Rainfall runoff x Delivery x Percentage of each type of farm with feedlots x Number of farms**

* The concentration of 5.0×10^9 faecal coliform per hectare per millimetre was assumed for the feedlot runoff (Hayman 1989).
* Average storage area in hectares was determined from the questionnaire.
* Rainfall runoff = Barnyard area x Annual precipitation x 0.60
    - The total annual precipitation for the St. Thomas area is approximately 912 mm.
    - The runoff from the yard area was assumed to be 60 percent of the annual precipitation (Coote and Hore 1978).
* Delivery to the watercourse was assumed to be 70 percent.
* Percentage of each animal type with feedlots closer than 150 metres to a watercourse or drain.
* Numbers of each type of livestock farms were taken from the Water Quality Questionnaire if interviewed, or from window surveys.

MANURE STACK RUNOFF ALGORITHM

The manure stack runoff algorithm estimates the total annual faecal coliform delivered to the watercourse as a result of runoff from manure stacks which are with 150 metres of stream and have no runoff containment.

Load =	**Conc. x Average area x Rainfall runoff x Delivery x Percentage of each type of farm with manure stack x Number of farms**

* The concentration of 5.0×10^9 faecal coliform per hectare per millimetre was assumed for the stack runoff (Hayman 1989).
* Average storage area in hectares was determined from the questionnaire.
* Rainfall runoff = Manure Stack area x Annual precipitation x 0.60
    - The total annual precipitation for the St. Thomas area is approximately 912 mm.
    - The runoff from the manure stack area was assumed to be 60 percent of the annual precipitation (Coote and Hore 1978).
* Delivery to the watercourse was assumed to be 70 percent.
* Percentage of each animal type with manure stacks closer than 150 metres to a watercourse or tile drain.
* Numbers of each type of livestock farms were taken from the Water Quality Questionnaire if interviewed, or from window surveys.

MANURE SPREADING ALGORITHM

The manure spreading algorithm estimates the total annual faecal coliform delivered to the watercourse as a result of manure being spread on farm land. There are four separate formulas which are used to determine the total manure spreading load.

A) WINTER SOLID MANURE SPREADING ALGORITHM

The winter manure spreading algorithm estimates the total annual faecal coliform load delivered to the watercourse from solid manure being spread in the winter.

Load = Number of bacteria x Percent spread in winter x Delivery x Stack decay rate x Field decay rate x Percentage of each type of farm that spread solid manure in winter x Number of farms

Number of bacteria = Volume of manure/animal/day x Concentration x Number of animals x Number of days in a year x Percent of manure produced in winter

- * The volume of manure/animal/day in m^3/day are listed in Appendix D
- * The concentration of faecal coliform per cubic metre are listed in Appendix E.
- * Number of animals was taken from the Water Quality Questionnaire.
- * Assumed that 25 percent of manure was produced in winter

* Percent spread in the winter was assumed to be 75 percent of the total manure produced in this season.
* The delivery to the watercourse was assumed to be 10 percent of the manure that was winter spread, within the critical distance of 150 metres of the watercourse, was delivered to the stream (Robinson and Draper 1978).
* Assumed that the stack decay rate was 0.01 (Hayman 1993).
* It was assumed that the field decay rate was 0.034 (Hayman 1993).
* Percentage of each animal type with that winter spreads manure.
* Number of each type of livestock operation were taken from the Water Quality Questionnaire if interviewed, or from window surveys.

B) SPRING, SUMMER AND FALL SOLID MANURE SPREADING ALGORITHM

This algorithm estimates the total annual faecal conform load delivered to the watercourse from manure being spread in the spring, summer and fall.

Load = Number of bacteria x Delivery x Stack decay rate x Field decay rate x Percentage of each type of farm that spread solid manure in spring, summer and fall x Number of farms

Number of Bacteria = (Volume of manure/animal/day x Concentration x Number of Animals x 365 days) - Number of bacteria winter spread - Access Load

* The volume of manure/animal/day in m^3/day are listed in Appendix D
* The concentration of faecal coliform per cubic metre are listed in Appendix E.
* Number of animals was taken from the Water Quality Questionnaire. The number of bacteria spread in winter was previously calculated.
* The number of bacteria delivered to watercourses from livestock access was previously calculated.

* The delivery to the watercourse was assumed to be 10 percent of the manure that was spring, summer and fall spread, within the critical distance of 150 metres of the watercourse, was delivered to the stream (Robinson and Draper 1978).
* Assumed that the stack decay rate was 0.01 (Hayman 1993).
* It was assumed that the field decay rate was 0.034 (Hayman 1993).
* Percentage of each animal type with that spread solid manure in spring, summer and fall.
* Number of each type of livestock operation were taken from the Water Quality Questionnaire if interviewed, or from window surveys.

C) OVERLAND LOADING FROM LIQUID MANURE

This formula estimates the total annual faecal coliform load delivered to a watercourse (overland) from the spreading of liquid manure.

Load =	**Volume x Conc. on-field x Field die-off x Critical zone x Delivery x Percentage of each type of farm that spread liquid manure x Number of farms**

Volume = Number of head x Daily manure production x Days

* Number of livestock taken from survey data.
* The volume of manure/animal/day in m^3/day are listed in appendix D
* assume 365 days

* The faecal coliform concentration per cubic metre of manure on a field was averaged from data collected by ABCA (Appendix E)
* Field die-off would occur between the time of spreading and a runoff event. The formula used to calculate this was 10^{-kt} where:
  - k = constant of 0.066.
  - t = time (in days) between significant rainfall events is 15 days.
* The critical zone is defined as lands within 150 metres of a watercourse. This covers 21% of the Catfish Creek watershed and 15% of the Kettle Creek area. The assumption that must be made is that the manure is spread evenly within the watersheds and that therefore 21% and 15% of manure would fall within the critical zone.
* Assume the delivery to be 10% of manure spread.
* Percentage of each animal type that spread liquid manure.
* Number of each type of livestock operation were taken from the Water Quality Questionnaire if interviewed, or from window surveys.

D) SUBSURFACE LOADING FROM LIQUID MANURE SPREADING

This formula estimates the total annual faecal coliform load delivered to a watercourse (subsurface) from the spreading of liquid manure.

Load = Volume x Conc. on-field x Delivery x Percentage of each type of farm that spread liquid manure x Number of farms

Volume = Number of head x Daily manure production x Days

* Number of livestock taken from survey data.
* The volume of manure/animal /day in m^3/day are listed in appendix D
* assume 365 days

* The faecal coliform concentration per cubic metre of manure on a field was averaged from data collected by ABCA (Appendix E)
* Assume the delivery to be 0.5% of manure spread on field.
* Percentage of each animal type that spread liquid manure.
* Number of each type of livestock operation were taken from the Water Quality Questionnaire if interviewed, or from window surveys.

PASTURE LAND RUNOFF LOAD

This formula estimates the total annual faecal coliform load delivered to a watercourse from runoff from pasture land.

Load =	**Average area x Precipitation x Percent runoff x conc. x critical zone x die-off x Percentage of each type of farm that have pastures x Number of farms**

- * Average area of the pasture in square metres is taken from the Water Quality Questionnaire.
- * The precipitation for the months of May to Oct (livestock grazing period) is approximately 0.445 metres.
- * The runoff from pasture lands is assumed to be 5 percent (KCCA/CCCA steering committee 1994).
- * The faecal coliform concentration from cow manure was assumed to be 5.0 x 10^{11} cubic metres (Appendix E).
- * The assumption was made that only pasture lands within the critical zone (150 metres of a watercourse) would be causing faecal coliform loading. The pastures were assumed to be spread evenly throughout the watershed and therefore 21% of Catfish and 15% of Kettle Creek pasture land is contributing bacteria loadings. This assumption will likely underestimate bacteria loadings since pastures are more likely found in lowland areas (Quinlan 1992).
- * Assume a 90 percent die-off rate from when the manure is deposited until it reaches the watercourse (Quinlan 1992).
- * Percentage of each animal type that have pastures.
- * Number of each type of livestock operation were taken from the Water Quality Questionnaire if interviewed, or from window surveys.

SEPTIC SYSTEM FAILURE ALGORITHM

The septic system failure algorithm estimates the total annual faecal coliform loading as a result of faulty septic system hook-ups.

Load =	**Conc. x volume/home/day x Days x Number of Homes x Percent failure rate x delivery**

* A concentration of 1.0 x 10^7 faecal coliform per litre of effluent at the tile outlet was assumed (MVCA 1989).
* A total volume of 450 litres per day was assumed (Hayman 1993).
* Number of days of was assumed to be 365 for, permanent residences.
* The number of homes were counted from topographic maps as well as from field checking.
* The failure rate was determined from the Water Quality Questionnaire. This percentage was determined by landowners either admitting to having a direct hook-up to tile or watercourse, or ⅔ of the landowner were also counted as having a faulty system is they did not know if they had such hook-up.
* It was assumed that 50 percent of the total faecal coliform load reaches the watercourse from the faulty septic systems

SEWAGE TREATMENT PLANT DISCHARGE ALGORITHM

There are several sewage treatment plants in the CURB watersheds contributing to bacteria loading. In the Catfish Creek watershed there are two lagoon type systems one in Aylmer and the other at the Ontario Police College. In the Kettle Creek watershed there are four sewage treatment plants. Three of these plants are lagoon type systems; Belmont, Port Stanley and Ford Talbotville. The St. Thomas plant is a activated sludge plant which treats and releases effluent on a daily basis.

The lagoon type systems release effluent twice annually during high flow periods in the spring and fall.

Load =	**Concentration x Volume**

* Concentration of faecal coliform present in the effluent water is based on MOEE water quality samples.
* Volume information from lagoon type systems is not available for discharges into the streams however, volumes into the lagoons are recorded. These information is therefore used when stream discharge data is not available.

URBAN RUNOFF ALGORITHM

The urban runoff algorithm estimates the total annual faecal coliform loadings to watercourses due to urban runoff during storm events. These build up areas include Port Stanley, St. Thomas, Talbotville and Belmont in the Kettle Creek Watershed and Port Bruce, Sparta, Aylmer and Springfield in the Catfish Creek Watershed.

Load = Conc. / m^3 x Urban area (ha) x Rain (m^3 / ha)

* The average concentration per hectare in low density (<50 people/ha) urban areas is 1.1 x 10^7 faecal coliform per cubic metre (Marsalek *et al*, 1985).
* The size of these communities was taken from 1:50 000 topographic maps.
* Annual rain which would runoff from a urban area would be 2845 m^3 per hectare.

WILDLIFE (DEER) ALGORITHM

The wildlife algorithm estimates the total annual faecal coliform loadings to watercourses due to presence of deer in the watersheds.

Load = Conc. / defecation x Av. excretion x # of deer x Delivery x # of days x # of hectares

* Concentration / defecation would be 1.59 x 10^5 faecal coliform / gram for deer (HRCA 1992).
* Average excretion per day would be 2800 grams for deer (HRCA 1992).
* Average number of deer per km^2 would be 3.5 in forested areas (Brunatti, 1993)(verified by Hunter, 1994)
* Delivery rate of 0.01 percent (Brunatti, 1993).
* Number of days is 365.
* Number of km^2 of forest cover (14% in Kettle and 15% in Catfish).

TABLE 4.1: Annual Faecal Coliform Loadings To Catfish Creek

	Bacteria Loading (fc x 10^{10})	Percentage of Total
Milkhouse	570	1.8
Livestock Access	8,400	26.3
Feedlot Runoff	700	2.2
Manure Stack Runoff	230	0.7
Manure Spreading	6,755	21.1
Winter	35	
Spring to Fall	4,000	
Liquid (Overland)	820	
Liquid (Subsurface)	1,900	
Pasture Runoff	410	1.3
Septic System Failure	13,000	4.6
Sewage Treatment	27	0.08
Urban Runoff (Towns)	1,900	5.9
Wildlife (Deer)	0.3	< 0.01

Note: Total Annual Load = 319,920,000,000,000 faecal coliform

TABLE 4.2 Annual Faecal Coliform Loadings To Kettle Creek

	Bacteria Loading (fc x 10^{10})	Percentage of Total
Milkhouse	560	1.2
Livestock Access	19,000	42
Feedlot Runoff	700	1.5
Manure Stack Runoff	160	0.4
Manure Spreading	3,790	8.4
Winter	670	
Spring to Fall	2,100	
Liquid (Overland)	240	
Liquid (Subsurface)	780	
Pasture Runoff	870	1.9
Septic System Failure	12,000	26.5
Sewage Treatment St. Thomas	2,100	4.6
St. Thomas By-passes	?	
Sewage Lagoons	97	0.2
Urban Runoff (Cities and Towns)	5,900	13.1
Wildlife (Deer)	0.41	< 0.01

Note: Total Annual Load = 452,070,000,000,000 faecal coliform

TABLE 4.3: Annual Faecal Coliform Loadings To Kettle Creek Above Dalewood Reservoir

	Bacteria Loading (fc x 10^{10})	Percentage of Total
Milkhouse	408	2.3
Livestock Access	10,330	58.8
Feedlot Runoff	396	2.3
Manure Stack Runoff	97	0.6
Manure Spreading	2,088	11.9
Winter	320	
Spring to Fall	1220	
Liquid (Overland)	126	
Liquid (Subsurface)	422	
Pasture Runoff	470	2.7
Septic System Failure	3,600	20.5
Sewage Lagoons Belmont	1.8	0.01
Urban Runoff (Belmont)	173	1
Wildlife (Deer)	0.1	< 0.01

Note: Total Annual Load = 175,620,000,000,000 faecal coliform

TABLE 4.4: Annual Faecal Coliform Loadings To Catfish Creek Above Springwater

	Bacteria Loading (fc x 10^{10})	Percentage of Total
Septic System Failure	723	66
Urban Runoff	372	34

Note: Total Annual Load = 10,950,000,000,000 faecal coliform

5.0 TRANSPORTATION AND SURVIVAL OF BACTERIA

Transportation and survival of bacteria in the watercourses from the source to the beach must be considered when determining bacterial numbers at the beaches. In the water column, bacteria survival is dependant on many factors such as temperature, nutrient levels, and sunlight. The longer the bacteria take to reach the beach area, the less will be present in the water medium. The formula below is used to determine the number of bacteria which reach the mouth of watersheds:

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

where:

- N_t = number of bacteria reaching the creek mouth
- N_O = number of bacteria entering the watercourse
- k = decay rate (table 5.2)
- t = travel time in days for the bacteria to reach the mouth (event vs. base flows)

5.1 TRAVEL TIMES (t)

Bacteria loading in the Catfish and Kettle Creek Watersheds has been divided into the categories of event flows and base flows for determining the counts at the mouth and beaches of the watersheds. It was performed in this manner since there is a greater chance of beach closures during a high flow event than during base flows, since the travel time is reduced and there are a greater influx of pollution sources. In the two watersheds there is an average of 24 storm events per year (determined from studying discharge rates in the Kettle Creek). In the Catfish and Kettle Creek watershed this causes the watersheds to swell on average for a two day period per event with the remaining days being base flows.

A delivery to the beach from winter spreading activities and lagoon discharges in the spring and fall were not calculated since these practices would not impact the beaches during the swimming season. The wildlife algorithm was not used in the die off calculations since its impact would not be measurable.

In regards to sewage by-passes, there is very limited information on overflows and by-passes at St. Thomas. Approximately twenty percent of the sewers in St. Thomas combine both stormwater and sewage (Proctor & Redfern Ltd 1992). For modelling purposes sewage by-passes were not included since information was not available for such components as the amount of rain needed to induce a by-pass, quantity of an average by-pass or the concentration of effluent which would enter the Kettle Creek. However, after large storm events, bacteria counts downstream have been elevated which seems to indicate a source (greater than other urban runoff) upstream. This would suggest that there is a problem with sewage by-pass discharges in the City of St. Thomas.

The velocity and discharge rates for Kettle and Catfish Creeks was determined from flow reading information averaged across the watersheds for both storm events and during base flows. Similarly, for Dalewood and Springwater Reservoir, the average velocities and discharges were determine in the watershed above these reservoirs. This information was collection weekly, in conjunction with water sampling and is presented in table 5.1.

Table 5.1: Average Velocity and Discharge Figures for the Catfish and Kettle Creek Watersheds

	CATFISH		KETTLE	
	Catfish Watershed	Springwater Reservoir	Kettle Watershed	Dalewood Reservoir
Average Creek Velocity (km/day)				
Event flow	13	6.5	17.3	12
Base flow	3.9	2.0	5.2	3.1
Discharge Rate (m^3/s)				
Event flow	0.84	0.15	0.68	0.23
Base flow	0.10	0.07	0.08	0.09
Discharge (Daily) (m^3)				
Event flow	72,500	13,000	58,700	20,000
Base flow	31,040	6,000	23,328	8,000

5.1.1 TRAVEL TIME FOR AVERAGE FARM LOCATION

Mouth of Catfish and Kettle Creek

The travel times for farm related algorithms are based on the average farm location in the watersheds. This was assumed to be ⅔ of the distance from the mouth to the head of the watershed for both Catfish and Kettle Creeks. This assumption was used because the vast majority of farms are located in the upper half of the watersheds. In Catfish Creek the average farm location would be 32 km from the mouth and in Kettle Creek it would be 42 km away. The travel times from the average farm location to Port Bruce and Port Stanley are outlined in tables 5.2 and 5.4. In the Catfish Creek, it would take about 2.5 days for bacteria to travel during event flows and 8 days for base flows. The Kettle Creek Watershed's travel time is 3 days for event flows and about 9 days during base flows.

