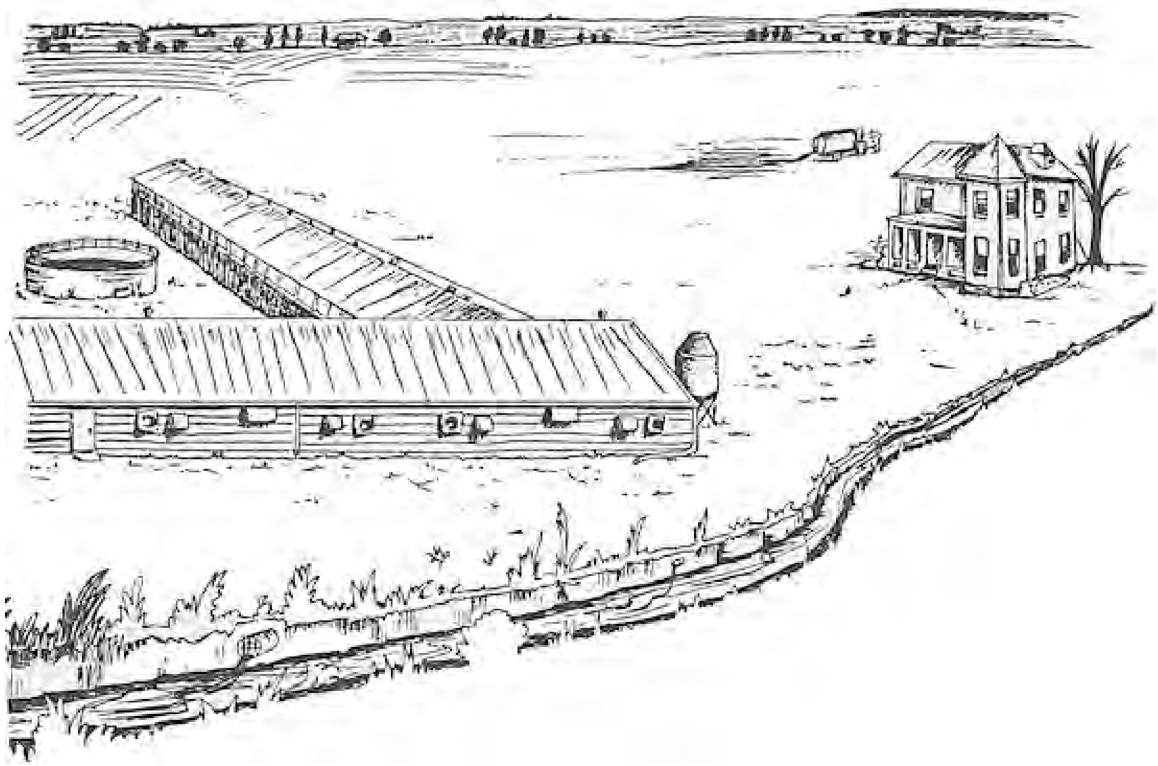
The Bear Creek Watershed
Water Quality Study
1988-89



St. Clair Region Conservation Authority
and the
Ministry of the Environment

The Bear Creek Watershed
Water Quality Study
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St. Clair Region Conservation Authority
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ACKNOWLEDGEMENTS

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SUMMARY

During the summer, fall and winter of 1988/1989, the microbiological and chemical quality of the water in Bear Creek upstream of the Warwick Conservation Area was assessed. The results indicate that the watercourse is carrying unacceptably high levels of bacteria, Total Kjeldahl Nitrogen, and phosphorus. In general, levels of bacteria were highest during the summer and early fall where they were present at approximately five to eight times the Ministry of the Environment (MOE) objectives for safe water. Fecal coliform levels at Warwick Conservation Area beach were also excessive during this period, coinciding with conditions in the creek.

This watershed was examined to investigate the influence of intensive farm operations, namely hog farms, on water quality. This area of Lambton County has been the source of numerous reports of pig manure spills over the years.

Weekly water sampling combined with a walking survey of the watercourse and interviews with local farmers, revealed several sources or suspected sources of the pollution. The sources are widespread throughout the watershed. Of the 10 tile outlets which were sampled and found to be polluted, 4 appeared to be from household septic systems, another 4 from agricultural fields, and another 2 from agricultural fields and barnyards. Thus, human and animal wastes are reaching the creek.

Stretches of the watercourse which recorded regularly high levels include the Perry Drain in the south part of the watershed, the mid-section of Bear Creek, the Zavitz Drain at the north end, and the Ross-Hall Drain in the north-east end.

Farmers appear to be acting in good faith by applying manure within OMAF guidelines. The average application rates were reported and calculated to be 3,000 to 4,000 gallons per acre. These figures undoubtedly vary widely depending on the time of year and the acreage on which the manure is spread. More than half of the farmers did not have 6 months storage and almost 60% were still applying manure in the winter months on frozen ground. Only half of the Dairy farmers had proper wash water treatment facilities.

A little over one quarter of the farmers may be over-fertilizing . Conservation tillage practices, buffer strips along drains, and windbreaks are not widely used in this watershed. However, there does appear to be a growing awareness and concern for the environment and the price tag it can carry.

CHAPTER 1

BACKGROUND

1.1 INTRODUCTION

Research has determined that today's modern agricultural operations and practices have a significant impact on surface water quality in southwestern Ontario. Pollutants can take the form of sediment from soil erosion and drainage practices, pesticides and chemicals, nutrients from fertilizers and manure and bacteria from manure and human waste.

Livestock operations in particular can have a significant input. Animal wastes can enter river systems through runoff from barnyards, feedlots, solid and semi-solid storages as well as from manure spread on fields. Contamination can also occur directly in cases where livestock have free access to a watercourse. Other sources of bacterial pollution include direct entry from overflowing liquid manure tanks, improperly managed manure irrigation systems, untreated milkhouse waste water, and improper septic hook-ups.

Hog operations are seen as one of the prime culprits in the agriculturally-induced water quality problem. This is because of the intensive nature of the operations and the difficulty of handling the comparatively large amounts of liquid manure which result. The particularly pungent odour associated with swine manure also draws negative attention to this industry.

Several complaints have been reported to the Ministry of the Environment Office in Sarnia over the years of suspected pig manure spills in Plympton, Warwick and Bosanquet Townships. Table 1 lists the location and date of these reports.

Table 1: Locations of suspected pig manure spills reported to the Ministry of the Environment Office in Sarnia from 1986 to 1989

Township	Lot and Con.	Month/Year
Plympton	Lot 28, Con. V	Nov. 1986
Warwick	Lot 18, Con. I	Nov. 1986
Plympton	Highland Creek	Jan. 1987
Bosanquet	R.R. 3 Thedford	Jan. 1987
Warwick	Lot 16 Con. III	Feb. 1987
Plympton	ditch along Hwy.7	Apr. 1987
Bosanquet	R.R.3 Thedford	Jun. 1987
Plympton	Lot 19 Con. XIV	Oct. 1987
Warwick	Lot 30 Con. V-VI	Oct. 1987
Plympton	Lot 43 Con. FLH	Oct. 1987
Bosanquet	Lot 10 Con. II	Nov. 1987
Warwick	Lot 26 Con. IV NER	Nov. 1987
Plympton	Lot 25 Con. VII NER	Dec. 1988

There were numerous reports of pig manure spills in the fall of 1987, but none in 1988. There were several complaints received by the MOE office in Sarnia throughout 1988, but all but one of these were unsubstantiated or very minimal incidents (Hutt, pers. comm. 1989). The only identified spill since the fall of 1987 was an incident in December of 1988.

Given this chronic history of spills and the generally poor reputation of hog farms in terms of water quality, a study seemed called for. This study was initiated by the St. Clair Region Conservation Authority to evaluate the influence of hog operations on water quality.