In the Kettle Creek Watershed the Dalewood Reservoir was taken into consideration when determining these flows. It was assumed that half the water flowed through the Dalewood Reservoir and half by way of Dodd's Creek into the main branch of Kettle Creek. This was confirmed by discharge reading taken at the mouth of Dodd's Creek and in Kettle Creek above the reservoir. The travel time across the Dalewood Reservoir was determined through the use of die off rates of bacteria, from samples taking in the summer of 1992. These results showed that average travel time from Hwy. 48 to the mouth of the reservoir would be 3.7 days at base flow conditions and 1.9 days during moderate event flows.

Dalewood Reservoir

The travel times for farm related algorithms above Dalewood Reservoir are based on the average farm location. The farms are evenly distributed above the reservoir therefore the average farm location was assumed to be half the distance from the reservoir to the head of Kettle Creek. The average farm location above the reservoir was therefore 15 km and the travel time is outlined in table 5.5.

Springwater Conservation Area

There are no livestock farms present in the drainage basin above the Springwater Conservation Area.

5.1.2 TRAVEL TIMES FOR HOUSEHOLD SEPTIC SYSTEMS AND URBAN RUNOFF

Mouth of Catfish and Kettle Creek

Rural house locations within the watersheds were shown from topographic maps to be similar to the farms with a greater number located in the upper half of the watershed. Therefore, the average house location was assumed to be ⅔ of the way from the mouth to the headwaters. The close proximity of some communities to the beaches, however were not being adequately addressed using this method. Therefore, villages and hamlets were studied on their own. These communities included Port Bruce, Sparta, Orwell, Springfield, and Brownsville in the Catfish Creek Watershed and Union, Talbotville and Glanworth in the Kettle. The travel times for bacteria derived from faulty septic systems in these communities are shown in table 5.2 and 5.4.

The sewage treatment plant in St. Thomas discharges treated effluent to the watercourse on a daily basis. During base flows, a 4-day period is required for bacteria to move from the sewage treatment plant to the mouth of Kettle Creek. This is shortened to 1.2 days during an event (table 5.4).

The travel times of bacteria from different urban areas must be address separately for each community. The travel times are based on the average flow reading shown in table 5.1. The areas in the Catfish watershed include Port Bruce, Sparta, Aylmer and Springfield. Communities identified in the Kettle watershed include Port Stanley, St. Thomas, Talbotville and Belmont. The travel times from these locations can be seen in tables 5.2 and 5.4.

Dalewood Reservoir

Approximately ⅓ of the homes within the watershed are located above the Dalewood Reservoir. These homes are evenly distributed above the reservoir therefore the average home location was assumed to be half the distance (15 km) from the reservoir to the headwaters. Travel times to the reservoir for farm related algorithms are outlined in table 5.5.

Urban runoff above the Dalewood reservoir would be derived from one source, the town of Belmont, located 16 km above the reservoir. The travel time for urban runoff from Belmont is outline in table 5.5. and would be approximately one day.

Springwater

Bradley Creek drainage basin above Springwater Conservation Area contains 143 rural homes as well as 120 hectares of urban area which are affecting water quality for the reservoir. Bradley Creek drains the south section of the town of Aylmer during storm events. The homes are relatively evenly distributed throughout the watershed and as a result the centre point was taken 4.5 km above Springwater. The travel times for septic system and urban runoff algorithms are outlined in table 5.3.

Table 5.2: Average Travel Times to Port Bruce for Bacteria loadings from Farms, Homes and Urban Areas.

	EVENT FLOW Travel Time in Days	BASE FLOW Travel Time in Days
Average Farm	2.46	8.21
Household Septic		
Rural Homes	2.46	8.21
Port Bruce	0	0
Sparta	1.08	3.59
Orwell	2.3	7.7
Brownsville	3.5	11.5
Springfield	2.8	9.5
Urban Runoff		
Port Bruce	0	
Sparta	1.08	
Aylmer	2.9	
Springfield	3.92	

Table 5.3: Average Travel Times to Springwater for Bacteria loadings from Homes and Urban Areas

	EVENT FLOW Travel Time in Days	BASE FLOW Travel Time in Days
Average Farm	N.A.	N.A.
Household Septic Rural Homes	0.69	2.3
Urban Runoff Belmont	0.69	

Table 5.4: Average Travel Times to Port Stanley for Bacteria loadings from Farms, Homes and Urban Areas.

	EVENT FLOW Travel Time in Days	BASE FLOW Travel Time in Days
Average Farm	3.17	9.07
Household Septic		
Rural Homes	3.17	9.07
Union	0.46	1.54
Talbotville	1.52	5
Glanworth	2.3	7.7
St. Thomas Sewage Treatment	1.21	4.03
Urban Runoff		
Port Stanley	0	
St. Thomas	1.21	
Talbotville	1.52	
Belmont	2.37	

Table 5.5: Average Travel Times to Dalewood Reservoir for Bacteria loadings from Farms, Homes and Urban Areas.

	EVENT FLOW Travel Time in Days	BASE FLOW Travel Time in Days
Average Farm	125	4.8
Household Septic Rural Homes	1.25	4.8
Urban Runoff Belmont	1.33	

5.2 DECAY RATES (k)

Bacteria are subject to a number of conditions that will result in a decrease in their numbers during travel. Several studies were undertaken by Conservation Authorities participating in the Rural Beaches Program to determine the decay rates of bacteria suspended in the water column. The results of these studies indicate a variety of decay rates due to varying conditions across the Province. Table 5.3 summaries the provincial data on faecal coliform decay rates (Young, 1990). For the purposes of this CURB report, 0.3 logs/day was used to determine bacteria die off during the recreational swimming season (May to October).

Table 5.6: Seasonal Faecal Coliform Decay Rates in logs/day

Spring	0.26
Summer	0.35
Fall	0.26
Winter	0.23

5.3 LOADINGS TO THE WATERSHED MOUTH / BEACHES

The beaches studied during the Clean Up Rural Beaches Program are at Port Bruce and Springwater Conservation Area in the Catfish Creek Watershed and Port Stanley and Dalewood Reservoir in the Kettle Creek Watershed. The beach at Port Bruce is found to the west of the Catfish Creek mouth on the shore of Lake Erie. The Springwater Conservation Area Beach is located southwest of Aylmer and along Bradley Creek. There are two beaches in Port Stanley , Little Beach and Main Beach. Main Beach is on Lake Erie located to the west of the Kettle Creek mouth and Little Beach is to the east and recessed in from the creeks mouth. Dalewood Reservoir is found along the main branch of Kettle Creek in the City of St. Thomas.

The bacteria sources located in the watersheds are address separately with their specific die off rate dependent on the travel time required to reach the creek's mouth. For the purposes of this report, the bacteria loading is divided into continuous versus event sources.

The loading to the beaches was taken on a daily basis so that verification of these numbers could be performed with actual water quality results taken. The daily discharges were only taken between May to October (180 days), when beaches were open and water sampling was performed. Through studying discharge rates in the Kettle Creek, it was determined that there are 14 events during the CURB modelling period.

Continuous annual discharge sources include milkhouse washwater, septic systems, and sewage treatment plants. The total annual discharge from these sources must be divided by the 365 days in the year. For livestock access, the number of average access days was determined from the farm survey for each watershed and the daily loading was derived from this. The number of access days in the Catfish Watershed averaged 190, and 205 days was determined to be the average for the Kettle. For runoff sources such as feedlot/barnyard, manure stack, manure spreading, pasture runoff and urban the annual loadings to the watersheds are divided into the average number of storm events which occur annually. This was determined to be 24 events annually and 14 events during the 180 day modelling period.

The relative bacteria loadings to the Catfish Creek mouth, the Kettle Creek mouth, Springwater Conservation Area and Dalewood Reservoir are outlined below in Tables 5.6 through 5.9 for base and event flows. The total daily loadings in the Catfish watershed were determined to be 2.43×10^{10} faecal coliform during base flows and 103.7×10^{10} amid event flows. The Kettle watershed would produce on average 1.34×10^{10} faecal coliform during base flows and 164.8×10^{10} during event flows.

Table 5.7: Relative Daily Bacteria Loading to Catfish Creek Mouth during base and event flows

	BASE FLOWS (percentage)	EVENT FLOWS (percentage)
Milkhouse washwater	0.2	0.3
Septic (Rural)	3.8	4.7
Septic (Towns)	89.6	3.4
Livestock Access	6.4	7.8
Feedlot Runoff		5.1
Manure Stack Runoff		1.6
Manure Spreading		49.6
Pasture Runoff		3
Urban Runoff		24.5

Note: Base Flow Faecal Coliform Loading (daily) 2.43×10^{10}
Event Flow Faecal Coliform Loading (daily) 103.7×10^{10}
Base Flow Faecal Coliform Loading (167 days) 406×10^{10}
Event Flow Faecal Coliform Loading (13 days) 1452×10^{10}

Table 5.8: Relative Daily Bacteria Loading to Springwater Reservoir during base and event flows

	BASE FLOWS (percentage)	EVENT FLOWS (percentage)
Septic (Rural)	100	11.4
Urban Runoff		88.6

Note: Base Flow Faecal Coliform Loading (daily) 0.4×10^{10}
Event Flow Faecal Coliform Loading (daily) 10.8×10^{10}
Base Flow Faecal Coliform Loading (167 days) 67×10^{10}
Event Flow Faecal Coliform Loading (13 days) 140×10^{10}

Table 5.9: Relative Daily Bacteria Loading to Kettle Creek Mouth during base and event flows.

	BASE FLOWS (percentage)	EVENT FLOWS (percentage)
Milkhouse washwater	0.4	0.2
Septic (Rural).	8.2	3.5
Septic (Towns)	39	0.9
Livestock Access	25.6	10.7
Sewage (St. Thomas)	26.8	1.5
Feedlot Runoff		3.4
Manure Stack Runoff		0.8
Manure Spreading		18.4
Pasture Runoff		4.2
Urban Runoff		56.5

Note: Base Flow Faecal Coliform Loading (daily) 1.34×10^{10}
Event Flow Faecal Coliform Loading (daily) 164.8×10^{10}
Base Flow Faecal Coliform Loading (167 days) 224×10^{10}
Event Flow Faecal Coliform Loading (13 days) 2307×10^{10}

Table 5.10: Relative Daily Bacteria Loading to Dalewood Reservoir during base and event flows.

	BASE FLOWS (percentage)	EVENT LOWS (percentage)
Milkhouse washwater	1.8	0.6
Septic	16.1	5.1
Livestock Access	82.1	25,8
Feedlot Runoff		8.4
Manure Stack Runoff		2.1
Manure Spreading		44.5
Pasture Runof		10
Urban Runoff		3.5

Note: Base Flow Faecal Coliform Loading (daily) 2.21×10^{10}
Event Flow Faecal Coliform Loading (daily) 82.1×10^{10}
Base Flow Faecal Coliform Loading (167 days) 369×10^{10}
Event Flow Faecal Coliform Loading (13 days) 1148×10^{10}

5.4 VERIFICATION

It is important to determine the accuracy of the CURB model vs. the actual water sample results which were collected at the creek mouths. The modelling process cannot be expected to exactly match the collected water sampling results due to the limited data which was collected and the bacteria dynamics in the environment.

The method used in this report, to compare the model predictions versus water samples collected was to convert the bacteria numbers in the creeks to a concentration (faecal coliform per 100 ml). This was performed by taking the model loading on a daily basis divided by the discharge at the mouth of the stream on a daily basis. Since the report is concerned about both base and event flows the faecal coliform concentrations at these times were calculated separately.

Table 5.11: Faecal Coliform Loadings to Watershed Mouths Predicted versus Actual Bacteria Counts

	Faecal Coliform per 100 ml	
	Model Prediction	Actual Bacteria Count
Port Bruce		
Base Flow	783	106
Event Flow	1,439	828
Springwater		
Base Flow	67	204
Event Flow	830	1,582
Port Stanley		
Base Flow	94	290
Event Flow	2,793	4,040
Dalewood Reservoir		
Base Flow	276	168
Event Flow	4,105	3,884

Conclusions of Verification

The actual bacteria counts used in table 5.10 were located at the nearest sampling location upstream of the watershed (beach) mouth and therefore may not include all the bacteria sources that are being included in the modelling number. Also, in some cases the die-off of bacteria to the watershed mouth could cause the actual count to be slightly higher than the modelling result. However, the concentrations predicted by the CURB model are plus or minus one order of magnitude of the actual sample concentration at the watershed mouths. This has been th standard which other CURB Programs have used, to indicate that the model is reasonable (Quinlan, 1992)

Port Bruce

The water sampling location used in the verification is located 4 km above Port Bruce. This has been shown to produce lower counts than that of the CURB model especially during base flows (106 actual vs. 783 predicted). This can be attributed to septic systems concerns in Port Bruce that are not figured into the actual count.

Springwater

The water sampling station for the Springwater Reservoir is located upstream of the mouth of Bradley Creek by about 2 kilometres. The actual counts were approximately twice the modelled results at the watershed mouth. This could be the result of many ponds located along Bradley Creek used for irrigation which are constantly being recharged during the summer months. This will have the effect of increasing the travel times during base and event flows and also eliminating bacteria which would otherwise enter these ponds from the watercourse.

Port Stanley

The water sampling location for the mouth of Kettle Creek is located at the north end of Port Stanley at the Warren Street Bridge. The model results are quite close in the base and event flow due to the close proximity of the creek mouth and the water sampling site.

Dalewood Reservoir

Dalewood reservoir water sampling station is located upstream approximately 4 kilometres from the mouth of the reservoir. The water sampling location takes into consideration most of the bacterial sources located above the reservoir. The concentration of bacteria at this station was quite similar to the model prediction results as shown on table 5.10.

6.0 REMEDIATION COSTS AND COST EFFECTIVENESS

Cost estimates were calculated for each source which was identified through the CURB modelling. This was performed on a watershed bases to determine the cost effectiveness of performing different remediation works. For many of the sources, the construction of a structure will alleviate the problem, however others require a change in management. The approximate number of pollution sources in need of repair are listed in table 6.1.

6.1 ESTIMATION OF COSTS

Septic System Replacement / Repair

The north part of both the Catfish Creek and Kettle Creek Watersheds have areas of clay soils which will require the use of raised bed systems. It has been estimated that approximately 15% of the homes in the watershed would require raised bed systems at a cost of $15,000 (Taylor, 1994). Raised bed systems for domestic homes have only been required for the past 2 years since the initiation of percolation tests to determine infiltration rates of leachates. The remaining 85% of the household septic systems would have a trench bed system which would range in price from $3,500 to $5,000. The watershed costs for replacement of faulty septic systems would be based on multiplying the numbers of faulty septic systems by the cost of replacement.

The numbers of faulty septic systems, for the Dalewood Reservoir north of St. Thomas, requiring raised beds would be approximately 28% of the total systems needing replacement due to the higher clay content of the north part of the Kettle Creek watershed. Septic systems installed above Springwater Reservoir would be trench weeping beds since the soil is predominately sandy loam.

TABLE 6.1: Pollution Sources Needing Remediation

	Number of Repairs Required			
	Catfish Watershed	Springwater Reservoir	Kettle Watershed	Dalewood Reservoir
Septic System Replacement/Repair	622	35	521	156
Fencing Livestock				
Access Sites (Dairy & Beef)	26	0	41	23
Total Length - both sides (feet)	93,640	0	140,320	78,200
Milkhouse Treatment System				
Dairy Farms with no Treatment	28	0	29	21
Liquid Manure Pits				
Farms with < 240 day storage	24	0	9	5
Containment for Feedlot / Manure Stacks				
Feedlots only Contributing	23	0	8	6
Manure Stacks only Contributing	11	0	10	6
Feedlot and Manure Stack both Contributing	40	0	28	18

Note: Numbers are estimates based on extrapolating information collected during surveys

Fencing Cattle

Water quality problems due to livestock access in both the Kettle and Catfish watersheds has been shown to be a significant source of bacterial pollution. The capital costs vary depending on whether both sides of the creek need to be fenced, if an alternative watering source is needed or if a creek crossing is required.

The cost for fencing varies depending on the materials used. The Clean Up Real Beaches Program will only fund to the cost of page wire fencing which is approximately $ 2.50 per foot (Briggs, 1994). This will be used as the estimated cost for fencing projects in the watersheds. It is assumed that due to the meandering nature of most creek and drains that most farmers would choose to fence both sides of the creek. With this being the case, the farmers would then have to install low flow crossings for a cost of about $ 5,000 or more per site. An alternative watering device (mechanical nose pump) would be required for only about 30% of the farms since the majority of the farmers water their livestock at the barns. The cost of a mechanical nose pump would be approximately $ 400 (Briggs, 1994).

Milkhouse Washwater Treatment Systems

Milkhouse washwater can be treated in either a treatment trench with septic tank or by creating a liquid storage tank which can be land applied. The liquid storage tank can be in combination with a liquid manure storage or barnyard runoff storage which would make the project more cost effective. In the Catfish Creek watershed, 28 washwater treatment systems are required and approximately 29 in the Kettle Creek watershed.

The treatment trench system with septic tank will cost approximately $ 4,000 to install (Briggs, 1994). Work is beeping performed to determine the effectiveness of these systems through the CURB Program.

A liquid concrete pit to store milkhouse washwater will have to be sized for 240 day storage based on the volume of washwater produced per day. The average pit size required for both Catfish and Kettle Creek watersheds would be 8 foot deep x 40 foot in diameter. The manure pit cost would be approximately $13,000 with a pump costing $2,000 (Loeffler, 1994). Regulations require a 1.5 metre safety fence which costs on average $42 / metre, or $ 1,600 per washwater storage tank on all open liquid manure tanks.

Liquid Manure Pits

Many farms surveyed with liquid manure systems did not have 240 day storage which is felt to be adequate by the CURB Program to prevent over-spreading or untimely application of manure. In the Catfish CURB study watershed 24 farms would need additional storage and 9 farms in the Kettle watershed.

In the Catfish watershed 7 dairy farms required on average an additional 100,000 gallons of storage at a cost of $ 20,000 each and 17 hog operations needed and 192,000 gallons of storage which would cost approximately $ 24,000 for an in-ground circular pit. Two dairy operations in the Kettle watershed would need an additional 50,000 gallons of storage and 7 hog farms would require on average 130,000 gallons, the costs would be $ 15,000 and $22,000 respectively per site.

In the case of established operations with liquid manure the farmers will already have a pumping system present and therefore the pumps cost was not included in the cost estimate. On average, Safety Fencing will cost $ 2,200 per storage.

Solid Manure Storages and Runoff Containment Systems

Ideally, the best system for operations which are presently solid manure based would be to retain their solid manure but have liquid runoff containment from the manure pile and barnyard. This would decrease the risk of tile contamination which has been shown to be a problem in totally liquid systems.

The solid manure storage would consist of a concrete pad with metre high walls on three sides with runoff from this area collected in a liquid pit. The average cost of concrete pad would be $ 21.60 per m^2 and concrete walls cost approximately $ 82 per m^3 (Hilborn, 1990). The average pad size required for the Catfish watershed would be 296 m^2 and 320 m^2 for the Kettle watershed.

The liquid runoff containment system must be sized for 240 day storage of runoff from both the manure pad and the barnyard/feedlot area. The average size varies depending on the watershed and livestock type which is present. The price of the open liquid runoff varies from $13,000 to $17,000 depending on the size of storage required. Additional, costs include a manure pump at $2,000, and Safety Fencing at about $2,200.

For cases where the manure pile is only the contributing and there is no feedlot area where runoff is occurring, the best alternative would be to install a roofed manure storage. The average cost for such a system, used for a 40 head dairy operation or 50 head beef operation would be approximately $30,000 (Robinson, 1994). This would be a cement storage with 6 foot walls on three sides, with sloped floor and roof.

St- Thomas Stormwater By-passes

The City of St. Thomas meets the MOEE guidelines of "no dry weather discharge" from sewers in the city's system. The city however has 20% combination storm and sanitary sewer system. During storm events the combined systems will overflow to storm sewers and by-pass the sewage treatment plant. These by-passes occur at different rainfall amounts depending on the sewer's capacity and other factors.

The cost of replacing these combination sewers with a separate storm and sanitary system would be estimated at $ 40 million (Proctor and Redfern 1992).

TABLE 6.2: Costs Of Watershed Remediation Projects

	Costs of Repairs Required			
	Catfish Watershed	Springwater Reservoir	Kettle Watershed	Dalewood Reservoir
Septic System Replacement/Repair				
Low Estimate	3,246,000	122,500	2,720,500	810,500
High Estimate	4,040,000	175,000	3,385,000	1,010,000
Fencing Livestock				
Total Cost	393,300	0	601,600	336,300
Milkhouse Treatment System				
Treatment Trench System (Low)	112,000	0	116,000	84,000
Concrete Manure Pit & Pump (High)	464,800	0	481,400	348,600
Liquid Manure Pits				
Additional Storage	602,800	0	203,800	114,000
Containment for Feedlot / Manure Stacks				
Feedlots only Contributing (Concrete Storage & Pump)	452,600	0	153,600	115,200
Manure Stacks only Contributing	330,000	0	300,000	180,000
Feedlot and Manure Stack both Contributing	1,026,000		766,600	485,600
Correction of St. Thomas By-passes			40,000,000	
Total (Least Expensive)	6,162,700	122,500	44,862,100	2,125,600
Total (Most Expensive)	7,309,500	175,000	45,892,000	2,589,700
Grant Required if all Remedial Measures Require Maximum Grant	2,820,000	70,000	2,257,000	1,067,000

6.2: COST EFFECTIVENESS OF REMEDIATION ACTION

The method used to determine the cost effectiveness of any remedial measure would be to take the total watershed cost for each source, divided by the number of faecal coliform produced by that source. In the case of liquid manure pits an arbitrary effectiveness of 70% was chosen since adequate storage does not ensure that timely and proper application rates are used. Table 6.3 to 6.6 outlines the cost to remove 10 billion faecal coliform bacteria by the different remediation works proposed in the CURB watersheds.

TABLE 6.3: Cost-effectiveness Of Remedial Measures In The Catfish Creek Watershed

Remedial Structure	Faecal Coliform Load (x 10^{10})	% of the Faecal Coliform Removed	Total Costs	$ to remove 10 billion F. Coliform
Septic System Replacement				
Low Estimate	13,000	100	3,246,000	250
High Estimate	13,000	100	4,040,000	310
Fencing Livestock Fence (2 sides), Culvert, etc	8,400	100	393,300	47
Milkhouse Treatment System				
Treatment Trench System	570	100	112,000	197
Concrete Pit & Pump	570	100	464,800	815
Liquid Manure Pits Additional Storage	2720*	70	602,800	317
Containment of Feedlot / Manure Stacks	930	100	1,808,600	1,945

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

TABLE 6.4: Cost-effectiveness Of Remedial Measures In The Catfish Creek Watershed Above Springwater

Remedial Structure	Faecal Coliform Load (x 10^{10})	% of the Faecal Coliform Removed	Total Costs	$ to remove 10 billion F. Coliform
Septic System Replacement				
Low Estimate	723	100	122,500	170
High Estimate	723	100	175,000	242

TABLE 6.5: Cost-effectiveness Of Remedial Measures In The Kettle Creek Watershed

Remedial Structure	Faecal Coliform Load (x 10^{10})	% of the Faecal Coliform Removed	Total Costs	$ to remove 10 billion F. Coliform
Septic System Replacement				
Low Estimate	12,000	100	2,720,500	227
High Estimate	12,000	100	3,385,000	282
Fencing Livestock				
Fence (2 sides), Culvert, etc	19,000	100	601,600	32
Milkhouse Treatment System				
Treatment Trench System	560	100	116,000	207
Concrete Pit & Pump	560	100	481,400	860
Liquid Manure Pits				
Additional Storage	1020*	70	203,800	285
Containment of Feedlot / Manure Stacks	860	100	1,220,200	1,420

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

TABLE 6.6: Cost-Effectiveness Of Remedial Measures In The Kettle Creek Watershed Above Dalewood Reservoir

Remedial Structure	Faecal Coliform Load ($x\ 10^{10}$)	% of the Faecal Coliform Removed	Total Costs	$ to remove 10 billion F. Coliform
Septic System Replacement				
Low Estimate	3,600	100	810,500	225
High Estimate	3,600	100	1,010,000	280
Fencing Livestock				
Fence (2 sides), Culvert, etc	10,330	100	336,300	33
Milkhouse Treatment System				
Treatment Trench System	408	100	84,000	206
Concrete Pit & Pump	408	100	348,600	854
Liquid Manure Pits				
Additional Storage	548*	70	114,000	297
Containment of Feedlot / Manure Stacks	493	100	780,800	1,583

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

6.3: COST EFFECTIVENESS RESULTS

Livestock access restriction proved to be the most cost effective remedial measure in both the Catfish Creek and Kettle Creek Watersheds. The cost to remove 10 billion faecal coliform from the creeks would be about $33 in Kettle and $47 in the Catfish Creek Watershed. This cost includes page wire fencing on both sides, a low flow culvert for crossings, and for 30% of the projects an alternative water supply. The problem must be solved not only through grant assistance in CURB but by education. Many farmers are reluctant to install fencing, since there is a loss of pasture land and there is also problems associated with floodwaters removing fences.

Milkhouse treatment trench systems would be the second most cost-effective practice which could be installed in both watersheds with an average cost of about $200 to remove 10 billion faecal coliform bacteria. However, if a open liquid pit was installed to capture the milkhouse waste the costs would increase to $830.

Domestic Septic Systems is also a cost-effective practice at approximately $225 to $300. Total remedial costs would range from $6 million to $7.3 million to install new systems within both watersheds. In some cases, a complete new system may not be required if proper upgrading is undertaken. In these situations, remedial costs would be reduced.

Additional liquid manure storages will also be cost-effective with typical costs in the range of $300 to remove 10 billion faecal coliform bacteria based on a 70% effectiveness rate. However, education is an important tool, as well as additional storage since manure, spreading practices can still have a large bearing on bacterial pollution.

The final remedial measure would be the containment of feedlot and manure stack runoff which would cost approximately $1,600/10 billion faecal coliform. The problem must be addressed on a site by site basis since some manure stacks and feedlots are polluting significantly to warrant remedial measures.

If the CURB Grant is given to correct each problem and the maximum grant rate is given, the total CURB allocation in the Catfish Creek Watershed would be $ 2, 820,000 and in the Kettle Creek Watershed $ 2,257,000.

7.0: IMPLEMENTATION STRATEGIES

The two Conservation Authorities are prepared to move into the Implementation Phase of the CURB Program and provide facilitation services for the program. The Catfish Creek and Kettle Creek Conservation Authorities will be administering the CURB Program and will be overseen by a Technical Steering Committee which will review and prioritize applications. This committee will be represented by the CCCA, KCCA, OMAF, MOEE, Health Unit and local OSCIA.

The goal of the Implementation Phase will be to improve surface water pollution problems through education and providing financial incentives. Within the guidelines of this voluntary program, the Technical Steering Committee will target the grant to those sources which contribute the greatest amount of bacteria and are the most cost effective to install (see tables 6.3 to 6.6).

Catfish Creek CURB Watershed

In the Catfish Creek watershed there are two beach areas that will be addressed separately for CURB remediation measures. These include the beaches at Port Bruce and Springwater Reservoir.

Springwater Reservoir

In the Springwater Reservoir watershed the problems associated with bacteria loadings include both urban runoff and septic systems. For the purposes of the CURB Program the septic system problems will be addressed. The Septic Systems are 100% of the problem during base flows and 12% during event flows. At the reservoir mouth the predicted base flow concentration is 67 faecal coliform and 830 during event flows. The actual bacteria counts at the sampling station upstream on Bradley Creek are approximately 204 during base flows. These bacteria numbers can be decreased through the installation of proper septic systems upstream of the Springwater Reservoir. In addition, studies should be conducted in Aylmer to determine the extent and feasibility of urban runoff control to curb event flow problems.

Port Bruce Beach

According to the CURB modelling at the mouth of Catfish Creek, the bacteria counts are approximately 783 faecal coliform per 100m1 during base flows and 1439 during event flows. Therefore there is a significant problem both in continuous and runoff sources of bacterial pollution.

Continuous sources that have been shown to impact the beach area to the greatest extent would be faulty septic systems and livestock access. The septic systems in the communities of Port Bruce, Sparta and rural areas are contributing 93% of the bacteria to the mouth Catfish Creek. Because of the close proximity of beach areas to the failed systems in rural homes, these septic systems should be targeted for remediation measures. The installation of proper septic systems will help alleviate the base flow concern at the Port Bruce Beaches.

During event flows the bacterial problems are distributed between rural homes and livestock related problems. The bacterial problems are distributed between septic (8.1%), livestock access (7.8%), feedlot/barnyard runoff (6.7%) and manure spreading (49.6%). With bacteria counts in excess of 1400 faecal coliform / 100ml during event flows there is a need to address runoff type structures such as solid manure storages with runoff containment and additional storage for liquid manure. This would allow timely application of manure to be carried out. Livestock access is a major concern both during base and event flows and should be targeted for remediation measures since the cost to fence cattle out of the creeks is relatively low.

In summary, remediation measures in the Catfish Creek watershed should include fixing of faulty septic systems, fencing of waterways to prevent livestock access (low cost), and installation of proper manure storages based on extend of bacterial pollution at the specific site.

Kettle Creek CURB Watershed

In the Kettle Creek watershed there are two beach areas that will be addressed separately for CURB remediation measures. These are the beaches at Port Stanley and Dalewood Reservoir.

Dalewood Reservoir

As outlined in chapter 1, Dalewood Reservoir has not been used for swimming since the 1970's, but there is interest in improving the water quality and restoring recreation features of the reservoir. The reservoir has been unsafe for swimming because of high bacteria counts and sediment coming downstream which degraded the water quality.

According to the CURB modelling at the mouth of Kettle Creek at the Dalewood Reservoir, the model predicted bacteria counts are approximately 276 faecal coliform per 100ml during base flows and 4105 during event flows. Therefore, there is a significant problem both in continuous and runoff sources of bacterial pollution and it is understandable that the reservoir is closed for swimming.

The greatest pollution sources during base flows is livestock access (82%) and rural septic systems (16.1%). These must be addressed during implementation since water quality in the reservoir is above the MOEE standard of 100 E. coli / 100ml in both base and event flow situations.

When there is a storm event, the bacteria level significantly escalates due to not only runoff sources, but also the same continuous sources outlined above, since the travel time is reduced. The breakdown of these sources include manure spreading (44.5%), livestock access (25%), feedlot / manure stack runoff (10.5%) and septic (5.1%). In regards to manure spreading, education is the key to decreasing this problem; however in many instances increasing the manure storage size will help to reduce the practice of untimely spreading. Livestock access restriction should be promoted in the Kettle Creek watershed due to the low costs and significant improvement in water quality that can be achieved. Manure storages and barnyard runoff containment systems have to be evaluated on a site by site basis since the costs of these structures are significant. As a grant eligible measure septic systems in this area should be corrected since they are a continuous source of pollution.

Port Stanley Beaches

According to the CURB modelling at the mouth of Kettle Creek at Port Stanley, the model predicted bacteria counts are approximately 94 faecal coliform per 100ml during base flows and 2793 during event flows. In this case, the water sampling location is very close to the creek mouth and the results show slightly higher counts especially during base flows (290 *E. coli* / 100ml).

The greatest rural related pollution sources during base flows is rural septic systems (47.2%) and livestock access (25.6%). When there is a storm event, the bacteria level increases significantly due to runoff sources, and also the same continuous sources outlined above. The breakdown of these sources include manure spreading (18.4%), livestock access (10.7%), feedlot / manure stack runoff (4.9%) and septic (4.4%).

The breakdown of the pollution sources are similar to Dalewood Reservoir in their relative contributions. The basis recommendations will therefore be similar to the aforementioned subwatershed of Dalewood Reservoir. Livestock access restriction should be highly promoted in the Kettle Creek watershed due to the low costs. Septic systems should also be funded to alleviate the bacterial and health concerns of this continuous flow problem. The costs of these structures are significant and as a result the evaluation of manure storages and barnyard runoff should be performed on a site by site basis.

8.0: RECOMMENDATIONS

The following are the recommendations of the CCCA/KCCA CURB Study Program:

1. That the Catfish Creek Conservation Authority and Kettle Creek Conservation Authority participate in the five year Implementation Phase of the Ontario Ministry of Environment and Energy's Clean Up Rural Beaches Program to address water quality problems which were identified during the study phase.

2. That the CCCA and KCCA CURB Program provide information to landowners of the grant assistance available to repair or replace faulty septic systems to expand manure storage facilities, to restrict livestock access to watercourses, and to establish a milkhouse washwater disposal system. Local organizations such as the OMAF, Elgin County Health Unit, OSCIA, and member municipalities should be notified of about the CURB Program and the grants which are available to the local landowners.

3. The CCCA and KCCA CURB Program must educate landowners on the benefits of improving and maintaining water quality through the use of technical factsheets, media releases, meetings, and information days.

4. The CURB Program should initiate demonstration projects which show innovative approaches to improving water quality in the CURB implementation areas.

5. CCCA and KCCA, in co-operation with the Ministry of Environment and Energy will continue to monitor water quality in the CURB Study areas as well as monitoring of local quality before and after projects are initiated to improve water quality.

6. Investigate the feasibility of re-establishing Dalewood Reservoir as a swimming area through the improvement of water quality in regards to bacteria contamination.

7. The efforts undertaken by the agricultural community be promoted throughout the watersheds to increase the awareness of urban populations.

8. Due to possible budget reductions in the future, the initiation of user fees for applications can be a possible source of revenue to offset the operation costs of the program.

9. Creation of a Freedom of Information Policy specifically geared towards the CURB Program.

8.1: ASSOCIATED RECOMMENDATIONS

Recommendations which will improve water quality in the Catfish Creek and Kettle Creek Watersheds but are not eligible for CURB grant assistance.

1. That the City of St. Thomas continue to actively seek provincial grant support to rectify sewage bypasses of the Sewage Treatment Plant.

2. That municipalities require all new development have an engineer's stormwater management plan. Existing stormwater systems should be evaluated to determine the extent of their bacterial load and the possibility of installation of remedial works.

3. That the farmers in the watersheds work together with the Conservation Authorities, OMAF, MOEE, and OSCIA to create comprehensive Farm Management Plan for their operation. This plans should include methods of soil and water conservation and preservation in regards to all farm pollution sources.