The presence of a large number of hog operations in the northwest corner of this Authority's watershed provided a good opportunity to investigate this situation. Approximately two-thirds of the hog operations in Lambton County are located in an area referred to as the "Hog Triangle" (Joanne Sanderson, OMAF, pers. comm. 1988). The towns of Thedford, Forest and Watford form the points of this triangle (see Figure 1).

After a preliminary survey of this region, the Bear Creek Watershed was selected for study for several reasons. Firstly, it forms the headwaters of the North Branch of the Sydenham River which is the major watercourse of the St. Clair Region Conservation Authority. Secondly, Bear Creek flows directly into the swimming reservoir at the Warwick Conservation Area. There have been complaints of poor water quality at this beach. Also, there is a large concentration of hog operations in this watershed. Finally, most of the Bear Creek was still flowing during the summer drought of 1988 while the smaller watercourses in the area were dry. This provided the opportunity to sample the water quality.

The overall goal of this study was to determine the influence of hog operations on water quality in the Bear Creek Watershed. The influence from other sources of pollution were also sought to determine the overall quality of the water in Bear Creek.

Funding and technical support were provided by the Ontario Ministry of the Environment, Southwest Region (M.O.E.).

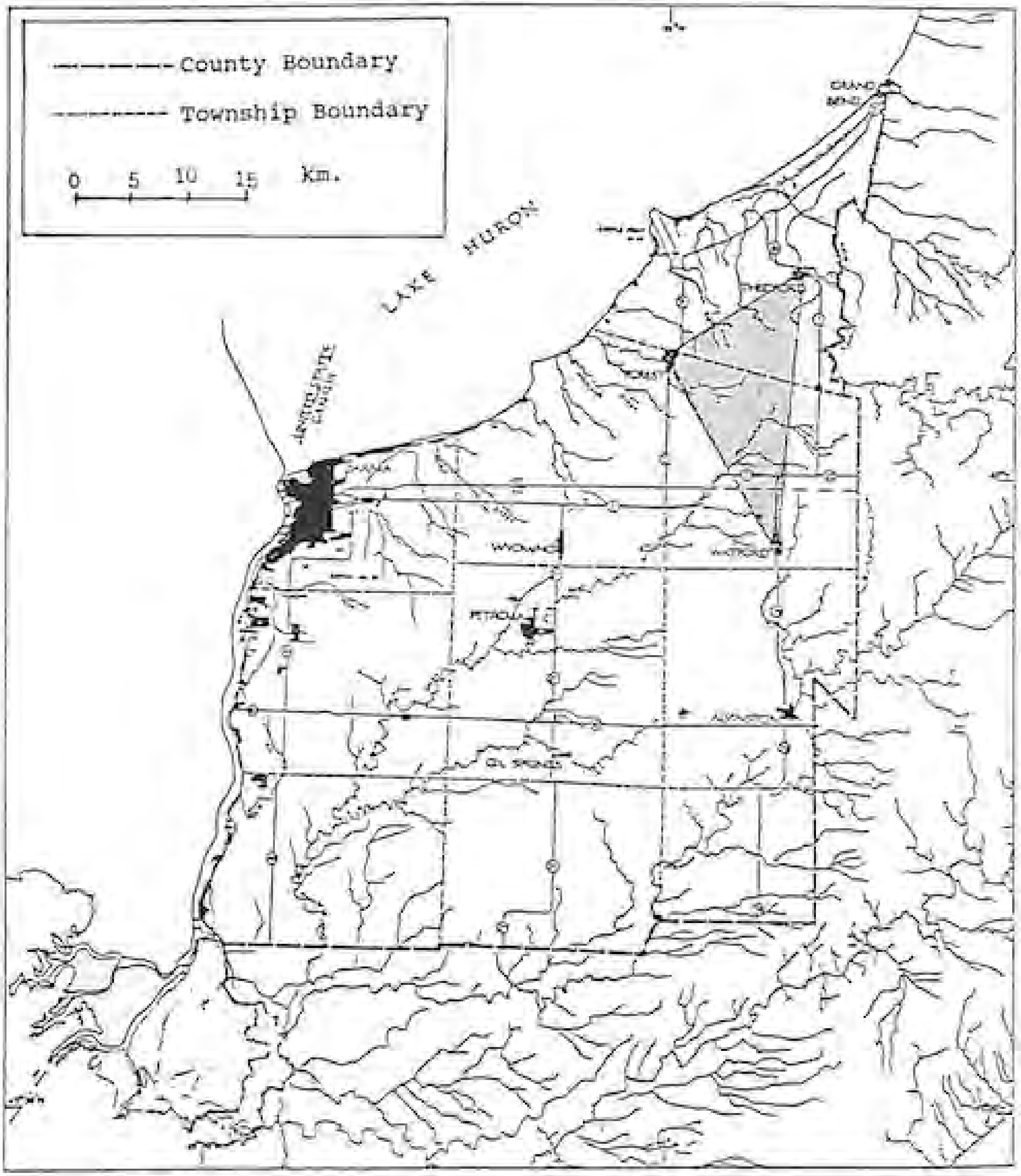


Figure 1: Location of the 'Hog Triangle' within Lambton County

1.2 THE BEAR CREEK WATERSHED

Location and land use:

The Bear Creek watershed is located in the northeast corner of Lambton County in the township of Warwick. Its situation within southern Ontario and the St. Clair Region Conservation Authority is illustrated in Figure 2. The watershed is bordered by the Village of Warwick to the southwest, the Lambton-Middlesex County line to the east and the Hamlet of Birnham to the north. It is approximately 77 square kilometers (30 square miles) in size. Figure 3 illustrates the lots and concessions, settlements and major roads in the area.

The land use in this watershed is predominantly agricultural. Hog operations are the most common type of livestock farm. Dairy and beef cattle operations are also abundant. Poultry and sheep/goat operations are smaller in number. Figure 4 illustrates the location and type of the livestock farms in the watershed. The list below displays the approximate number of each.

LIVESTOCK OPERATIONS:	28	HOG
	14	DAIRY
	14	BEEF CATTLE 8 POULTRY
	3	SHEEP/GOATS

A few non-agricultural businesses are located in the watershed as well, predominantly in the town of Warwick. These include a tree nursery, tractor dealer, pottery business, wood-working business and two variety stores. The other major industry is an aggregate excavating company located near Birnham.

Figure 2: The situation of the St. Clair Region Conservation Authority and Bear Creek within Southern Ontario