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10.0 APPENDICES

APPENDIX A

WATER QUALITY SAMPLING DATA 1993
(BACTERIAL AND CHEMICAL)

KETTLE CREEK WATERSHED - BACTERIAL
SITE K1 - KETTLE CREEK, LAKE WHITTAKER

DATE	TEMP °C	D.O.	E. COLI	FECAL STREP.	PSEUDO AERU
JUN 10/93 *	17.2		200	830	108
JUN 17/93	18.5		170	220	4
JUN 24/93 *	18.5	8.5	320	520	68
JUL 01/93	14.3	9.4	270	490	4
JUL 08/93	21.5	9.4	300	1130	4
JUL 15/93	18.4	10.0	100	710	4
JUL 22/93	19.2	10.9	70	590	4
JUL 29/93	19.6	7.9	160	580	4
AUG 05/93	16.2	8.6	230	1090	4
AUG 12/93	19.2	7.9	110	830	4
AUG 19/93	18.8	10.5	160	1210	4
AUG 26/93	18.1	7.0	60	880	4
SEP 02/93	16.4	6.8		1000	8
SEP 09/93	14.8	9.5	310	2800	4
SEP 14/93	18.2	6.8	1500	3800	4
SEP 23/93	13.5	8.0	300	800	4
SEP 28/93 *	10.3	9.8	470	3900	-8
OCT 07/93	13.4	9.1	20	470	4
OCT 14/93					
OCT 21/93 *	11.2	9.4		1500	104
OCT 28/93	7.2	12.7	130	230	4
MIN	7.2	6.8	20	220	4
MAX	21.5	12.7	1500	3900	108
AVG	16.2	9.0	271	1179	18
GEOM			180	873	7

SITE K2 - KETTLE CREEK, SIDEROAD S. DORCHESTER

DATE	TEMP °C	D.O.	E. COLI	FECAL STREP.	PSEUDO AERU
JUN 10/93 *	17.7		1700	650	28
JUN 17/93	21.2		750	120	4
JUN 24/93 *	19.6	9.2	250	1300	20
JUL 01/93	16.0	7.8	1000	710	4
JUL 08/93	24.8	6.6	1000	450	12
JUL 15/93	22.7	9.0	520	400	48
JUL 22/93	21.0	8.8	250	550	12
JUL 29/93	22.6	7.0	380	390	4
AUG 05/93	18.7	8.5	320	470	4
AUG 12/93	22.5	9.6	60	300	4
AUG 19/93	24.3	9.6	520	630	4
AUG 26/93	23.6	8.0	290	530	4
SEP 02/93	21.4	7.3		660	4
SEP 09/93	16.3	10.2	330	2200	4
SEP 14/93	19.0	9.1	430	1900	4
SEP 23/93	13.6	7.5	310	1300	4
SEP 28/93 *	11.2	10.7	160	480	4
OCT 07/93	12.8	9.9	80	240	4
OCT 14/93	7.3	14.2	350	200	4
OCT 21/93 *	11.1	8.2	850	1480	4
OCT 28/93	7.8	8.1	140	340	4
MIN	7.3	6.6	60	120	4
MAX	24.8	14.2	1700	2200	48
AVG	17.9	8.9	485	729	9
GEOM			356	561	6

SITE K3 - KETTLE CREEK. CTY RD 48-BRIDGE

DATE	TEMP °C	D.O.	E. COLI	FECAL STREP.	PSEUDO AERU
JUN 10/93 *	18.8		3300	960	4
JUN 17/93			100	610	4
JUN 24/93 *	18.2	10.0	180	280	4
JUL 01/93	17.0	7.2	100	200	4
JUL 08/93	23.8	4.5	640	730	4
JUL 15/93	18.4	6.0	310	310	4
JUL 22/93	18.0	6.5	470	610	4
JUL 29/93	21.9	5.4	220	530	4
AUG 05/93	19.2	6.6	140	590	4
AUG 12/93	18.3	7.1	110	580	4
AUG 19/93	20.5	7.2	1600	810	4
AUG 26/93	19.5	5.5	630	640	4
SEP 02/93	17.3	7.0	170	480	4
SEP 09/93	14.5	10.1	220	1000	4
SEP 14/93	17.7	7.8	240	550	4
SEP 23/93	14.2	9.6	100	410	4
SEP 28/93 *	11.1	9.3	220	1000	4
OCT 07/93	9.9	11.8	10	180	4
OCT 14/93	5.1	12.3	70	220	4
OCT 21/93 *	11.3	15.0	110	380	4
OCT 28/93	7.5	15.0	40	180	4
MIN	5.1	4.5	10	180	4
MAX	23.8	15.0	3300	1000	4
AVG	16.1	8.6	428	536	4
GEOM			194	469	4

SITE K4 - DODOS CREEK, PAYNES MILLS

DATE	TEMP °C	D.O.	E. COLI	FECAL STREP.	PSEUDO AERU
JUN 10/93 *	19.6		3600	2300	16
JUN 17/93	17.2		400	510	4
JUN 24/93 *	19.5		590	440	4
JUL 01/93	15.2	9.4	440	350	4
JUL 08/93	22.7	5.8	480	320	4
JUL 15/93	18.9	5.6	1800	2000	4
JUL 22/93	17.1	6.7	2800	5000	4
JUL 29/93	21.6	4.6	800	1600	4
AUG 05/93	16.8	7.4	400	600	4
AUG 12/93	18.7	5.5	410	2300	4
AUG 19/93	21.1	6.2	410	650	4
AUG 26/93	20.7	5.4	1000	780	4
SEP 02/93	18.4	6.1	410	380	4
SEP 09/93	15.2	9.9	440	1000	16
SEP 14/93	17.0	6.8	410	480	4
SEP 23/93	18.3	7.8	500	380	4
SEP 28/93 *	12.3	10.5	300	440	4
OCT 07/93	10.9	10.4	440	320	4
OCT 14/93	6.6	13.0	130	120	4
OCT 21/93 *	11.8	14.8	110	170	4
OCT 28/93	8.9	12.3	110	160	4
MIN	6.6	4.6	110	120	4
MAX	22.7	14.8	3600	5000	16
AVG	16.6	8.2	761	967	5
GEOM			494	598	5

SITE K5 - DODD'S CREEK, CTY RD 25-BRIDGE

DATE	TEMP °C	D.O.	E. COLI	FECAL STREP.	PSEUDO AERU
JUN 10/93 *	19.7		310	340	4
JUN 17/93	20.3		130	220	4
JUN 24/93 *	20.3		370	260	4
JUL 01/93	17.2	9.2	170	210	4
JUL 08/93	25.2	5.7	670	590	4
JUL 15/93	20.5	6.5	260	1500	8
JUL 22/93	18.4	5.5	1100	1700	4
JUL 29/93	23.0	4.8	200	1100	4
AUG 05/93	18.7	7.9	200	300	4
AUG 12/93	19.4	7.5	100	340	4
AUG 19/93	22.0	5.6	1000	870	4
AUG 26/93	21.1	4.3	400	1000	4
SEP 02/93	19.3	6.0	130	1500	4
SEP 09/93	16.1	12.5	200	1600	4
SEP 14/93	18.5	7.1	380	1000	4
SEP 23/93	15.3	8.7	90	1100	4
SEP 28/93 *	12.6	10.6	120	320	4
OCT 07/93	10.8	9.4	30	180	4
OCT14/93	6.4	14.6	50	860	4
OCT 21/93 *	11.2	11.6	40	360	4
OCT 28/93	8.1	1.7	70	210	4
MIN	6.4	4.3	30	180	4
MAX	25.2	14.6	1100	1700	8
AVG	17.3	8.3	287	742	4
GEOM			184	564	4

SITE K6 - KETTLE CREEK, FULTON BRIDGE

DATE	TEMP °C	D.O.	E.COLI	FECAL STREP.	PSEUDO AERU
JUN 10/93 *	19.3		880	530	40
JUN 17/93	18.9		150	280	4
JUN 24/93 *	19.2		340	150	4
JUL 01/93	19.4	8.6	130	130	4
JUL 08/93	24.8	5.5	2200	380	20
JUL 15/93	20.7	7.5	37	280	4
JUL 22/93	20.5	8.9	70	100	4
JUL 29/93	23.2	10.3	200	600	8
AUG 05/93	18.8	9.3	350	140	4
AUG 12/93	21.0	8.5	150	280	4
AUG 19/93	23.1	7.5	150	320	4
AUG 26/93	22.6	6.4	90	100	4
SEP 02/93	19.6	7.7	120	330	4
SEP 09/93	16.2	10.8	890	380	28
SEP 14/93	19.5	8.2	1000	1200	8
SEP 23/93	16.0	8.4	160	160	8
SEP 28/93 *	13.2	11.2	240	440	4
OCT 07/93	12.3	11.4	30	130	4
OCT 14/93	7.6	13.9	390	100	4
OCT 21/93 *	13.6	11.4	1000	460	8
OCT 28/93	9.1	13.0	120	50	4
MIN	7.6	5.5	30	50	4
MAX	24.8	13.9	2200	1200	40
AVG	18.0	9.4	430	311	8
GEOM			252	237	6

SITE K7 - KETTLE CREEK, CTY RD. 21, PORT STANLEY

DATE	TEMP °C	D.O.	E.COLI	FECAL STREP.	PSEUDO AERU
JUN 10/93 *	19.2		400	100	4
JUN 17/93	20.7		20	60	4
JUN 24/93 *	21.8		210	120	8
JUL 01/93	19.3	8.5	200	150	4
JUL 08/93	25.7	7.0	210	300	4
JUL 15/93	20.7		430	380	28
JUL 22/93	22.3	13.2	70	190	4
JUL 29/93	24.7	8.4	100	100	4
AUG 05/93	21.2	13.2	100	900	4
AUG 12/93	22.4	15.0	110	160	4
AUG 19/93	24.7	13.0	60	110	4
AUG 26/93	23.4	11.6	50	100	4
SEP 02/93	21.2	7.0	850	220	12
SEP 09/93	17.2	9.8	280	440	12
SEP 14/93	18.6	8.6	100	150	4
SEP 23/93	14.2	7.8	120	210	4
SEP 28/93 *	13.0	10.1	150	150	4
OCT 07/93	11.7	12.3	10	60	-4
OCT 14/93	8.6	14.4	20	10	4
OCT 21/93 *	12.5	15.0	170	360	4
OCT 28/93	9.2	15.0	20	100	4
MIN	8.6	7.0	10	10	4
MAX	25.7	15.0	850	900	28
AVG	18.7	11.2	175	208	6
GEOM			103	148	5

* - High Flow Events

CATFISH CREEK WATERSHED - BACTERIAL

SITE CI - CON II YARMOUTH

DATE	TEMP °C	D.O.	E. COLI	FECAL STREP.
JUN 10/93 *	18.3		800	180
JUN 17/93	19.3		60	110
JUN 24/93 *	17.3		610	260
JUL 01/93	18.0	10.5	150	150
JUL 08/93	24.8	8.1	1000	280
JUL 15/93	21.2	8.5	340	810
JUL 22/93	20.6	8.2	180	280
JUL 29/93	23.7	7.2	140	500
AUG 05193	19.7	8.8	130	130
AUG 12/93	21.8	8.0	170	320
AUG 19/93	23.1	7.5	250	280
AUG 26/93	22.7	7.0	200	440
SEP 02/93	19.4	7.6	150	330
SEP 09/93	16.6	10.5	180	1000
SEP 14/93	18.9	8.1	150	380
SEP 23/93	15.7	8.5	230	230-
SEP 28/93 *	12.7	12.1	230	1300
OCT 07/93	12.2	13.2	20	150
OCT 14/93	8.1	15.0	10	40
OCT 21/93 *	12.5	12.4	60	160
OCT 28/93	8.5	15.0	40	150
MIN	8.1	7.0	10	40
MAX	24.8	15.0	1000	1300
AVG	17.9	9.8	243	356
GEOM			149	263

SITE C2 - BRADLEY CREEK. ROGER'S SIDE RD. S

DATE	TEMP °C	D.O.	E.COLI	FECAL STREP.
JUN 10/93 *	18.3		390	200
JUN 17/93			190	210
JUN 24/93 *	19.7	9.0	410	320
JUL 01/93	16.6	7.6	160	560
JUL 08/93	25.6	6.3	330	690
JUL 15/93	21.7	5.1	430	700
JUL 22/93	21.6	5.0	420	580
JUL 29/93	24.7	6.8	700	1000
AUG 05/93	20.2	8.8	100	500
AUG 12/93	21.3	7.2	1000	500
AUG 19/93	24.1	6.8	230	460
AUG 26/93	23.2	6.6	120	440
SEP 02/93	21.1	5.0	70	410
SEP 09/93		7.2	110	380
SEP 14/93	19.7	7.2	140	410
SEP 23/93	15.5	8.8	30	120
SEP 28/93 *	12.3	9.5	280	240
OCT 07/93	11.8	10.1	120	290
OCT 14/93	6.4	11.5	70	180
OCT 21/93 *	12.8	9.5	1000	1500
OCT 28/93	6.7	11.9	960	1100
MIN	6.4	5.0	30	120
MAX	25.6	11.9	1000	1500
GEOM	18.1	7.9	346	514
			230	426

SITE C3 - CATFISH CREEK, HWY #3. NEW SARUM E

DATE	TEMP °C	D.O.	E.COLI	FECAL STREP.
JUN 10/93 *	18.6		9000	1120
JUN 17/93			360	250
JUN 24/93 *	18.2	8.0	1900	330
JUL 01/93	16.2	6.8	210	280
JUL 08/93	20.1	4.7	2800	1400
JUL 15/93	14.1	4.3	980	880
JUL 22/93	13.3	5.2	340	660
JUL 29/93	16.6	4.2	1000	1500
AUG 05/93	13.2	3.2	170	400
AUG 12/93	14.3	4.8	1200	1200
AUG 19/93	15.5	4.3	260	800
AUG 26/93	15.2	5.0	140	430
SEP 02/93	13.8	5.0	30	280
SEP 09/93	11.8	5.3	20	480
SEP 14/93	15.5	3.9	60	300
SEP 23/93	13.5	4.8	-60	1000
SEP 28/93 *	10.0	6.0	30	150
OCT 07/93	9.8	6.5	10	40
OCT 14/93	6.3	7.2	10	20-
OCT 21/93 *	10.8	8.3	10	280
OCT 28/93	7.9	7.1	10	30
MIN	6.3	3.2	10	20
MAX	20.1	8.3	9000	1500
AVG	13.7	5.5	886	563
GEOM			151	346

SITE C4 - CATFISH CREEK, ON DINGLE ST.

DATE	TEMP °C	D.O.	E.COLI	FECAL STREP.
JUN 10/93 *	15.8		5500	3700
JUN 17/93	17.7		560	290
JUN 24/93 *	18.1		1000	620
JUL 01/93	15.2	8.0	770	600
JUL 08/93	22.8	7.1	2500	950
JUL 15/93	20.5	9.8	1000	660
JUL 22/93	19.1	9.6	740	810
JUL 29/93	21.7	8.1	550	1200
AUG 05/93	17.2	9.6	380	1180
AUG 12/93	19.8	9.4	380	1500
AUG 19/93	21.5	5.2	800	1500
AUG 26/93	20.7	8.0	890	1500
SEP 02/93	15.1	7.1	540	480
SEP 09/93	16.1	12.5	690	1600
SEP 14/93	16.4	7.9	480	940
SEP 23/93	13.8	7.2	810	1500
SEP 28/93 *	12.4	134	1000	1100
OCT 07/93	12.8	13.2	40	110
OCT 14/93	7.4	15.0	180	150
OCT 21/93 *	11.6	9.1	1000	1330
OCT 28/93	8.6	13.2	740	1600
MIN	7.4	5.2	40	110
MAX	22.8	15.0	5500	3700
AVG	16.5	9.6	979	1110
GEOM			665	858

SITE C5 - CATFISH CREEK. ELGIN/OXFORD LINE

DATE	TEMP °C	D.O.	E.COLI	FECAL STREP.
JUN 10/93 *	16.3		970	2000
JUN 17/93	21.2		1170	550
JUN24/93 *	21.1	8.0	600	2300
JUL 01/93	13.3	9.0	780	890
JUL 08/93	23.3	11.8	1400	1900
JUL 15/93	23.0	14.3	330	770
JUL 22/93	22.7	11.2	930	1400
JUL 29/93	22.8	8.5	1000	6800
AUG 05/93	20.3	9.9	1200	1220
AUG 12/93	25.1	8.2	2600	3500
AUG 19/93	26.4	10.0	1600	2200
AUG 26/93	26.5	10.8	110	3200
SEP 02/93	18.7	8.4	360	1000
SEP 09/93	16.1	12.5	800	3300
SEP 14/93	19.5	8.5	1300	2500
SEP 23/93	15.0	7.6	7000	2800
SEP 28/93 *	12.4	14.2	330	1300
OCT 07/93	12.8	15.0	190	930
OCT 14/93	7.3	1.0	400	720
OCT 21/93 *	11.6	12.4	1400	7100
OCT 28/93	83	15.0	310	590
MIN	7.3	7.6	110	550
MAX	26.5	15.0	7000	7100
AVG	18.3	11.1	1180	2237
GEOM			765	1711

SITE C6 - CATFISH CREEK, CTY RD. #48 (LYONS)

DATE JUN	TEMP °C	D.O.	E.COLI	FECAL STREP.
JUN 10/93 *	19.2		4700	2800
JUN 17/93	25.6		1600	580
JUN 24/93 *	22.7	9.8	3100	2800
JUL 01/93	15.6	5.6	1000	1500
JUL 08/93	26.7	10.8	6500	2100
JUL 15/93	22.5	10.9	45000	9200
JUL 22/93	21.8	11.2	1400	1600
JUL 29/93	25.0	15.0	5600	10000
AUG 05/93	21.2	15.0	5000	7300
AUG 12/93	23.2	15.0	390	53000
AUG 19/93	22.5	1.2	3400	1500
AUG 26/93	21.3	2.2	3900	3800
SEP 02/93	19.5	3.5	500	800
SEP 09/93	17.2	1.9	1500000	110000
SEP 14/93	19.0	2.5	49000	49000
SEP 23/93	13.8	2.1	2400000	2400000
SEP 28/93 *	12.4	1.1	4800000	1000000
OCT 07/93	12.9	1.9	200000	130000
OCT 14/93	7.6	1.8	520000	2200000
OCT 21/93 *	12.4	4.6	5000	480000
OCT 28/93	7.6	1.2	5000	70000
MIN	7.6	1.1	390	580
MAX	26.7	15.0	4800000	2400000
AVG	18.6	6.2	455290	311237
GEOM			14175	18611