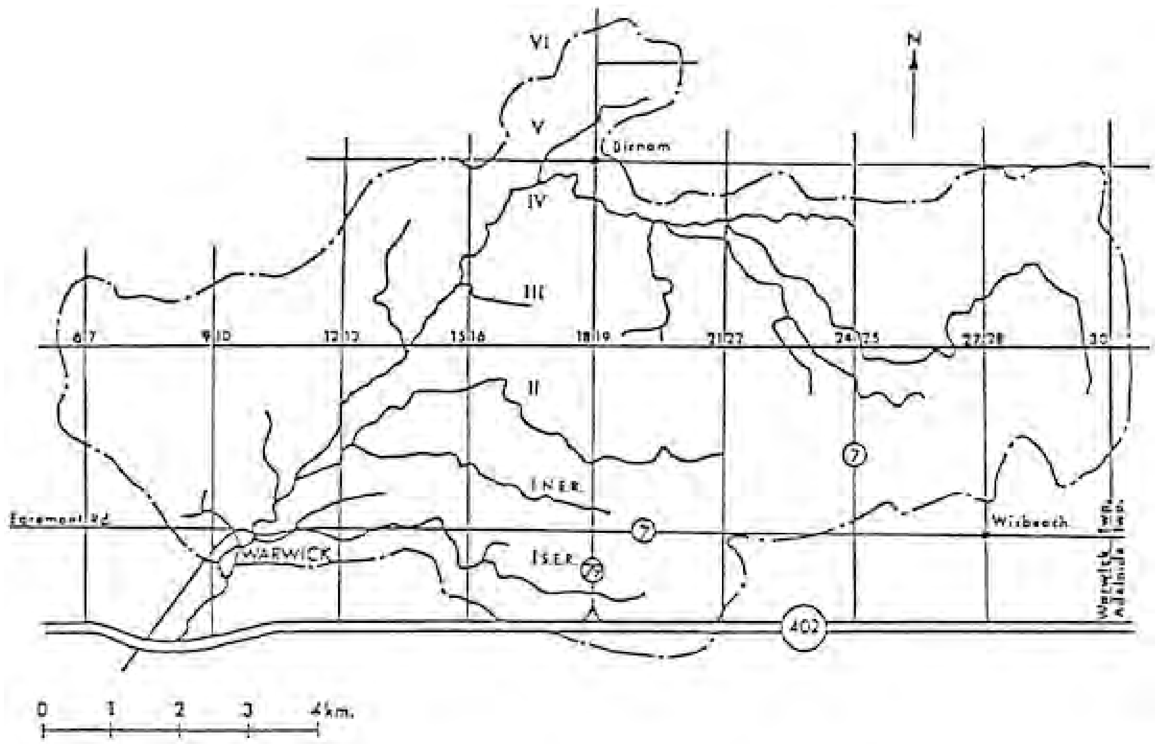


Figure 3: The Bear Creek watershed showing lots and concessions, settlements, and major roads.

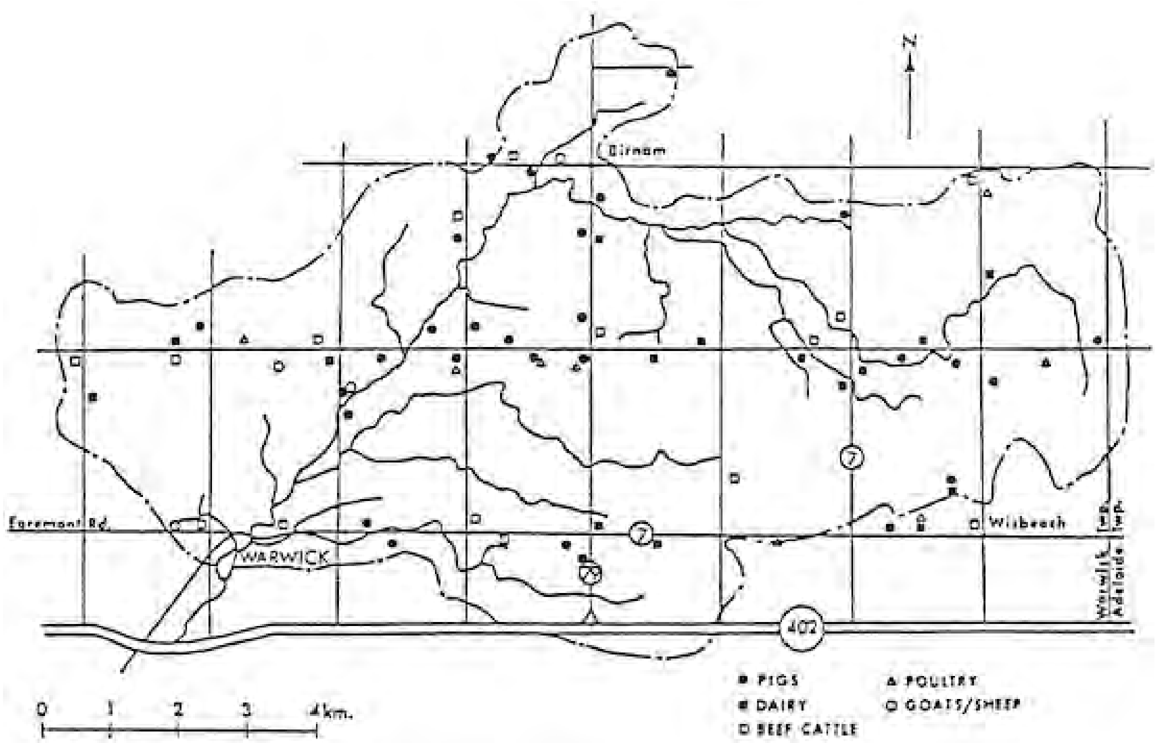


Figure 4: Location of livestock farms in the Bear Creek watershed

Geology and glacial history:

In southern Ontario the ancient granite and gneiss of the Canadian Shield is overlain by softer sedimentary limestones, shales and sandstones. These sediments were deposited 500 million years ago during the Paleozoic Era when warm salt seas covered much of North America. The sediments originated as marine sediments of marl, clay and sand and are the oldest rocks to harbour the petrified remains of primitive saltwater plants and animals. These seas also deposited great quantities of salt in Lambton County and in Michigan (Chapman and Putnam, 1984).

In the Bear Creek watershed, the bedrock geology is made up of the Hamilton and Kettle Point Formations (Figure 5). The Hamilton Formation consists of gray shale and argillaceous limestone reaching depths of 77 meters. Oil reserves are found at the base of this formation in the Petrolia area. The Kettle Point Formation is composed of dark bituminous shale and underlies most of Lambton County to a depth of 5 meters.

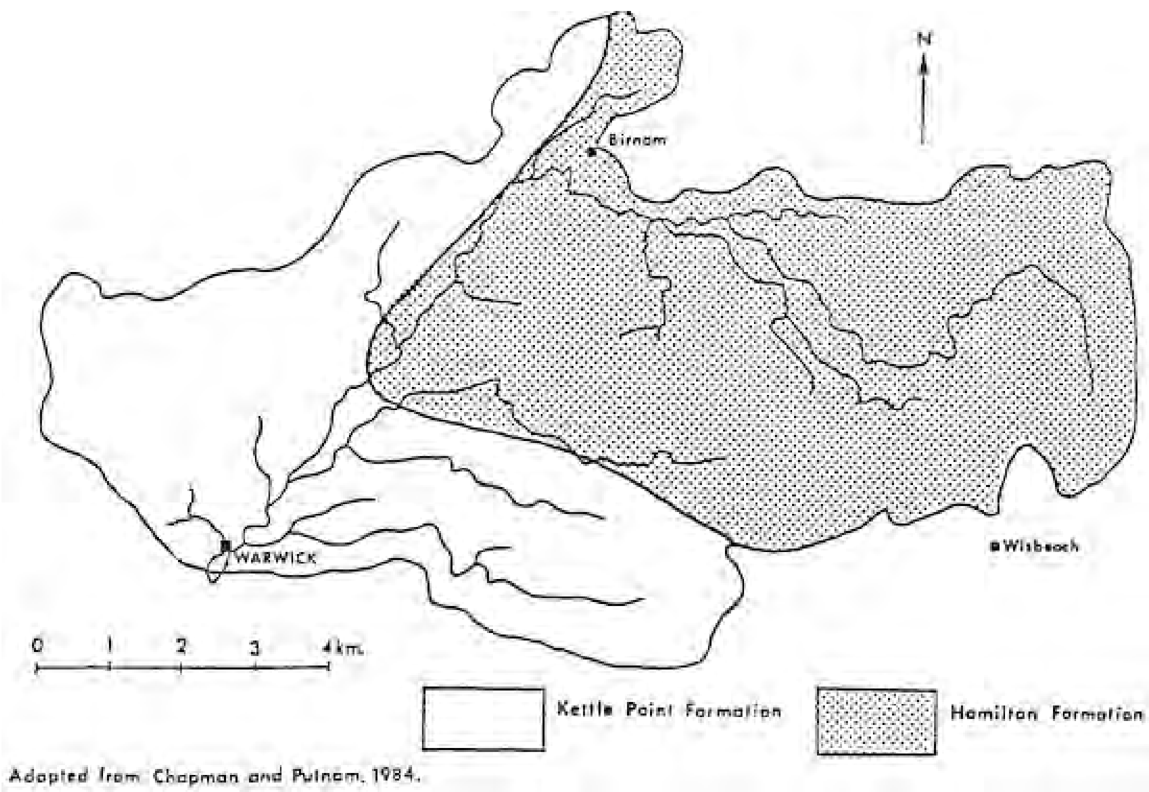


Figure 5: Bedrock geology of the Bear Creek watershed.

Following the retreat of these warm inland seas, the land rebounded and rose. Millions of years later, the climate cooled and glaciers formed and advanced southward. Because these sedimentary rocks were relatively soft and easily eroded, they yielded a good deal of material to the glaciers as they advanced over this area. This rock was crushed and eroded by the glacier and later deposited over the bedrock, giving southern Ontario some of the richest soil for agriculture.

The Wisconsin Glacier retreated from this part of southern Ontario between 10,000 and 12,000 years ago. After its retreat, a great glacial lake was formed, submersing the present-day Great Lakes Basin. As the climate changed, the lake receded and the land rebounded from its weight. It left behind the characteristic flat lake-bed topography and clay and sand plains we see today in this region.

The glaciers also deposited a great deal of material in the form of moraines, eskers and drumlins. Figure 6 illustrates the physiography of the Bear Creek Watershed. The Wyoming Moraine is a till deposit composed of clay, sand, pebbles and boulders. Although this Moraine is characterized by rolling hills in its northern range (Grey County), it forms low, smooth and broad clay ridges with sand plains near Warwick and Ailsa Craig (Chapman and Putnam, 1984, p. 178).

The Wyoming Moraine is also the predominant glacial landform giving relief in Warwick Township (Figure 7). The Wyoming Till Moraine and the Arkona Moraine both reach elevations of approximately 700 feet, while the Seaforth Moraine has an elevation of 800 feet. Due to the presence of these moraines, this watershed and Lambton County as a whole slope gently to the shore of Lake St. Clair in a south westerly direction.

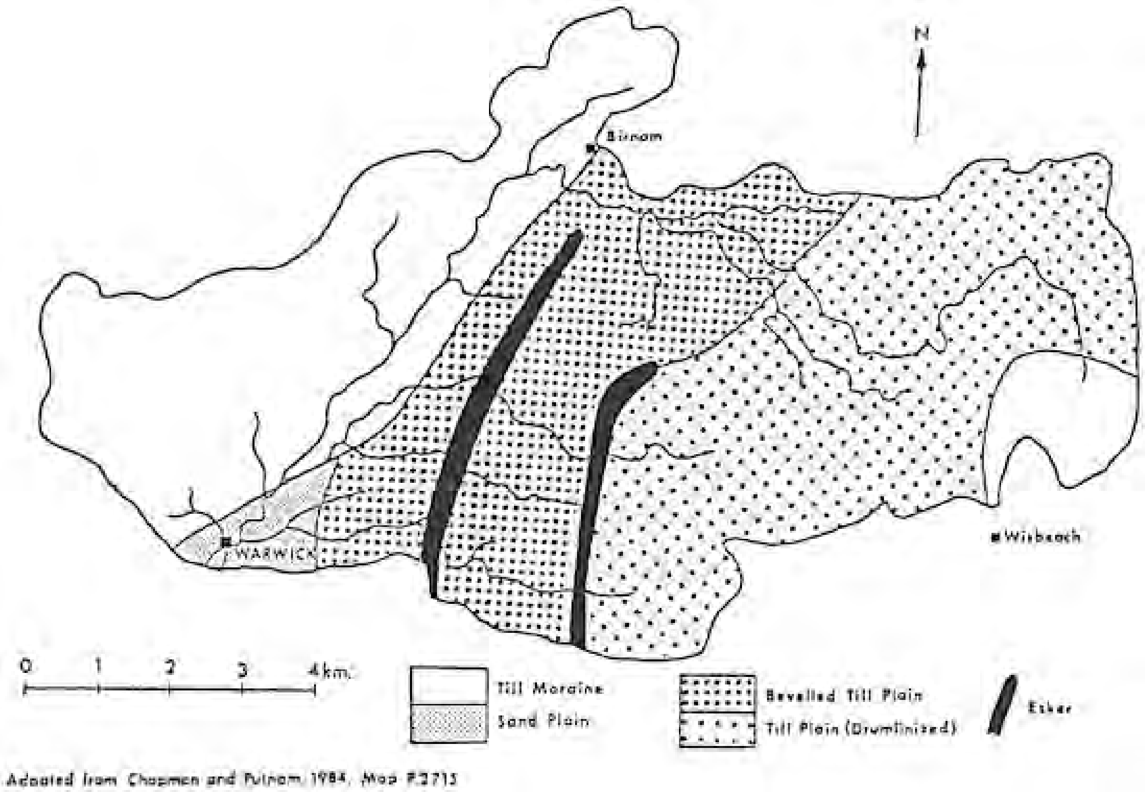


Figure 6: Physiography of the Bear Creek watershed

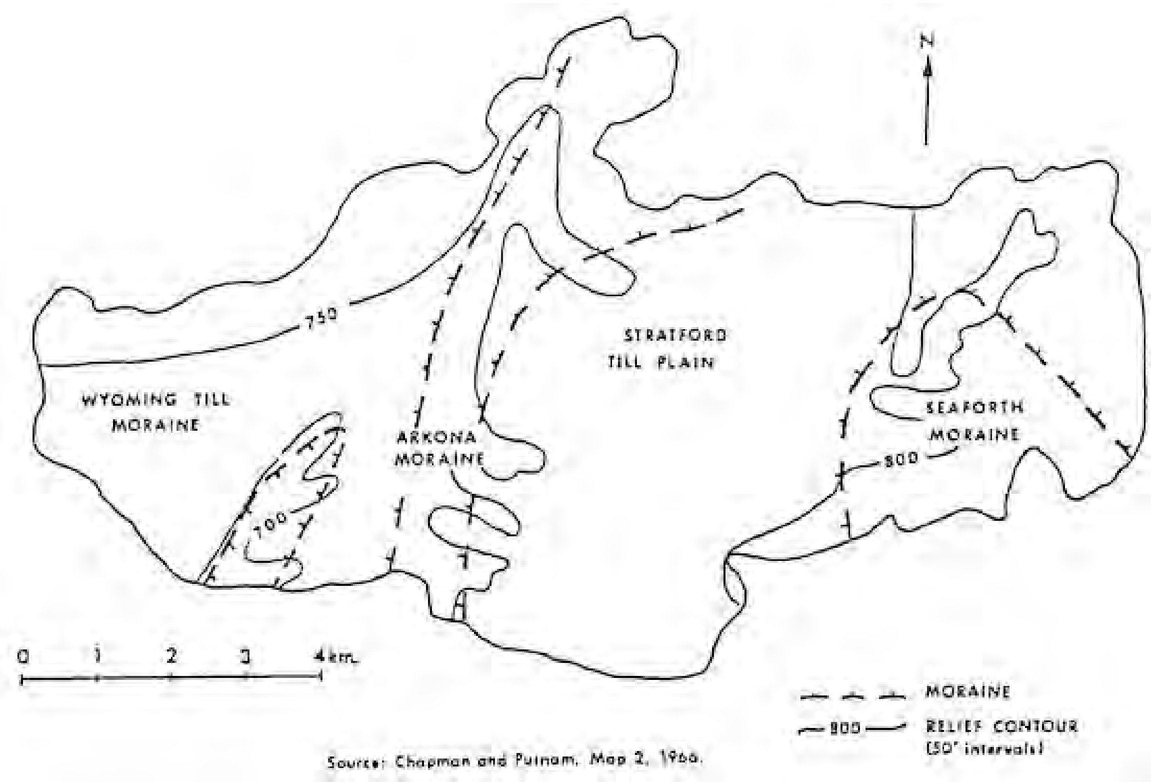


Figure 7: Relief of the Bear Creek watershed

Soils:

In the Bear Creek watershed, the soil is comprised primarily of glacial drift. Figure 8 illustrates the soil composition within this watershed. Perth and Huron clay soils of the Grey-Brown Podzolic Soil Group are the most common here.