SITE C7- CATFISH CREEK. CON X LOT 17/18

DATE	TEMP °C	D.O.	E.COLI	FECAL STREP.
JUN10/93 *	18.3		2100	820
JUN 17/93	24.8		900	490
JUN 24/93 *	22.8	6.8	2200	1500
JUL 01/93	17.5	13,0	1000	400
JUL 08/93	30.2	15.0	1000	380
JUL 15/93	30.4	15.0	80	130
JUL 22/93	31.4	15.0	280	1190
JUL 29/93				
AUG 05/93	18.8	7.0	1000	1000
AUG 12/93	20.4	10.6	610	400
AUG 19/93	23.1	9.0	690	410
AUG 26/93	22.3	4.6	110	480
SEP 02/93	17.2	3.4	120	150
SEP 09/93	16.4	7.2	200	200
SEP 14/93	19.4	4.3	-60	.190
SEP 23/93	14.0	5.9	100	300
SEP 28/93 *	10.6	10.4	100	100
OCT 07/93	13.5	10.1	10	40
OCT 14/93	7.3	12.3	20	30
OCT 21/93 *	12.4	11.4	310	2400
OCT 28/93	5.1	12.7	2900	500
MIN	5.1	3.4	10	30
MAX	31.4	15.0	3100	2400
AVG	18.8	9.7	829	556
GEOM			318	333

SITE CL1 - 19 MILE CREEK, HWY #3 NEW SARUM W

DATE	TEMP °C	D.O.	E.COLI	FECAL STREP.
JUN 10/93 *	17.5	0.5	1800	960
JUN 24/93 *	17.5	7.0	800	2400
JUL 08/93	23.8	4.5	910	1500
JUL 22/93	16.2	6.8	80	210
AUG 05/93	15.8	7.0	90	410
AUG 19/93	19.1	3.8	500	720
SEP 02/93	17.2	4.6		3300
SEP 14/93	19.4	4.3	100	260
SEP 28/93 *	11.3	8.6	150	320
OCT 14/93	5.5	11.9	20	220
OCT 28/93	8.5	12.8	40	150
MIN	5.5	0.5	20	150
MAX	23.8	12.8	1800	3300
AVG	15.6	6.5	449	950
GEOM			188	567

SITE CL2 - 19 MILE CREEK, CON VII YARMOUTH

DATE	TEMP °C	D.O.	E.COLI	FECAL STREP.
JUN 17/93			620	280
JUL 01/93	15.2	6.0	480	330
JUL 15/93	18.7	4.2	1400	710
JUL 29/93	21.9	3.2	2700	2600
AUG 12/93	19.3	5.8	310	300
AUG 26/93	20.5	5.1	1000	680
SEP 09/93	14.2	8.9	440	1100
SEP 23/93	14.8	6.7	140	240
OCT 07/93	10.3	8.6		210
OCT 21/93	11.8	9.8	1000	1500
MIN	10.3	3.2	140	210
MAX	21.9	9.8	2700	2600
AVG	16.3	6.5	899	795
GEOM			653	557

SITE H1 - BRADLEY CREEK, HWY #73

DATE	TEMP °C	D.O.	E.COLI
JUN 10/93 *	14.1		1000
JUN 17/93			1000
JUN 24/93 *	13.0		240
JUL 01/93			270
JUL 08/93	16.4	8.2	570
JUL 15/93	13.9	8.4	1700
JUL 22/93	11.9	9.6	710
JUL 29/93	15,8	6.5	880
AUG 05/93	12.0	8.6	680
AUG 12/93	13.3	7.8	260
AUG 19/93	14.7	8.4	2000
AUG 26/93	14.7	8.6	690
SEP 02/93	13.6	8.8	890
SEP 09/93		10.0	
SEP 14/93	16.0	7.6	4800
SEP 23/93	14.1	8.5	250
SEP 28/93 *	10.3	9.7	450
OCT 07/93	11.7	9.9	240
OCT 14/93	5.7	12.8	270
OCT 21/93 *	11.8	8.5	150
OCT 28/93	7.7	10.0	510
MIN	5.7	6.5	150
MAX	16.4	12.8	4800
AVG	12.8	8.9	878
GEOM			586

SITE H2 - CATFISH CREEK, ROGER'S SIDE RD. N.

DATE	TEMP °C	D.O.	E.COLI
JUN 10/93 *	17.0		8000
JUN 17/93			1000
JUN 24/93 *	17.3	7.5	490
JUL 01/93	16.1		220
JUL 08/93	23.8	5.4	260
JUL 15/93	18.5	6.2	360
JUL 22/93	18.7	7.1	930
JUL 29/93	22.1	4.0	6600
AUG 05/93	19.2	8.1	680
AUG 12/93	20.1	7.8	800
AUG 19/93	22.0	5.8	1500
AUG 26/93	21.5	5.1	1200
SEP 02/93	19.1	6.3	1400
SEP 09/93	14.7	8.5	
SEP 14/93	18.8	7.3	340
SEP 23/93	15.5	8.1	1800
SEP 28/93 *	11.3	9.1	450
OCT 07/93	11.4	11.9	150
OCT 14/93	5.1	13.8	1100
OCT 21/93 *	11.9	8.8	4600
OCT 28/93	7.4	11.1	1600
MIN	5.1	4.0	150
MAX	23.8	13.8	8000
AVG	16.6	7.9	1674
GEOM			929

* - High Flow Event

KETTLE CREEK WATERSHED - CHEMICAL SITE K1 - KETTLE CREEK, LAKE WHITTAKER

DATE	Temp °C	D.O.	Susp. Solids	Free NH_3	Total KJELD	NO_2	NO_3	Total Phos.	Diss. Reactive	pH	µmho/cm @ 25C	Cl^-
JUN 10/93 *	17.2		10.0	0.047	1.03	0.06	5.5	0.095	0.046	7.99	597	24.7
JUN 17/93	18.5		5.1	0.027	0.94	0.06	4.4	0.080	0.056	8.24	616	26.0
JUN 24/93 *	18.5	8.5	5.0	0.019	0.92	0.06	7.1	0.079	0.051	8.04	714	34.0
JUL 01/93	14.3	9.4	2.6	0.090	0.95	0.14	5.0	0.089	0.072	8.09	658	26.5
JUL 08/93	21.5	9.4	5.0	0.005	0.83	0.10	4.6	0.101	0.069	8.20	681	29.9
JUL 15/93	18.4	10.0	5.0	0.005	0.84	0.05	4.0	0.082	0.052	8.14	660	30.1
JUL 22/93	19.2	10.9	5.0	0.005	0.61	0.02	4.3	0.065	0.044	8.13	688	29.6
JUL 29/93	19.6	7.9	5.0	0.005	0.52	0.05	4.9	0.084	0.053	8.16	709	31.8
AUG 05/93	16.2	8.6	12.4	0.005	0.70	0.03	6.0	0.119	0.049	8.16	696	30.4
AUG 12/93	19.2	7.9	2.8	0.017	0.52	0.05	5.5	0.079	0.043	8.06	750	34.0
AUG 19/93	18.8	10.5	8.7	0.032	0.57	0.07	5.9	0.095	0.060	8.04	728	28.7
AUG 26/93	18.1	7.0	5.0	0.043	0.54	0.08	5.7	0.089	0.062	8.06	701	27.7
SEP 02/93	16.4	6.8	10.5	0.023	0.61	0.05	5.9	0.150	0.066	8.06	711	29.0
SEP 09/93	14.6	9.5	24.1	0.005	0.88	0.02	3.3	0.118	0.059	8.03	580	25.5
SEP 14/93	18.2	6.8	5.1	1.140	2.70	0.08	2.9	0.325	0.240	8.02	718	61.8
SEP 23/93	13.5	8.0	6.7	0.019	0.63	0.04	4.2	0.085	0.053	8.09	636	26.4
SEP 28/93 *	10.3	9.8	5.5	0.041	0.72	0.03	0.1	0.144	0.131	8.04	573	28.0
OCT 07/93	13.4	9.1	188.0	0.026	1.30	0.03	3.8	0.310	0.040	8.01	696	30.7
OCT 14/93												
OCT 21/93*	11.2	9.4	24.7	0.048	1.17	0.14	4.8	0.142	0.082	7.78	859	67.7
OCT 28/93	7.2	12.7	14.5	0.030	0.72	0.02	2.6	0.044	0.019	7.96	826	53.7
MIN	7.2	6.8	2.6	0.005	0.52	0.02	0.1	0.044	0.019	7.78	573	24.7
MAX	21.5	12.7	188.0	1.140	2.70	0.14	7.1	0.325	0.240	8.24	859	67.7
AVG	16.2	9.0	17.5	0.082	0.89	0.06	4.5	0.119	0.067	8.07	690	33.8
GEOM			8.2	0.022	0.81	0.05	3.8	0.105	0.059	8.06	686	323

SITE K2 - KETTLE CREEK, SIDEROAD S. DORCHESTER

DATE	Temp °C	D.O.	Susp. Solids	Free NH_3	Total KJELD	NO_2	NO_3	Total Phos.	Diss. Reactive	pH	µmho/cm @ 25C	Cl^-
JUN 10/93 *	17.7		23.7	0.089	1.07	0.11	7.0	0.134	0.065	8.16	684	32.0
JUN 17/93	21.2		14.2	0.067	1.03	0.09	3.2	0.136	0.100	8.30	660	32.1
JUN 24/93 *	19.6	9.2	24.1	0.005	1.01	0.11	6.1	0.137	0.074	8.24	691	31.7
JUL 01/93	16.0	7.8	41.2	0.081	1.30	0.14	4.2	0.230	0.110	8.29	704	35.1
JUL 08/93	24.8	6.6	28.1	0.060	1.00	0.09	1.9	0.325	0.154	8.30	676	35.2
JUL 15/93	22.7	9.0	20.2	0.051	0.96	0.04	1.4	0.240	0.150	8.25	666	33.6
JUL 22/93	21.0	8.8	17.4	0.005	0.97	0.06	0.9	0.215	0.109	8.17	658	30.4
JUL 29/93	22.6	7.0	13.3	0.052	0.87	0.06	0.3	0.195	0.122	8.16	586	29.3
AUG 05/93	18.7	8.5	22.0	0.043	0.87	0.01	0.3	0.182	0.114	8.20	566	28.7
AUG 12/93	22.5	9.6	6.1	0.060	0.74	0.01	0.1	0.194	0.105	8.26	569	21.3
AUG 19/93	24.3	9.6	9.8	0.068	0.61	0.02	0.4	0.275	0.141	8.18	574	19.9
AUG 26/93	23.6	8.0	10.5	0.095	0.88	0.01	0.2	0.214	0.131	8.31	567	17.1
SEP 02/93	21.4	7.3	7.5	0.058	0.78	0.01	0.1	0.215	0.127	8.19	562	17.4
SEP 09/93	16.3	10.2	14.0	0.068	2.90	0.09	1.3	0.660	0.410	8.10	686	51.5
SEP 14/93	19.0	9.1	9.1	0.005	1.18	0.02	0.4	0.265	0.158	8.14	672	58.6
SEP 23/93	13.6	7.5	9.7	0.012	0.73	0.01	0.2	0.225	0.155	8.14	622	21.1
SEP 28/93 *	11.2	10.7	4.4	0.010	0.65	0.01	0.1	0.166	0.131	8.19	645	31.5
OCT 07/93	12.8	9.9	9.8	0.045	0.73	0.01	0.1	0.106	0.048	7.98	658	42.0
OCT 14/93	7.3	14.2	4.9	0.005	0.81	0.01	0.5	0.131	0.081	8.03	697	34.3
OCT 21/93 *	11.1	8.2	14.6	0.089	1.60	0.15	1.9	0.348	0.218	7.73	767	63.5
OCT 28/93	7.8	8.1	14.9	0.057	1.14	0.05	0.6	0.210	0.111	7.75	911	91.4
MIN	7.3	6.6	4.4	0.005	0.61	0.01	0.1	0.106	0.048	7.73	562	17.1
MAX	24.8	14.2	41.2	0.095	2.90	0.15	7.0	0.660	0.410	8.31	911	91.4
AVG	17.9	8.9	15.2	0.049	1.04	0.05	1.5	0.229	0.134	8.15	658	36.1
GEOM			13.0	0.033	0.97	0.03	0.6	0210	0.121	8.14	654	32.9

SITE K3 - KETTLE CREEK. CTY RD 48-BRIDGE

DATE	Temp °C	D.O.	Susp. Solids	Free NH_3	Total KJELD	NO_2	NO_3	Total Phos.	Diss. Reactive	pH	µmho/cm @ 25C	Cl^-
JUN 10/93 *	18.8		65.7	0.136	1.17	0.17	4.8	0.179	0.053	8.23	598	35.9
JUN 17/93			81.6	0.086	1.20	0.11	2.0	0.180	0.059	8.22	629	30.6
JUN 24/93 *	18.2	10.0	80.0	0.005	1.36	0.05	13.9	0.154	0.061	8.09	862	31.5
JUL 01/93	17.0	7.2	40.2	0.048	0.98	0.05	2.9	0.138	0.067	8.25	617	33.3
JUL 08/93	23.8	4.5	42.9	0.030	1.02	0.09	0.8	0.153	0.044	8.22	598	30.3
JUL 15/93	18.4	6.0	50.4	0.042	0.92	0.01	0.1	0.161	0.045	8.14	553	27.6
JUL 22/93	18.0	6.5	47.3	0.019	0.85	0.03	0.1	0.151	0.057	8.14	530	22.8
JUL 29/93	21.9	5.4	39.2	0.064	0.92	0.08	0.1	0.098	0.017	8.02	483	20.7
AUG 05/93	19.2	6.6	95.9	0.011	1.45	0.01	0.1	0.260	0.023	8.09	495	19.4
AUG 12/93	18.3	7.1	37.5	0.085	0.70	0.01	0.1	0.101	0.027	8.00	476	14.8
AUG 19/93	20.5	7.2	33.9	0.062	0.67	0.01	0.1	0.084	0.021	7.89	442	11.4
AUG 26/93	19.5	5.5	34.3	0.116	0.71	0.02	0.1	0.099	0.027	8.18	417	9.4
SEP 02/93	17.3	7.0	33.4	0.077	0.65	0.01	0.1	0.134	0.031	8.01	406	8.6
SEP 09/93	14.5	10.1	30.4	0.008	0.78	0.01	0.7	0.096	0.022	8.10	493	32.8
SEP 14/93	17.7	7.8	28.6	0.020	0.69	0.01	0.1	0.079	0.005	8.11	457	19.6
SEP 23/93	14.2	9.6	14.3	0.005	0.80	0.01	0.1	0.053	0.015	8.15	493	28.3
SEP 28/93 *	11.1	9.3	18.7	0.016	0.58	0.01	0.1	0.069	0.025	8.03	481	20.6
OCT 07/93	9.9	11.8	8.3	0.030	0.61	0.01	0.1	0.044	0.012	8.01	507	192
OCT 14/93	5.1	12.3	9.1	0.005	0.45	0.01	0.1	0.061	0.032	7.94	513	17.6
OCT 21/93 *	11.3	15.0	30.6	0.043	0.65	0.01	0.3	0.113	0.051	8.01	632	42.1
OCT 28/93	7.5	15.0	11.2	0.088	0.77	0.01	0.1	0.055	0.016	8.06	653	51.7
MIN	5.1	4.5	8.3	0.005	0.45	0.01	0.1	0.044	0.005	7.89	406	8.6
MAX	23.8	15.0	95.9	0.136	1.45	0.17	13.9	0.260	0.067	8.25	662	51.7
AVG	16.1	8.6	39.7	0.046	0.84	0.03	1.3	0.117	0.034	8.09	530	25.2
GEOM			32.6	0.030	0.81	0.02	0.3	0.106	0.028	8.09	525	22.8