The Perth soils, which predominate, are designated as a clay till. They are also classified as a Class 1 Soil having no significant limitations for crops (Dept. of Agriculture). Drainage is imperfect. The Huron soils are similar except that drainage is good (Mathews et al, 1957). The Huron soils are classified as a mixture of Class 1 and 3 due to some topographic limitations. The other major soil groups in this watershed include the Brisbane and Burford Loams. They are designated as Class 2 soils with some fertility and moisture limitations.

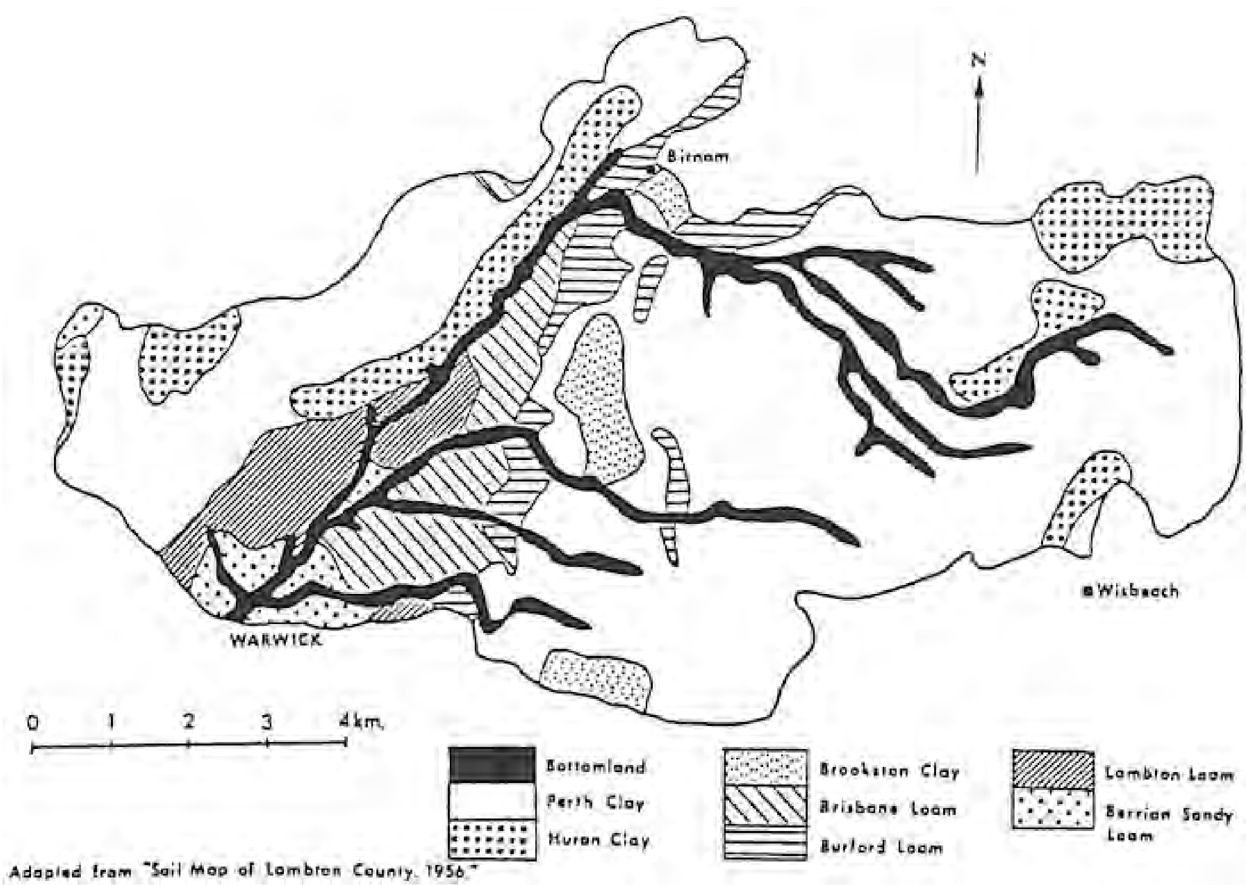


Figure 8: Soils of the Bear Creek watershed

Perth soils are well suited to the production of most crops except tree fruits and early vegetables. They usually have a large reserve supply of moisture in dry years. With some improvement in drainage, this soil yields good harvests of fall wheat and alfalfa. Corn, soybeans and spring grains yield fairly well even without artificial drainage. A crop rotation of hay and/or pasture is important to maintain organic matter.

The Huron series produces moderate to high yields of general farm crops when simple management practices are employed. The external drainage is rapid but internal drainage is slow due to underlying impermeable clay. These soils are well suited to the production of winter wheat, spring grains, alfalfa, clover and corn (City of Sarnia, 1972). In fact, these are the predominant crops grown in this watershed. Huron soils are also susceptible to erosion and hence cover crops are advised.

Drainage:

The Bear Creek watershed forms the upper basin of the north branch of the Sydenham River (Figure 9). The relief or slope in the Sydenham River watershed is very low. Along the east branch, the elevation drops only 100 meters over its 170 kilometer length (350 feet over 100 miles) and along the north branch it drops 75 meters over 140 kilometers (250 feet over 85 miles).

The flat topography and heavy clay soils result in sluggish streamflow and flooding problems in the Sydenham River watershed. Lack of gradient is also a problem in the Bear Creek watershed (S.V.C.A. 1965, Mr. Frank Kanters, pers. comm).

Figure 10 illustrates the drainage pattern of the Bear Creek and its associated tributaries and buried drains. In general, the tributaries carry water in a westerly direction to Bear Creek which in turn flows southwest to the Warwick Reservoir.

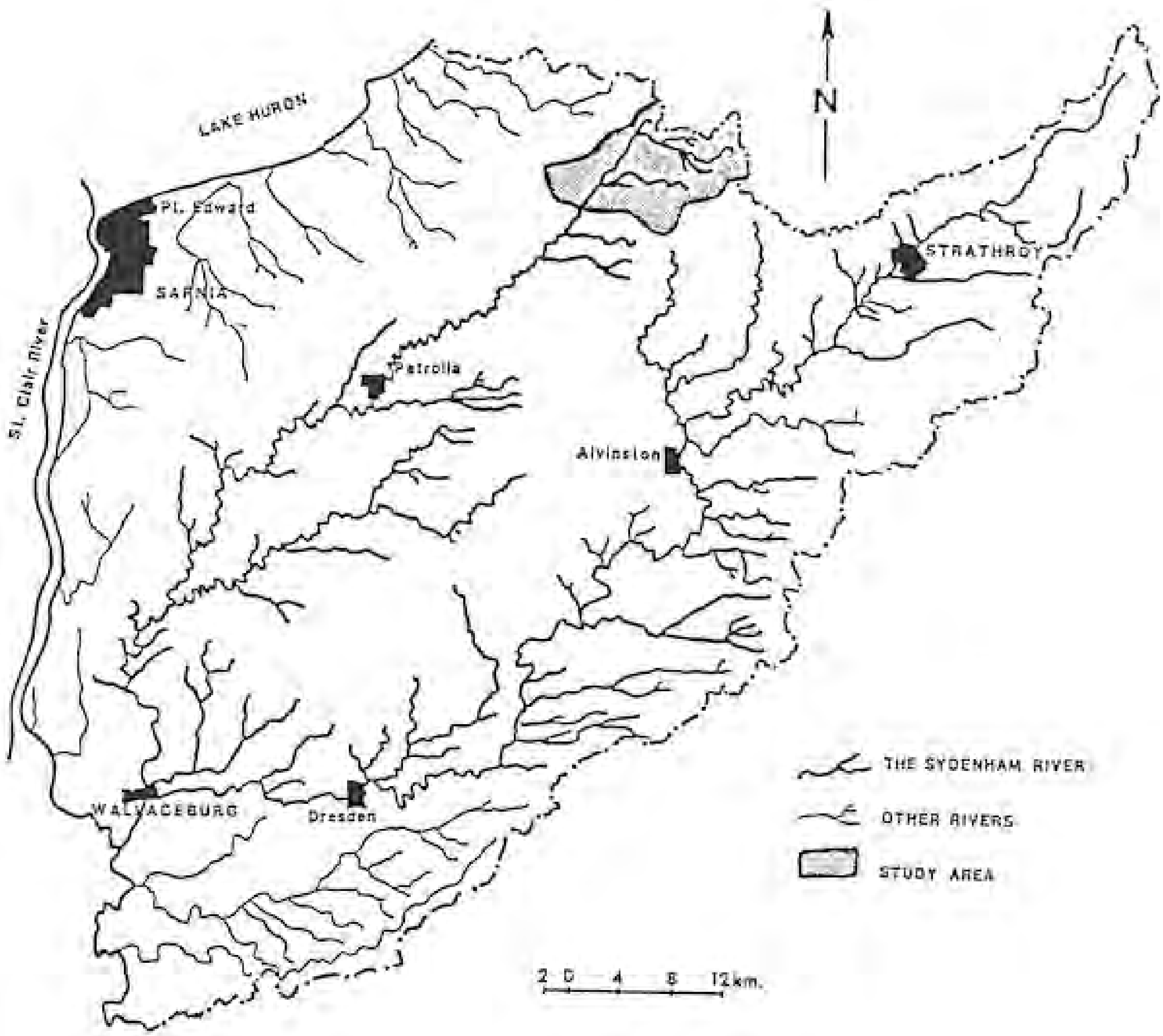
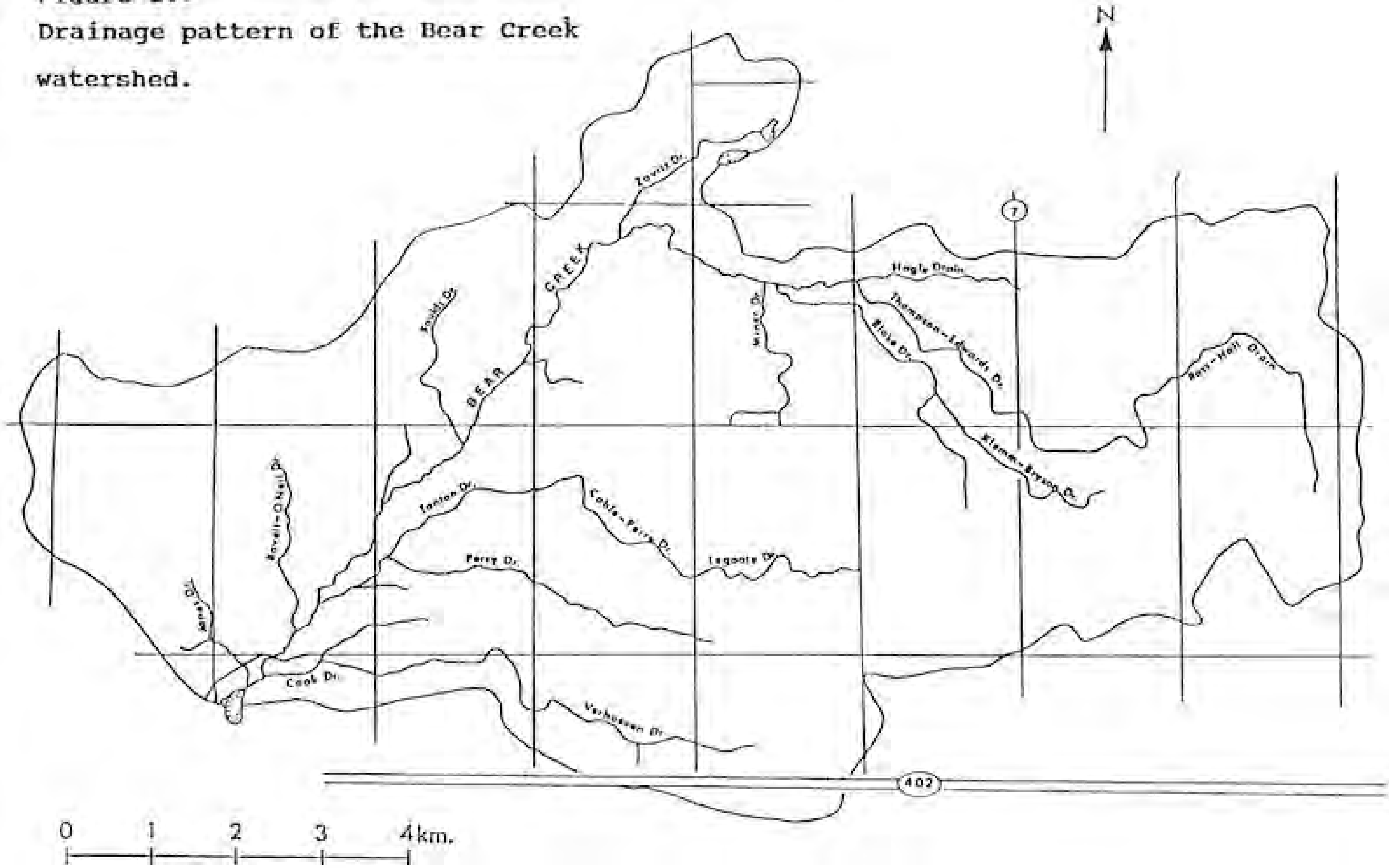


Figure 9: Location of the Bear Creek watershed along the Sydenham River and within the St. Clair Region Conservation Authority watershed.

Figure 10.
Drainage pattern of the Bear Creek watershed.



Ground water:

Despite the predominance of heavy clay soils throughout much of Lambton County, the presence of the Wyoming Moraine in the Warwick/Plympton area with its coarse grained sediments provides this area with adequate supplies of ground water at shallow depths. Most of the water in Lambton County is very hard (City of Sarnia, 1972, p 76), and the chemical quality seems to deteriorate across the County from east to west.

Artesian wells were common in the Warwick area at one time. However, heavy consumption by the Town of Thedford has lowered the water table considerably. Figure 11 illustrates the amount of variability in groundwater flow across the watershed. Most of the watershed has moderate to good flow.