SITE K4 - DODD'S CREEK, PAYNES MILLS

DATE	Temp °C	D.O.	Susp. Solids	Free NH_3	Total KJELD	NO_2	NO_3	Total Phos.	Diss. Reactive	pH	µmho/cm @ 25C	Cl^-
JUN 10/93 *	19.6		45.7	0.101	1.46	0.10	3.2	0.206	0.079	7.98	743	90.1
JUN 17/93	17.2		55.4	0.135	2.88	0.10	1.7	0.344	0.190	7.86	723	93.7
JUN 24/93 *	19.5		62.1	0.007	2.48	0.11	4.1	0.314	0.179	7.81	765	105.0
JUL 01/93	15.2	9.4	37.8	0.006	2.10	0.11	3.0	0.270	0.173	7.85	696	82.4
JUL 08/93	22.7	5.8	66.4	0.042	2.25	0.03	1.7	0.410	0.228	7.86	648	80.6
JUL 15/93	18.9	5.6	44.9	0.066	2.40	0.02	1.6	0.358	0.228	7.76	772	101.0
JUL 22/93	17.1	6.7	53.6	0.029	3.05	0.03	0.7	0.415	0.220	7.79	788	108.0
JUL 29/93	21.6	4.6	50.1	0.071	2.75	0.05	0.8	0.420	0.240	7.72	754	99.4
AUG 05/93	16.8	7.4	8.5	0.026	2.00	0.03	1.4	0.475	0.001	7.93	664	93.2
AUG 12/93	18.7	5.5	10.2	0.110	1.90	0.03	0.5	0.380	0.296	7.73	722	87.9
AUG 19/93	21.1	5.2	17.7	0.072	2.20	0.08	1.8	0.480	0.370	7.69	744	109.0
AUG 26/93	20.7	5.4	19.9	0.085	2.80	0.07	1.9	0.520	0.350	7.91	807	114.0
SEP 02/93	18.4	6.1	31.6	0.063	3.10	0.03	1.9	0.590	0.360	7.84	798	113.0
SEP 09/93	15.2	9.9	16.6	0.027	2.00	0.03	2.1	0.375	0.290	7.84	735	110.0
SEP 14/93	17.0	6.8	18.1	0.011	2.50	0.01	2.0	0.470	0.340	7.85	812	119.0
SEP 23/93	18.3	7.8	19.6	0.017	2.55	0.02	1.9	0.390	0.290	7.98	816	113.0
SEP 28/93 *	12.3	10.5	13.6	0.019	2.65	0.01	1.5	0.355	0.250	7.93	789	97.9
OCT 07/93	10.9	10.4	14.9	0.026	2.18	0.01	0.9	0.246	0.186	7.78	692	90.7
OCT 14/93	6.6	13.0	8.6	0.005	2.25	0.01	0.7	0.245	0.103	7.84	665	86.1
OCT 21/93 *	11.8	14.8	8.2	0.046	1.80	0.01	0.6	0.220	0.153	7.80	867	137.0
OCT 28/93	8.9	12.3	7.5	0.057	2.70	0.01	0.7	0.280	0.219	7.79	814	121.0
MIN	6.6	4.6	7.5	0.005	1.46	0.01	0.5	0.206	0.001	7.69	648	80.6
MAX	22.7	14.8	66.4	0.135	3.10	0.11	4.1	0.590	0.370	7.98	867	137.0
AVG	16.6	8.2	29.1	0.049	2.38	0.04	1.7	0.370	0.226	7.84	753	102.5
GEOM			22.7	0.034	2.34	0.03	1.4	0.356	0.171	7.83	751	101.5

SITE K5 - DODD'S CREEK CTY RD 25-BRIDGE

DATE	Temp °C	D.O.	Susp. Solids	Free NH_3	Total KJELD	NO_2	NO_3	Total Phos.	Diss. Reactive	pH	µmho/cm @ 25C	Cl^-
JUN 10/93 *	19.7		64.7	0.140	1.62	0.15	5.8	0.184	0.066	8.08	690	69.0
JUN 17/93	20.3		93.8	0.106	2.00	0.11	1.5	0.178	0.072	8.06	727	76.5
JUN 24/93 *	20.3		96.9	0.014	1.72	0.11	3.4	0.214	0.079	8.00	760	80.0
JUL 01/93	172	9.2	67.4	0.039	1.55	0.04	2.8	0.185	0.083	8.16	769	97.8
JUL 08/93	25.2	5.7	81.6	0.033	1.85	0.01	0.9	0.230	0.083	8.10	686	73.7
JUL 15/93	20.5	6.5	97.3	0.060	2.24	0.03	0.8	0.264	0.106	7.97	685	86.0
JUL 22/93	18.4	6.5	80.9	0.040	2.25	0.01	0.1	0.190	0.041	7.86	700	90.7
JUL 29/93	23.0	4.8	86.3	0.051	2.25	0.02	0.1	0.195	0.073	7.92	722	89.6
AUG 05/93	18.7	7.9	110.0	0.034	2.85	0.05	0.1	0.345	0.065	8.38	700	83.9
AUG 12/93	19.4	7.5	90.0	0.055	2.55	0.03	0.1	0.270	0.040	7.89	634	82.9
AUG 19/93	22.0	5.6	67.3	0.063	1.94	0.01	0.1	0.164	0.043	7.83	710	86.7
AUG 26/93	21.1	4.3	59.0	0.114	2.00	0.02	0.1	0.200	0.050	7.84	743	94.8
SEP 02/93	19.3	6.0	108.0	0.082	2.30	0.04	0.6	0.340	0.092	8.15	786	106.0
SEP 09/93	16.1	12.5	67.8	0.054	1.22	0.03	1.4	0.300	0.134	7.93	755	117.0
SEP 14/93	18.5	7.1	64.1	0.009	1.75	0.01	1.1	0.265	0.109	7.98	803	127.0
SEP 23/93	15.3	8.7	47.8	0.031	2.15	0.02	0.8	0.230	0.090	8.10	783	76.6
SEP 28/93 *	12.6	10.6	55.6	0.030	2.00	0.01	0.6	0.210	0.134	8.12	773	99.1
OCT 07/93	10.8	9.4	51.1	0.072	2.55	0.01	0.8	0.235	0.139	7.88	823	109.0
OCT 14/93	6.4	14.6	13.9	0.007	1.67	0.01	0.2	0.134	0.105	7.95	750	96.8
OCT 21/93 *	11.2	11.6	30.8	0.007	1.82	0.01	0.2	0.164	0.091	7.91	753	95.2
OCT 28/93	8.1	12.7	22.3	0.028	1.32	0.01	0.1	0.107	0.045	7.96	927	70.4
MIN	6.4	4.3	13.9	0.007	1.22	0.01	0.1	0.107	0.040	7.83	634	69.0
MAX	25.2	14.6	110.0	0.140	2.85	0.15	5.8	0.345	0.139	8.38	927	127.0
AVG	17.3	8.3	69.4	0.051	1.98	0.04	1.0	0.219	0.083	8.00	747	90.9
GEOM			62.5	0.038	1.94	0.02	0.5	0.211	0.077	8.00	744	89.7

SITE K6 - KETTLE CREEK, FULTON BRIDGE

DATE	Temp °C	D.O.	Susp. Solids	Free NH_3	Total KJELD	NO_2	NO_3	Total Phos.	Diss. Reactive	pH	µmho/cm @ 25C	Cl^-
JUN 10/93 *	19.3		39.7	0.122	1.30	0.10	3.2	0.254	0.125	8.02	630	60.2
JUN 17/93	18.9		72.4	0.278	1.58	0.24	4.3	0.316	0.190	7.99	674	62.4
JUN 24/93 *	19.2		118.0	0.006	1.34	0.12	4.4	0.340	0.134	7.97	631	55.4
JUL 01/93	19.4	8.6	69.2	0.061	1.50	0.11	4.9	0.300	0.149	8.05	645	61.0
JUL 08/93	24.8	5.5	66.0	0.112	1.35	0.24	4.4	0.410	0.208	7.91	580	58.7
JUL 15/93	20.7	7.5	58.2	0.053	1.14	0.07	7.1	0.425	0.288	7.96	641	72.5
JUL 22/93	20.5	8.9	75.0	0.033	1.48	0.03	7.9	0.510	0.178	8.56	681	82.7
JUL 29/93	23.2	10.3	60.1	0.048	1.10	0.07	8.8	0.620	0.370	7.96	697	77.1
AUG 05/93	18.8	9.3	46.3	0.017	1.29	0.02	7.0	0.560	0.310	8.41	661	70.3
AUG 12/93	21.0	8.5	50.1	0.114	1.46	0.04	9.4	0.540	0.376	8.40	680	69.2
AUG 19/93	23.1	7.5	98.8	0.017	1.54	0.02	6.4	0.540	0.260	8.32	602	61.9
AUG 26/93	22.6	6.4	42.5	0.069	1.26	0.04	11.2	0.610	0.450	8.07	687	72.1
SEP 02/93	19.6	7.7	38.8	0.033	1.01	0.03	6.2	0.325	0.200	8.25	610	62.3
SEP 09/93	16.2	10.8	35.7	0.052	1.25	0.04	5.5	0.550	0.400	8.00	611	65.7
SEP 14/93	19.5	8.2	31.8	0.005	1.16	0.03	8.3	0.450	0.290	8.11	701	88.2
SEP 23/93	16.0	8.4	20.2	0.024	0.98	0.05	11.0	0.490	0.330	8.08	702	69.4
SEP 28/93 *	13.2	11.2	23.9	0.032	1.22	0.03	7.7	0.480	0.350	8.06	624	63.9
OCT 07/93	12.3	11.4	18.4	0.034	0.99	0.03	9.3	0.350	0.290	8.17	727	62.0
OCT 14/93	7.6	13.9	11.5	0.006	1.12	0.02	7.2	0.410	0.240	8.01	704	76.6
OCT 21/93 *	13.6	11.4	35.6	0.073	1.19	0.05	6.8	0.330	0.188	7.84	699	76.9
OCT 28/93	9.1	13.0	11.7	0.129	1.06	0.13	7.0	0.290	0.240	7.97	714	74.8
MIN	7.6	5.5	11.5	0.005	0.98	0.02	3.2	0.254	0.125	7.84	580	55.4
MAX	24.8	13.9	118.0	0.278	1.58	0.24	11.2	0.620	0.450	8.56	727	88.2
AVG	18.0	9.4	48.8	0.063	1.25	0.07	7.0	0.433	0.265	8.10	662	68.7
GEOM			41.0	0.039	1.24	0.05	6.7	0.419	0.249	8.10	661	68.2

SITE K7 - KETTLE CREEK, CTY RD. 21, PORT STANLEY

DATE	Temp °C	D.O.	Susp. Solids	Free NH_3	Total KJELD	NO_2	NO_3	Total Phos.	Diss. Reactive	pH	µmho/cm @ 25C	Cl^-
JUN 10/93 *	19.2		34.2	0.102	1.07	0.09	3.5	0.184	0.800	8.10	620	56.0
JUN 17/93	20.7		54.6	0.248	0.76	0.18	4.0	0.112	0.103	8.10	663	57.0
JUN 24/93 *	21.8		70.5	0.142	1.34	0.11	3.0	0.230	0.099	7.99	609	48.9
JUL 01/93	19.3	8.5	115.0	0.071	1.40	0.08	3.8	0.305	0.124	8.06	617	53.5
JUL 08/93	25.7	7.0	96.9	0.061	1.60	0.08	4.4	0.374	0.120	8.32	645	57.2
JUL 15/93	20.7		75.0	0.054	1.12	0.05	4.2	0.315	0.144	8.05	645	82.8
JUL 22/93	22.3	13.2	93.9	0.024	1.54	0.04	3.6	0.306	0.017	8.14	556	54.8
JUL 29/93	24.7	8.4	149.0	0.021	1.76	0.06	5.4	0.384	0.034	8.27	610	61.3
AUG 05/93	21.2	13.2	57.6	0.012	1.52	0.03	4.7	0.320	0.091	8.72	596	53.7
AUG 12/93	22.4	15.0	53.2	0.194	1.74	0.03	4.2	0.188	0.014	8.37	581	57.2
AUG 19/93	24.7	13.0	94.4	0.101	2.20	0.12	5.1	0.345	0.050	7.75	556	54.8
AUG 26/93	23.4	11.6	42.7	0.188	1.54	0.05	5.2	0.292	0.117	8.34	632	56.6
SEP 02/93	21.2	7.0	51.5	0.071	1.01	0.06	5.8	0.335	0.007	8.32	623	55.2
SEP 09/93	17.2	9.8	33.4	0.039	1.20	0.03	4.1	0.276	0.186	8.07	639	59.2
SEP 14/93	18.6	8.6	31.1	0.005	0.97	0.02	6.6	0.305	0.176	8.18	657	70.3
SEP 23/93	14.2	7.8	55.2	0.025	0.98	0.02	7.0	0.294	0.202	8.21	664	61.8
SEP 28/93 *	13.0	10.1	49.8	0.043	0.83	0.01	7.1	0.320	0.243	8.13	653	58.2
OCT 07/93	11.7	12.3	31.2	0.035	1.00	0.01	6.0	0.166	0.079	8.33	674	6.0
OCT 14/93	8.6	14.4	12.3	0.006	0.82	0.01	2.9	0.158	0.104	8.17	583	43.7
OCT 21/93 *	12.5	15.0	57.5	0.036	1.02	0.02	3.4	0.260	0.123	7.93	615	522
OCT 28/93	9.2	15.0	25.0	0.043	0.93	0.03	3.5	0.163	0.094	8.04	680	63.0
MIN	8.6	7.0	12.3	0.005	0.76	0.01	2.9	0.112	0.007	7.75	556	6.0
MAX	25.7	15.0	149.0	0.248	2.20	0.18	7.1	0.384	0.800	8.72	680	70.3
AVG	18.7	11.2	01.1	0.072	1.25	0.05	4.6	0.268	0.139	8.17	625	54.4
GEOM			52.9	0.046	120	0.04	4.5	0.255	0.089	8.17	624	50.9

CATFISH CREEK WATERSHED - CHEMICAL SITE C1 - CON II YARMOUTH

DATE	Temp °C	D.O.	Susp. Solids	Free NH_3	Total KJELD	NO_2	NO_3	Total Phos.	Diss. Reactive	pH	µmho/cm @ 25C	Cl^-
JUN 10/93 *	18.3		73.6	0.051	0.87	0.16	6.2	0.154	0.037	8.21	650	34.2
JUN 17/93	19.3		57.4	0.030	0.88	0.07	3.0	0.108	0.044	8.26	612	26.3
JUN 24/93 *	17.3		87.6	0.005	1.22	0.20	10.0	0.188	0.041	8.19	623	27.1
JUL 01/93	18.0	10.5	63.4	0.016	0.79	0.03	2.8	0.145	0.400	8.32	589	26.7
JUL 08/93	24.8	8.1	93.3	0.023	1.00	0.03	0.6	0.154	0.008	8.25	521	23.6
JUL 15/93	21.2	8.5	42.8	0.023	0.76	0.01	0.8	0.099	0.017	8.13	576	21.8
JUL 72/93	20.6	8.2	43.7	0.027	0.76	0.01	0.5	0.097	0.012	8.07	548	20.6
JUL 29/93	23.7	7.2	72.7	0.011	0.73	0.02	0.5	0.111	0.019	8.10	536	20.0
AUG 05/93	19.7	8.8	51.0	0.020	0.73	0.01	0.4	0.092	0.019	8.12	547	20.3
AUG 12/93	21.8	8.0	49.8	0.097	0.73	0.01	0.3	0.089	0.001	8.05	534	17.4
AUG 19/93	23.1	7.5	55.3	0.005	0.82	0.01	0.5	0.100	0.002	8.24	514	17.4
AUG 26/93	22.7	7.0	51.4	0.074	0.68	0.01	0.7	0.086	0.003	8.20	530	17.6
SEP 02/93	19.4	7.6	49.4	0.030		0.01	0.6		0.002	8.08	523	17.4
SEP 09/93	16.6	10.5	38.5	0.010	0.62	0.01	1.1	0.076	0.011	8.17	525	25.2
SEP 14/93	18.9	8.1	34.2	0.005	0.57	0.01	0.7	0.072	0.018	8.17	525	22.0
SEP 23/93	15.7	8.5	24.7	0.013	0.58	0.01	0.6	0.056	0.011	8.21	533	20.0
SEP 28/93 *	12.7	12.1	23.4	0.014	0.51	0.01	0.5	0.054	0.018	8.23	532	17.1
OCT 07/93	12.2	13.2	15.4	0.026	0.42	0.01	0.8	0.035	0.001	8.10	542	19.3
OCT 14/93	8.1	15.0	6.7	0.005	0.47	0.01	0.5	0.027	0.011	8.22	553	21.3
OCT 21/93 *	12.5	12.4	28.4	0.047	0.69	0.02	0.9	0.065	0.017	8.19	626	35.8
OCT 28/93	8.5	15.0	10.5	0.074	0.77	0.01	0.4	0.090	0.040	8.29	725	67.8
MIN	8.1	7.0	6.7	0.005	0.42	0.01	0.3	0.027	0.001	8.05	514	17.1
MAX	24.8	15.0	93.3	0.097	1.22	0.20	10.0	0.188	0.400	8.32	725	67.8
AVG	17.9	9.8	46.3	0.029	0.73	0.03	1.5	0.095	0.035	8.18	565	24.7
GEOM			38.9	0.020	0.71	0.02	0.9	0.086	0.012	8.18	563	23.2

SITE C2 - BRADLEY CREEK, ROGER'S SIDE RD. S

DATE	Temp °C	D.O.	Susp. Solids	Free NH_3	Total KJELD	NO_2	NO_3	Total Phos.	Diss. Reactive	pH	µmho/cm @ 25C	Cl^-
JUN 10/93 *	18.3		15.1	0.109	0.93	0.06	2.5	0.064	0.014	7.85	569	20.7
JUN 17/93			27.6	0.202	1.10	0.07	2.0	0.080	0.009	7.89	554	22.7
JUN 24/93 *	19.7	9.0	73.2	0.005	1.20	0.08	1.8	0.180	0.021	7.82	568	23.3
JUL 01/93	16.6	74	26.1	0.227	0.92	0.15	1.9	0.089	0.024	8.03	563	23.1
JUL 08/93	25.6		33.0	0.193	1.16	0.22	1.4	0.152	0.006	7.82	533	23.1
JUL 15/93	21.7	5.1	16.4	0.496	1.31	0.05	0.8	0.093	0.012	7.62	599	24.8
JUL 22/93	21.6	5.0	27.0	0.005	1.07	0.39	1.1	0.166	0.020	7.66	610	25.2
JUL 29/93	24.7	6.8	63.6	0.017	2.05	0.01	0.5	0.280	0.022	7.69	526	28.2
AUG 05/93	20.2	8.8	5.0	0.048	1.56	0.03	0.9	0.157	0.010	7.77	559	24.0
AUG 12/93	21.3	'7.2	26.7	0.143	1.26	0.02	0.6	0.140	0.006	7.67	581	25.4
AUG 19/93	24.1	6.8	39.6	0.185	1.18	0.09	0.9	0.114	0.025	7.60	564	24.9
AUG 26/93	23.2	6.6	15.3	0.139	0.97	0.09	1.2	0.089	0.012	8.05	595	24.9
SEP 02/93	21.1	5.0	12.2	0.200	0.94	0.14	1.0	0.116	0.015	7.71	608	30.9
SEP 09/93		7.2	17.5	0.124	0.09	0.05	1.4	0.078	0.007	7.83	555	24.3
SEP 14/93	19.7	7.2	15.0	0.066	0.86	0.04	1.5	0.068	0.006	7.86	599	28.0
SEP 23/93	15.5	8.8	25.5	0.071	0.90	0.03	1.7	0.070	0.007	8.01	593	28.0
SEP 28/93 *	12.3	9.5	52.3	0.059	1.14	0.02	1.2	0.122	0.010	7.86	542	21.9
OCT 07/93	11.8	10.1	13.2	0.062	0.63	0.02	1.4	0.043	0.007	7.82	592	25.2
OCT 14/93	6.4	11.5	10.2	0.121	0.74	0.03	1.4	0.043	0.011	7.87	590	23.5
OCT 21/93 *	12.8	9.5	27.0	0.038	0.78	0.03	1.2	0.071	0.001	7.66	510	18.3
OCT 28/93	6.7	11.9	7.1	0.045	0.61	0.03	1.6	0.032	0.005	7.85	594	23.6
MIN	6.4	5.0	5.0	0.005	0.09	0.01	0.5	0.032	0.001	7.60	510	18.3
MAX	25.6	11.9	73.2	0.496	2.05	0.39	2.5	0.280	0.025	8.05	610	30.9
AVG	18.1	8.0	26.1	0.122	1.02	0.08	1.3	0.107	0.012	7.81	572	244
GEOM			21.1	0.076	0.91	0.05	1.2	0.094	0.010	7.81	571	24.3

SITE C3 - CATFISH CREEK, HWY #3, NEW SARUM E

DATE	Temp °C	D.O.	Susp. Solids	Free NH_3	Total KJELD	NO_2	NO_3	Total Phos.	Diss. Reactive	pH	µmho/cm @ 25C	Cl^-
JUN 10/93 *	18.6		91.4	0.063	1.04	0.25	9.8	0.190	0.045	8.17	682	40.6
JUN 17/93			26.2	0.034	0.82	0.09	5.5	0.070	0.400	8.12	654	40.2
JUN 24/93 *	18.2	8.0	80.8	0.006	1.75	0.30	23.2	0.200	0.071	8.14	713	34.7
JUL 01/93	16.2	6.8	26.5	0.079	0.90			0.080	0.036	8.23	664	41.6
JUL 08/93	20.1	4.7	15.7	0.091	0.84	0.04	1.5	0.057	0.011	7.80	594	44.3
JUL 15/93	14.1	4.3	6.2	0.102	0.51	0.01	0.1	0.037	0.006	7.64	653	41.6
JUL 22/93	13.3	5.2	9.2	0.180	0.60	0.01	0.1	0.046	0.016	7.57	687	40.8
JUL 29/93	16.6	4.2	39.2	0.096	0.39	0.05	0.1	0.067	0.010	7.66	664	39.6
AUG 05/93	13.2	3.2	5.0	0.160	0.51	0.02	0.1	0.035	0.002	7.66	692	41.6
AUG 12/93	14.3	4.8	10.5	0.118	0.36	0.01	0.1	0.023	0.004	7.58	699	39.1
AUG 19/93	15.5	4.3	17.4	0.138	0.46	0.01	0.2	0.025	0.001	7.62	687	37.1
AUG 26/93	15.2	5.0	13.0	0.132	0.40	0.01	0.1	0.032	0.003	7.99	687	38.5
SEP 02/93	13.8	5.0	5.0	0.124	0.35	0.01	0.1	0.028	0.006	7.67	687	41.2
SEP 09/93	11.8	5.3	4.8	0.082	0.41	0.01	0.6	0.027	0.001	7.68	678	42.7
SEP 14/93	15.5	3.9	6.2	0.102	0.40	0.01	0.1	0.027	0.005	7.74	688	40.1
SEP 23/93	13.5	4.8	16.7	0.064	0.34	0.01	0.1	0.027	0.003	7.81	667	35.8
SEP 28/93 *	10.0	6.0	4.1	0.059	0.32	0.01	0.1	0.027	0.005	7.68	692	39.5
OCT 07/93	9.8	6.5	3.2	0.106	0.27	0.01	0.1	0.016	0.003	7.66	672	35.2
OCT 14/93	6.3	7.2	3.1	0.101	0.41	0.01	0.1	0.029	0.001	7.62	682	39.3
OCT 21/93 *	10.8	8.3	10.5	0.107	0.37	0.01	0.1	0.030	0.002	7.82	665	36.4
OCT 28/93	7.9	7.1	5.7	0.141	0.53	0.01	0.1	0.039	0.007	7.60	641	36.5
MIN	6.3	3.2	3.1	0.006	0.27	0.01	0.1	0.016	0.001	7.57	594	34.7
MAX	20.1	8.3	91.4	0.180	1.75	0.30	23.2	0.200	0.400	8.23	713	44.3
AVG	13.7	5.5	19.1	0.099	0.57	0.04	2.1	0.053	0.030	7.78	674	39.4
GEOM			11.3	0.085	0.51	0.02	0.3	0.041	0.007	7.78	673	39.3

SITE C4 - CATFISH CREEK, ON DINGLE ST.

DATE	Temp °C	D.O.	Susp. Solids	Free NH_3	Total KJELD	NO_2	NO_3	Total Phos.	Diss. Reactive	pH	µmho/cm @ 25C	Cl^-
JUN 10/93 *	15.8		64.2	0.283	1.21	0.35	10.7	0.280	0.900	8.03	688	34.0
JUN 17/93	17.7		28.9	0.079	0.88	0.11	4.4	0.125	0.063	8.21	660	26.4
JUN 24/93 *	18.1		30.7	0.005	0.92	0.11	5.5	0.135	0.047	8.16	662	27.1
JUL 01/93	15.2	8.0	28.7	0.079	0.94	0.14	4.2	0.130	0.063	8.15	666	27.8
JUL 08/93	22.8	7.1	24.6	0.008	0.87	0.13	3.0	0.151	0.057	8.14	627	24.2
JUL 15/93	20.5	9.8	19.6	0.023	0.84	0.03	2.3	0.142	0.064	8.12	635	21.5
JUL 22/93	19.1	9.6	15.2	0.005	0.81	0.04	2.7	0.117	0.053	8.15	625	23.0
JUL 29/93	21.7	8.1	22.9	0.023	0.98	0.06	1.9	0.151	0.058	8.11	595	24.6
AUG 05/93	17.2	9.6	11.8	0.011	0.86	0.03	2.5	0.100	0.050	8.17	632	23.1
AUG 12/93	19.8	9.4	8.0	0.022	0.77	0.02	2.8	0.084	0.036	8:15	624	17.9
AUG 19/93	21.5	5.2	12.2	0.053	1.04	0.10	2.9	0.100	0.052	8.08	646	22.3
AUG 26/93	20.7	8.0	10.3	0.090	0.92	0.04	2.4	0.085	0.033	8.18	641	21.0
SEP 02/93	15.1	7.1	16.5	0.028	0.87	0.03	2.8	0.163	0.052	8.05	652	24.2
SEP 09/93	16.1	12.5	19.3	0.005	1.17	0.02	2.6	0.133	0.036	8.25	651	28.6
SEP 14/93	18.4	7.9	22.7	0.005	1.19	0.01	2.2	0.145	0.014	8.10	643	24.5
SEP 23/93	13.8	7.2	17.9	0.021	0.84	0.02	2.5	0.088	0.033	8.02	648	22.3
SEP 28/93 *	12.4	13.4	8.2	0.006	0.80	0.01	2.0	0.086	0.041	8.28	637	26.2
OCT 07/93	12.8	13.2	11.9	0.107	0.87	0.01	2.0	0.085	0.020	8.13	650	23.2
OCT 14/93	7.4	15.0	7.6	0.005	0.79	0.01	2.3	0.062	0.018	8.09	664	26.9
OCT 21/93 *	11.6	9.1	10.6	0.050	0.85	0.06	2.4	0.081	0.034	7.84	725	38.3
OCT 28/93	8.6	13.2	4.2	0.063	0.70	0.02	3.2	0.047	0.022	7.99	701	29.9
MIN	7.4	5.2	4.2	0.005	0.70	0.01	1.9	0.047	0.014	7.84	595	17.9
MAX	22.8	15.0	64.2	0.263	1.21	0.35	10.7	0.280	0.900	6.28	725	38.3
AVG	16.5	9.6	18.9	0.045	0.91	0.06	3.2	0.119	0.083	8.11	651	25.6
GEOM			15.8	0.023	0.90	0.04	2.9	0.110	0.045	8.11	650	25.2

SITE C5 - CATFISH CREEK, ELGIN/OXFORD LINE

DATE	Temp °C	D.O.	Susp. Solids	Free NH_3	Total KJELD	NO_2	NO_3	Total Phos.	Diss. Reactive	pH	µmho/cm @ 25C	Cl^-
JUN 10/93 *	16.3		22.8	0.091	0.88	0.09	8.8	0.129	0.059	7.96	734	32.8
JUN 17/93	21.2		7.0	0.023	0.78	0.08	3.5	0.058	0.033	8.19	698	29.0
JUN 24/93 *	21.1	8.0	8.4	0.045	0.90	0.10	4.1	0.088	0.041	8.19	698	29.0
JUL 01/93	13.3	8.0	8.0	0.084	0.75	0.10	3.7	0.074	0.048	7.95	691	28.6
JUL 08/93	23.3	11.8	6.4	0.005	0.74	0.08	3.3	0.078	0.038	8.30	671	26.4
JUL 15/93	23.0	14.3	6.6	0.006	0.73	0.04	3.3	0.081	0.039	8.34	665	28.5
JUL 22/93	22.7	112	10.5	0.460	7.90	0.01	0.1	1.950	0.920	8.98	716	60.5
JUL 29/93	22.8	8.5	20.0	0.010	0.77	0.10	3.0	0.127	0.054	8.19	669	32.2
AUG 05/93	20.3	9.9	30.6	0.022	0.94	0.08	3.5	0.129	0.041	8.14	671	31.1
AUG 12/93	25.1	8.2	50.9	0.041	1.14	0.08	2.6	1.780	0.042	8.06	658	31.8
AUG 19/93	26.4	10.0	25.0	0.098	1.03	0.12	2.1	0.137	0.065	8.15	605	34.6
AUG 26/93	26.5	10.8	15.0	0.010	1.10	0.13	1.7	0.138	0.061	8.27	670	39.2
SEP 02/93	18.7	8.4	23.2	0.057	0.94	0.09	2.5	0.160	0.055	8.15	692	41.0
SEP 09/93	16.1	12.5	33.9	0.057	0.85	0.07	4.4	0.087	0.029	8.19	732	36.8
SEP 14/93	19.5	8.5	24.4	0.038	1.06	0.12	3.7	0.104	0.020	8.12	707	37.9
SEP 23/93	15.0	7.6	20.3	0.055	0.96	0.09	4.2	0.072	0.029	7.98	706	36.4
SEP 28/93 *	12.4	14.2	12.6	0.027	0.82	0.05	4.0	0.054	0.029	8.29	702	37.1
OCT 07/93	12.8	15.0	19.8	0.032	0.76	0.06	3.9	0.048	0.010	8.24	726	37.2
OCT 14/93	7.3	15.0	25.1	0.051	0.82	0.04	4.4	0.067	0.035	8.16	726	33.1
OCT 21/93 *	11.6	12.4	24.5	0.042	0.98	0.05	3.5	0.106	0.037	7.76	785	46.9
OCT 28/93	8.3	15.0	16.2	0.037	0.77	0.04	0.1	0.045	0.009	8.09	764	36.0
MIN	7.3	7.6	6.4	0.005	0.73	0.01	0.1	0.045	0.009	7.76	605	26.4
MAX	26.5	15.0	50.9	0.460	7.90	0.13	8.8	1.950	0.920	8.98	785	60.5
AVG	18.3	11.1	19.6	0.061	1.22	0.08	3.4	0.262	0.081	8.18	699	35.5
GEOM			16.8	0.036	0.97	0.07	2.5	0.117	0.041	8.17	698	34.9

SITE C6 - CATFISH CREEK, CTY RD. #48 (LYONS)

DATE	Temp °C	D.O.	Susp. Solids	Free NH_3	Total KJELD	NO_2	NO_3	Total Phos.	Diss. Reactive	pH	µmho/cm @ 25C	Cl^-
JUN 10/93 *	19.2		10.0	0.087	1.03	0.10	14.4	0.162	0.086	8.16	722	33.0
JUN 17/93	25.6		11.4	0.302	1.42	0.22	4.0	0.320	0.186	8.22	564	27.2
JUN 24/93 *	22.7	9.8	17.6	0.230	1.21	0.25	11.8	0.153	0.098	8.12	708	25.1
JUL 01/93	15.6	5.6	8.4	0.004	1.68	0.50	6.0	0.204	0.141	7.98	699	30.5
JUL 08/93	26.7	10.8	17.0	0.316	1.85	0.35	0.2	0.650	0.390	8.34	654	33.3
JUL 15/93	22.5	10.9	26.3	0.454	3.30	0.01	0.1	1.490	0.830	8.64	658	44.2
JUL 22/93	21.8	11.2	27.4	0.460	7.90	0.01	0.1	1.950	0.920	8.98	716	60.5
JUL 29/93	25.0	15.0	29.1	0.222	10.30	0.02	0.1	4.200	1.740	8.76	743	66.7
AUG 05/93	21.2	15.0	274.0	3.560	28.80	0.12	0.1	6.900	3.100	8.59	866	86.4
AUG 12/93	23.2	15.0	268.0	2.160	27.00	0.36	0.1	7.150	3.330	8.82	804	86.6
AUG 19/93	22.5	1.2	238.0	15.200	26.80	0.12	0.4	7.600	5.020	7.47	994	83.5
AUG 26/93	21.3	2.2	126.0	23.400	34.20	0.05	0.2	6.600	4.030	7.70	1204	96.3
SEP 02/93	19.5	3.5	123.0	19.100		0.01	0.1	6.700	3.860	7.77	1027	85.2
SEP 09/93	17.2	1.9	111.0	17.500	43.30	0.17	0.3	17.000	11.700	7.66	1297	96.0
SEP 14/93	19.0	2.5	163.0	17.600	38.20	0.15	0.1	17.000	12.100	7.78	1241	89.2
SEP 23/93	13.8	2.1	528.0	28.800	62.80	0.09	0.1	19.600	10.100	6.45	1370	116.0
SEP 28/93 *	12.4	1.1	186.0	29.900	61.00	0.15	0.1	14.800	10.800	7.53	1720	194.0
OCT 07/93	12.9	1.9	240.0	24.000	57.30	0.17	0.1	16.300	11.800	7.49	1730	151.0
OCT 14/93	7.6	1.8	306.0	17.500	45.70	0.04	0.1	13.000	8.600	7.60	1370	86.6
OCT 21/93 *	12.4	4.6	34.3	1.200	5.25	0.04	0.3	2.350	1.260	7.57	1066	144.0
OCT 28/93	7.6	1.2	66.0	8.920	16.80	0.01	0.1	6.300	3.700	7.49	1204	122.0
MIN	7.6	1.1	8.4	0.004	1.03	0.01	0.1	0.153	0.086	6.45	564	25.1
MAX	26.7	15.0	528.0	29.900	62.80	0.50	14.4	19.600	12.100	8.98	1730	194.0
AVG	18.6	6.2	133.8	10.044	23.79	0.14	1.8	7.163	4.466	7.96	1017	83.7
GEOM			69.5	2.237	11.47	0.08	0.3	3.249	1.895	7.94	963	71.7