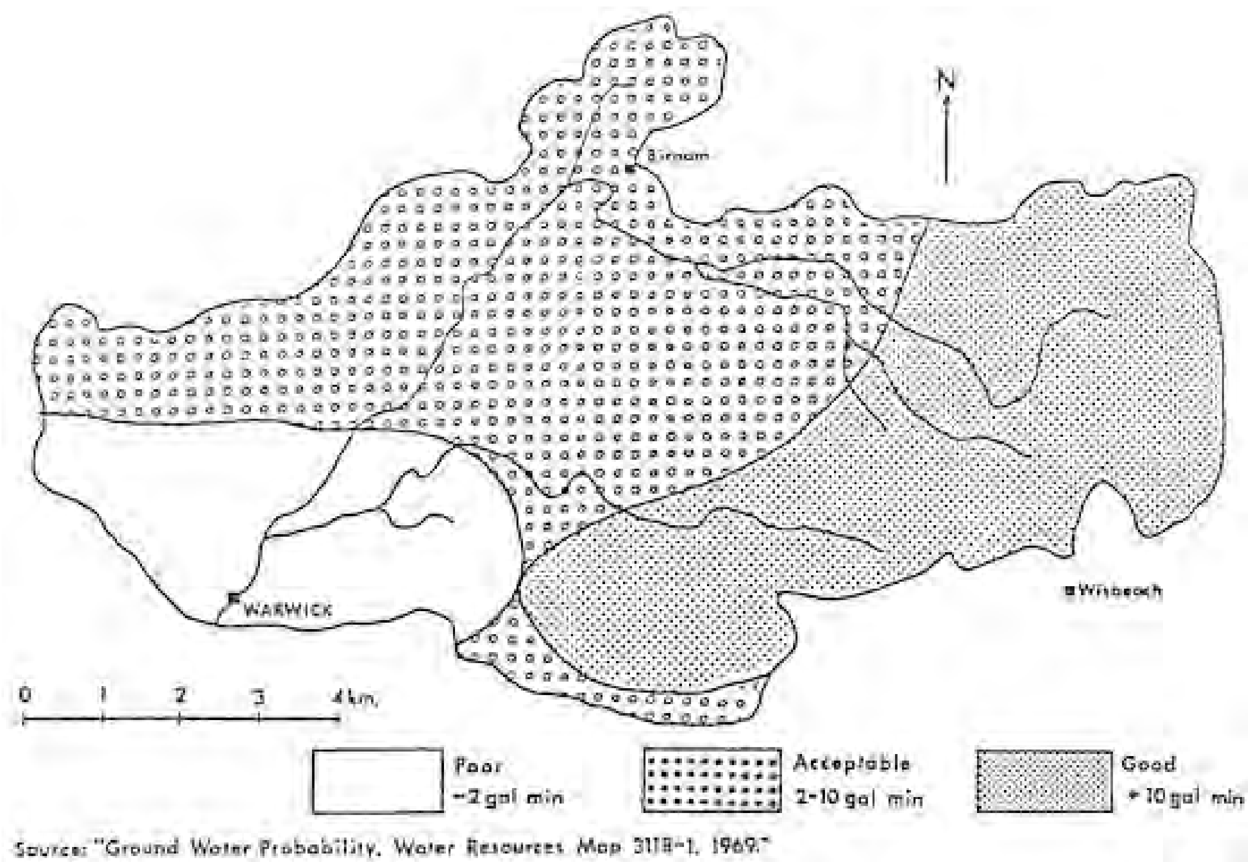


Figure 11: Ground water capability within the Bear Creek watershed

History:

The first people to inhabit this region of southwestern Ontario were the Huron, Neutral and Tobacco Indians. Warwick Township was transferred from the Indians to the white settlers between 1822 and 1827. The first known European settlers in Warwick Township were James and Robert Hume who arrived here in 1832. One year later in 1833, Sir John Colborne employed destitute people of the district to construct the Egremont Road from London to Errol. The Egremont Road bisected Warwick Township and allowed settlement in the Town of Warwick.

An Anglican Church was established in the Town of Warwick in 1843 and later in 1861 a Methodist Church was built. A salt mine was opened in the town in 1870. Salt mining and salt transportation were important in the early history of Lambton County. At Warwick, a private railway was constructed using wooden rails, oxen and horses to transport the salt to the mainline at Kingscourt.

Initially, people were reluctant to settle in Lambton County because of the presence of heavily wooded areas, swamps, swamp fever and the threat of American attack (City of Sarnia, 1972).

Climate:

Warwick Township is located in the warm and humid region of southwestern Ontario. The area is denoted by warm summers, mild winters and a long growing season with usually reliable rainfall. There are 211 days in the growing season (days over 6°C or 42°F) and 150 frost-free days in Warwick Township.

Due to the Lake effect Lambton County experiences significantly more cloud and precipitation and moderate temperatures than areas farther inland (Dept. of Transport, 1962 and 1967). Mean annual rainfall in the Warwick area is 76 - 86 centimeters or 30 - 34 inches.

The summer of 1988 was particularly dry and warm. The drought, however, did end in mid-July with the arrival of a major rainstorm. Figure 12 illustrates the temperature and rainfall levels over the course of this study period of June 1988 to March 31, 1989. The information presented represents the average weather conditions as reported from the Sarnia and London weather offices.

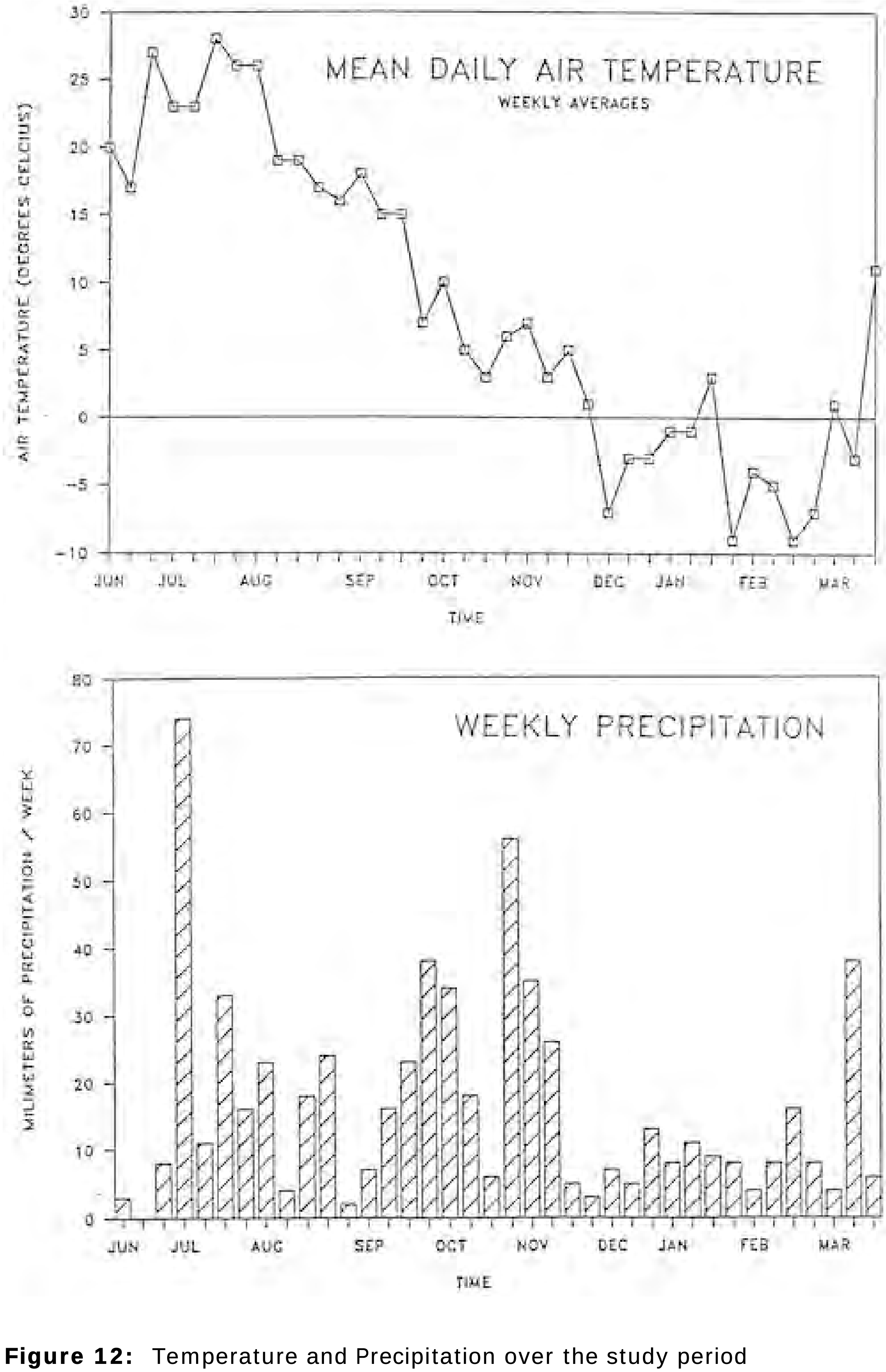


Figure 12: Temperature and Precipitation over the study period

CHAPTER 2

METHODS

To determine the quality of the water in Bear Creek and its tributaries, water samples were collected weekly from eleven MOE approved stations along the watercourse. Figure 14 illustrates the location of these stations.