SITE C7 - CATFISH CREEK, CON X LOT 17/18

DATE	Temp °C	D.O.	Susp. Solids	Free NH_3	Total KJELD	NO_2	NO_3	Total Phos.	Diss. Reactive	pH	µmho/cm @ 25C	Cl^-
JUN 10/93 *	18.3		23.2	0.128	1.25	0.15	19.9	0.132	0.074	8.28	712	34.2
JUN 17/93	24.8		15.3	0.011	0.78	0.11	5.2	0.036	0.014	8.34	524	29.5
JUN 24/93 *	22.8	6.8	29.7	0.027	0.92	0.10	11.9	0.092	0.035	8.40	695	26.2
JUL 01/93	17.5	13.0	9.4	0.029	0.80	0.12	7.9	0.055	0.032	8.26	664	32.6
JUL 08/93	30.2	15.0	11.5	0.009	0.90	0.09	0.7	0.062	0.016	8.70	469	33.8
JUL 15/93	30.4	15.0	7.1	0.014	1.08	0.01	0.1	0.089	0.031	9.07	388	36.2
JUL 22/93	31.4	15.0	12.6	0.033	1.15	0.01	0.1	0.090	0.021	8.72	437	28.8
JUL 29/93												
AUG 05/93	18.8	7.0	66.5	0.070	1.74	0.01	0.1	0.220	0.045	8.00	613	48.7
AUG 12/93	20.4	10.6	79.5	0.455	3.20	0.02	0.1	0.360	0.039	7.97	626	54.5
AUG 19/93	23.1	9.0	55.0	0.274	2.50	0.01	0.1	0.310	0.034	7.56	744	96.6
AUG 26/93	22.3	4.6	31.8	0.261	1.61	0.02	0.1	0.136	0.030	8.09	749	96.6
SEP 02/93	17.2	3.4	99.3	0.208	1.83	0.01	0.1	0.285	0.041	7.70	809	114.0
SEP 09/93	16.4	7.2	60.0	0.017	2.00	0.01	0.5	0.247	0.031	7.12	725	124.0
SEP 14/93	19.4	4.3	54.1	0.091	1.85	0.01	0.1	0.260	0.018	7.71	749	101.0
SEP 23/93	14.0	5.9	114.0	0.146	2.80	0.02	0.1	0.480	0.039	7.71	747	115.0
SEP 28/93 *	10.6	10.4	46.8	0.051	1.85	0.01	0.1	0.255	0.068	7.92	716	98.5
OCT 07/93	13.5	10.1	51.5	0.209	1.60	0.02	0.1	0.165	0.034	7.91	730	105.0
OCT 14/93	7.3	12.3	33.2	0.045	1.30	0.01	0.1	0.112	0.055	7.76	706	82.2
OCT 21/93 *	12.4	11.4	35.8	0.214	2.24	0.19	3.1	0.398	0.220	7.84	1120	197.0
OCT 28/93	5.1	12.7	17.8	0.179	1.71	0.14	1.9	0.161	0.051	7.81	1103	153.0
MIN	5.1	3.4	7.1	0.009	0.78	0.01	0.1	0.036	0.014	7.12	386	26.2
MAX	31.4	15.0	114.0	0.455	3.20	0.19	19.9	0.480	0.220	9.07	1120	197.0
AVG	18.8	9.7	42.7	0.124	1.66	0.05	2.6	0.197	0.046	8.04	701	80.4
GEOM			32.5	0.070	1.53	0.03	0.4	0.159	0.037	8.03	679	66.8

SITE CL1 - 19 MILE CREEK, HWY #3 NEW SARUM W

DATE	Temp °C	D.O.	Susp. Solids	Free NH_3	Total KJELD	NO_2	NO_3	Total Phos.	Diss. Reactive	pH	µmho/cm @ 25C	Cl^-
JUN 10/93 *	17.5	0.5	29.3	0.437	1.13	0.30	6.1	0.345	0.221	7.95	730	71.2
JUN 24/93 *	17.5	7.0	13.3	0.007	0.83	0.14	4.6	0.184	0.130	7.89	746	77.8
JUL 08/93	23.8	4.5	12.4	0.050	0.68	0.02	0.1	0.102	0.040	7.87	786	123.0
JUL 22/93	16.2	6.8	18.3	0.041	0.76	0.01	0.1	0.088	0.026	7.89	956	160.0
AUG 05/93	15.8	7.0	5.0	0.131	2.31	0.03	1.6	0.330	0.019	7.92	955	157.0
AUG 19/93	19.1	3.8	22.7	0.230	1.38	0.01	0.1	0.132	0.063	7.57	937	154.0
SEP 02/93	17.2	4.6	18.9	0.158	1.02	0.05	0.1	0.200	0.089	7.78	834	129.0
SEP 14/93	19.4	4.3	7.2	0.015	0.62	0.01	0.1	0.083	0.032	8.06	842	133.0
SEP 28/93 *	11.3	8.6	7.3	0.031	0.82	0.05	1.8	0.080	0.044	7.91	925	133.0
OCT 14/93	5.5	11.9	10.4	0.005	0.59	0.01	0.4	0.137	0.101	7.70	661	98.9
OCT 28/93	8.5	12.8	8.1	0.031	0.59	0.01	0.1	0.119	0.074	7.94	980	154.0
MIN	5.5	0.5	5.0	0.005	0.59	0.01	0.1	0.080	0.019	7.57	661	71.2
MAX	23.8	12.8	29.3	0.437	2.31	0.30	6.1	0.345	0.221	8.06	980	160.0
AVG	15.6	6.5	13.9	0.103	0.98	0.06	1.4	0.164	0.076	7.86	850	126.4
GEOM			12.1	0.046	0.89	0.03	0.4	0.144	0.060	7.86	844	122.3

SITE CL2 -19 MILE CREEK, CON VII YARMOUTH

DATE	Temp °C	D.O.	Susp. Solids	Free NH_3	Total KJELD	NO_2	NO_3	Total Phos.	Diss. Reactive	pH	µmho/cm @ 25C	Cl^-
JUN 17/93			14.9	0.051	0.69	0.04	1.4	0.089	0.064	8.07	687	70.9
JUL 01/93	15.2	6.0	29.8	0.054	0.64	0.03	0.9	0.104	0.048	8.05	684	74.9
JUL 15/93	18.7	4.2	40.9	0.047	0.68	0.01	0.1	0.111	0.022	7.72	602	59.9
JUL 29/93	21.9	3.2	70.6	0.060	0.47	0.05	0.1	0.127	0.030	7.67	579	61.1
AUG 12/93	19.3	5.8	95.1	0.150	0.93	0.01	0.1	0.240	0.046	7.70	495	21.7
AUG 26/93	20.5	5.1	59.5	0.106	0.68	0.02	0.1	0.146	0.029	7.96	465	13.2
SEP 09/93	14.2	8.9	36.6	0.008	0.68	0.02	1.1	0.140	0.059	7.96	724	103.0
SEP 23/93	14.8	6.7	15.2	0.015	0.50	0.01	0.1	0.080	0.021	7.90	609	57.2
OCT 07/93	10.3	8.6	10.4	0.037	0.43	0.01	0.1	0.066	0.024	7.76	697	85.0
OCT 21/93 *	11.8	9.8	20.9	0.095	0.92	0.07	0.8	0.260	0.147	7.83	772	108.0
MIN	10.3	3.2	10.4	0.008	0.43	0.01	0.1	0.066	0.021	7.67	65	13.2
MAX	21.9	9.8	95.1	0.150	0.93	0.07	1.4	0.260	0.147	8.07	772	108.0
AVG	16.3	6.5	39.4	0.062	0.66	0.03	0.5	0.136	0.049	7.86	631	65.5
GEOM			5.6	0.217	0.80	0.14	0.5	0.353	0.201	2.80	25	7.5

* - High Flow Event

APPENDIX B

WATER QUALITY QUESTIONNAIRE

THIS QUESTIONNAIRE IS STRICTLY CONFIDENTIAL.

NAME: ______________________________ DATE: _____________
ADDRESS: __________________________ PHONE: _____________
__________________________ TOWNSHIP: _____________
__________________________ LOT/CON: _____________
DRAIN SITE: _____________________

SECTION 1: CROPS AND DRAINAGE

TOTAL FARM ACRES: _____________

CROP	# OF ACRES	ACRES TILED	RANDOM (%)	SYSTEMATIC (%)
________	__________	_________	_________	___________
________	__________	_________	_________	___________
________	__________	_________	_________	___________
________	__________	_________	_________	___________
________	__________	_________	_________	___________
________	__________	_________	_________	___________

SECTION 2: TYPE OF ENTERPRISE

LIVESTOCK	NUMBER		
DAIRY	COWS ______	CALF _____	HEIFERS ______
BEEF	COWS ______	CALF _____	SLAUGHTER STEERS _____
SWINE	FARROWING _____	FEEDER _____	
POULTRY	BROILERS ______	LAYERS ______	BREEDERS _____
HORSES	______		
SHEEP	______		
OTHER	____		
CROPS	CHECK CROPS WHERE MANURE IS USED AS FERTILIZER		

CROPS   CHECK CROPS WHERE MANURE IS USED AS FERTILIZER

______   _____   Indicate liquid or solid manure.

______   _____

______   _____

______   _____

______   _____

______   _____

SECTION 3: MANURE MANAGEMENT

SOLID MANURE

MANURE STORED: INSIDE ______   OUTSIDE _____   ON PAD _____

IN FEEDLOT _____   ON GROUND _____

PAD DIMENSIONS   _______________

A) HOW OFTEN IS PAD SCRAPED? _______________

B) ARE THERE WALLS AROUND PAD?   YES _____   NO ____

C) IS THERE RUNOFF CONTAINMENT ?   YES _____   NO ____

IF YES, TYPE?   POND ____   TANK ____   CAPACITY ________

DIMENSIONS _________________

DAYS STORAGE: ____________

D) HOW CLOSE IS THE NEAREST TILE OR OPEN DITCH? ______________

LIQUID MANURE

COVERED TANK _____   OPEN TANK _______   EARTHEN PIT _______

DIMENSIONS __________________________

CAPACITY _____________________________

DAYS STORAGE: _________

HOW CLOSE IS THE NEAREST OPEN DITCH OR CREEK? ______________________

F) DO YOU SPREAD ON YOUR OWN PROPERTY OR ON NEIGHBOURS AS WELL? _____

G) WHAT 2 SOURCES OF INFORMATION ARE THE MOST USEFUL TO YOU CONCERNING MANURE MANAGEMENT AND STORAGE?

DEMONSTRATIONS ___ EQUIPMENT DEALERS ______

FACT SHEETS ____ FARM NEWSPAPERS/MAGAZINES ____

OMAF CANADA PLAN INSURANCE ____

ONTARIO AGRICULTURAL CODE OF PRACTICE ____

OTHER ___________________________________

H) HOW FAR IS YOUR WELL FROM YOUR MANURE STORAGE? ______________

SECTION 4: FEEDLOT/CEMENT YARD/EXERCISE YARD

NUMBER OF AND TYPE OF ANIMALS USING FEEDLOT/YARD? ___________________

____

DIMENSIONS OF LOT/YARD: ______________________

IS THE YARD ROOFED? ? YES _____ NO ____

PAVED? YES _____ NO ____

EAVESTROUGHS? YES _____ NO ____

RETAINING WALLS? YES _____ NO ____

RUNOFF CONTAINMENT? YES _____ NO ____

IF YES, DESCRIBE: ____

DISTANCE TO NEAREST TILE OR OPEN DITCH: _______________________

NUMBER OF MONTHS IN USE: _________________________

HOURS PER DAY USED: ___________ NUMBER OF CLEANOUTS PER YEAR: ________

SECTION 5: MANURE APPLICATION

TYPE OF APPLICATION ____________________

TIME OF APPLICATION SPRING ___ SUMMER ________

FALL ____ WINTER ________

AA) LENGTH OF OPEN DITCH ON FARM _____________________

A) HOW MANY ACRES ARE SPREAD WITH MANURE? _________________

B) IS THE LAND TILLED BEFORE SPREADING? ____________________

C) ESTIMATE THE RATE OF APPLICATION:

______ GAL/ACRE _____ TONS/ACRE

D) IS THE MANURE WORKED IN AFTERWARDS? YES _____ NO ____

IF YES, HOW SOON AFTERWARDS? ___________________

E) DO YOU HAVE YOUR SOIL TESTED? YES _____ NO ____

IF YES, HOW OFTEN? _________________

F) TYPE OF SOIL: ____________________

G) DO YOU HAVE YOUR MANURE ANALYZED: YES _____ NO ____

IF YES, HOW OFTEN? __________________

H) HOW MUCH VALUE DO YOU FEEL MANURE HAS IN YOUR OPERATION?

NO VALUE ____ MINOR VALUE _____ MODERATE VALUE _______

CONSIDERABLE VALUE _____ VERY GREAT VALUE ____

WHY? ____________________________________

SECTION 6: STORAGE IMPROVEMENTS

A) HAVE YOU CHANGED OR IMPROVED YOUR HANDLING OR STORAGE SYSTEM IN THE LAST 5 YEARS? YES _____ NO ____

IF YES, WHY DID YOU MAKE THE CHANGES? _______________

B) DO YOU FEEL OTHER IMPROVEMENTS ARE REQUIRED? YES _____ NO ____

EXPLAIN: ___________________________________

IF NO:

C) WOULD YOU BE INTERESTED IN IMPROVING OR CHANGING YOUR MANURE STORAGE SYSTEM?

IF YES, WHY? ____

IF NO, GIVE REASONS: ECONOMIC ___ NEAR RETIREMENT _______

OPERATION TOO SMALL ______ NOT REQUIRED ________

INSUFFICIENT ON FARM BENEFITS _____

OTHER ____

D) IF GRANTS WERE AVAILABLE WOULD YOU UPGRADE THE PRESENT MANURE STORAGE SYSTEM?

YES _____ NO ____

SECTION 7: DAIRY

TYPE OF SYSTEM: PIPELINE _____ PARLOUR _____

WHAT HAPPENS TO THE WASH WATER?

SEPTIC TANK ___ HOLDING TANK _____ LAGOON _______

MANURE STORAGE SYSTEM __ TILE DRAIN _____ TRENCH ______

OTHER ____

SECTION 7B: VOLUME OF WASHWATER \ MILKING

NO OF CYCLES PER DAY: _______________

IS THE FIRST RINSE FED TO CALVES? YES _____ NO ____

IF NO, WHY NOT? _________________________

ADDITIONAL COMMENTS: PLEASE GIVE YOUR COMMENTS ON THE FOLLOWING

ALGAL BLOOMS

FISH KILLS

SEDIMENTATION LOADING

OXYGEN DEPLETION

WATER QUALITY

APPENDIX C
EQUIVALENT ANIMAL UNITS (EAU)

ANIMAL TYPE	WEIGHT (kg)	EAU P*	EAU FC**
BEEF			
Beef Cow	455	1.04	1.04
Slaughter Steer	455	1	1
Yearly Beef	365	0.78	0.71
Beef Calf	180	0.53	0.48
DAIRY			
Dairy Cow	-	1.5	1.62
Dairy Heifer	318	0.75	0.71
Dairy Calf	136	0.46	0.36
SWINE			
Sow/Boar	-	0.6	-
Feeder Pig	22-99	0.4	-
SHEEP	45	0.17	0.02
TURKEY	5	0.03	0.03
CHICKEN/DUCK	2	0.02	-
HORSE	455	1.2	0.01

* P = Phosphorus,

** FC = Faecal Coliform

Source: Ecologistics 1988.

APPENDIX D

MANURE PRODUCTION PER DAY BY ANIMAL TYPE

ANIMAL TYPE	PRODUCTION (m^3/day)
BEEF or DAIRY	
Calf (6-15 months)	0.02
Juvenile (15-24 months)	0.02
Beef cows (550 kg)	0.03
Dairy cows - free stall	0.06
Dairy cows - tie stall	0.06
SWINE	
Weaners	0
Feeders	0.01
Sows + litters	0.17
POULTRY-	
Chickens - broilers	0
Turkeys - broilers	0
Turkeys - breeders + toms	0
SHEEP	0
HORSES	0.06

Source: OMAF Factsheet 1983, Agdex 400/721.
"Sizing of Manure Storages".

APPENDIX E

AVERAGE FAECAL COLIFORM DENSITIES IN ANIMAL FECES

ANIMAL TYPE	FAECAL COLIFORM per gram	FAECAL COLIFORM per m^3
Cattle	5.0×10^{5}	5.0×10^{11}
Swine	1.0×10^{7}	1.0×10^{13}
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}

Source: Mike Young, MOE, Toronto.

APPENDIX F

NEWSPAPER ARTICLE: AYLMER EXPRESS (August 18,1993)

CURB project looks at water quality in Elgin

by Sue Bachner
of The Aylmer Express

For three months Don Depuydt has been taking weekly water samples from Elgin county streams and has been counting the number of E. coli bacteria living in it.

He is doing research for Clean Up Rural Beaches (CURB), a joint project of Catfish Creek and Kettle Creek conservation authorities that aims at improving water quality in Elgin County.

The program was created in the early 1980s, when the two authorities and the general public were concerned about beach closures due to high bacteria counts. They approached Ministry of Environment to do something.

This year, the Ministry contributed $40,000 for research and water quality monitoring.

The program is in its second and final year of research, to determine which areas of the watersheds are the worst, and what can be done to reduce bacteria counts.

Mr. Depuydt has been taking 15 samples a week since June in both watersheds, and will continue until October.

He says dry weather has lowered his bacteria counts. Water sources are drying up. Bacteria stay in the sediments and can live there for a few months. Without rain, the water is not getting barnyard runoff, or flushes of manure. "But once it rains, you get really high counts."

The highest counts have been in the northern regions, where livestock farming is prominent. The guideline for closing a beach is a bacteria count of 100 per 100 millilitres of water. In livestock areas, he has counted as many as 800 to 1200.

In southern cash crop regions of Elgin county, he counts 175 to 350.

To explore possible sources of the problem, he is conducting a confidential survey with farmers. He visits the property to see how the establishment operates. He looks for what happens to wash water, for example, and where manure is stored. On a livestock farm, he pays close attention to "whether they have a pasture near a stream-- can they (livestock) defecate in the streams?"

This gives him a chance to educate the farmers, and to keep a record of what areas need guidance the most.

Farmers have been co-operative, says Mr. Depuydt.

Since June, only 2 or 3 did not want to participate. "Most of them want to see what's available (for improvement). Many of them want to do their part for the environment."

So far, the biggest contributing factor to bacteria in water is livestock access to streams in Catfish Creek Conservation Authority. For Kettle Creek, it seems to be milkhouse water.

Next year, conservation authorities will begin implementing water resource management measures. Once they know which areas to target for improvement, they will send Mr. Depuydt's recommendations to the Ministry. With future grants from the Ministry, they hope to be able to financially assist farmers who are willing to set up improvements such as manure storage facilities.