Two sterilized bottles were filled at each station, one for bacterial analysis and the other for chemical analysis. Where possible, the samples were taken from the middle of the creek or drain where flow was greatest. Water depth in the creek was generally less than a foot (30 centimeters) in depth so the bottles were submerged only a few inches below the surface for filling.

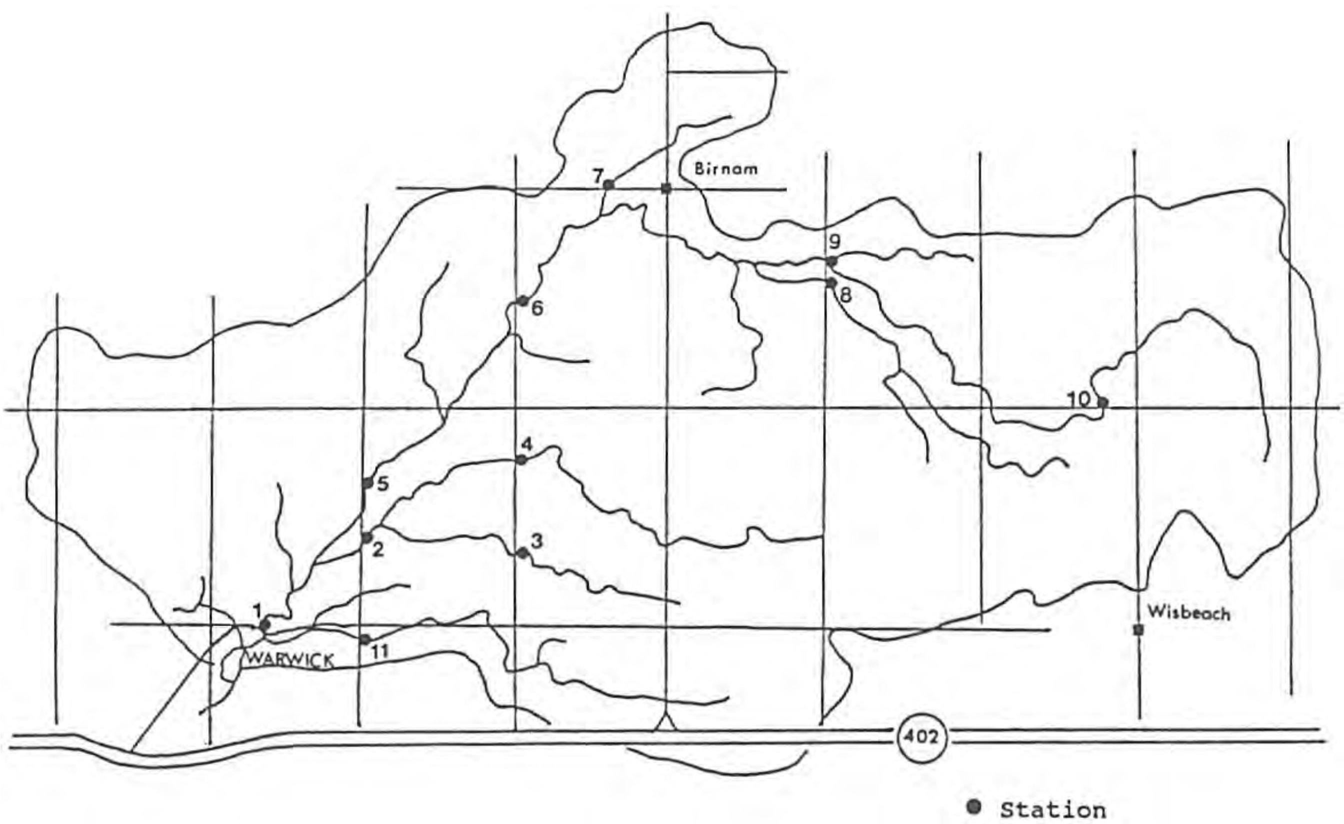


Figure 13: Location of the weekly water sampling stations.

The samples were sent to the MOE lab in London for analysis. They were tested for the following bacteriological and chemical parameters (MOE, 1983):

Chemical	Bacterial
Biological Oxygen Demand	fecal coliform
Suspended Solids	fecal *Streptococci*
Free Ammonia	*Pseudomonas aeruginosa*
Total Kjeldahl Nitrogen Nitrite	*Escherichia coli*
Nitrate	
Total Phosphorus	
Soluble Phosphorus	
pH	
Chloride	
Conductivity	

The results of the laboratory analysis were assessed against the Provincial Water Quality Objectives. These objectives are set to ensure that surface waters in the province are of a satisfactory quality for recreational usage and aquatic life.

Most of the open sections of the watercourse were surveyed on foot in an attempt to locate all of the tile outlets and potential pollution sources. However, this was not possible in a few sections of Bear Creek which were densely wooded. The tangle of twigs and roots and deep water made walking treacherous. These areas also tended to lack tile outlets.

The locations of all of the drainage outlets were mapped using 1972 aerial photographs at a scale of 1:15,840. Other observations such as size of the outlet and appearance and smell of the water being emitted were also recorded. Water samples were taken in cases where the tile outlet appeared polluted. Additional paired samples were collected upstream and downstream of certain stations to try to isolate sources of pollution between the stations.

The locations of all livestock operations throughout the watershed were mapped as well. On farms where animals were not visible, the type of livestock operation was determined by the sizes and shapes of the barns. This was later cross-checked through farmer interviews.

A four page questionnaire was given to local farmers within the watershed to determine specific information on farm management practices and to solicit opinions and concerns on water quality. Letters explaining the purpose of the questionnaires were delivered to approximately 40 farms (Appendix A). Landowners were then contacted by telephone to arrange for a meeting time. Twenty nine interviews were completed in total.

On February 21, 1989, a Rural Water Quality Information Day was held in Arkona. This was a joint effort with the Ausable-Bayfield Conservation Authority. Five speakers were invited to speak on various topics relating to rural/agricultural water pollution. They included representatives from the Ministry of the Environment, Ontario Ministry of Agriculture and Food, Ausable-Bayfield Conservation Authority and St. Clair Region Conservation Authority. Approximately 100 people attended, 70 of whom were farmers. The flyers and agenda are attached in Appendix A.

CHAPTER 3

POLLUTION PARAMETERS AND DATA ANALYSIS

3.1 BACTERIAL INDICATORS

The presence and concentration of certain types of bacteria are used to determine the safety of water for recreational use.

Because it is difficult to detect pathogenic or disease-causing bacteria and viruses in the laboratory, the microbial safety of water is determined indirectly by measuring certain indicator bacteria. Fecal coliforms, fecal *streptococci* and *E. coli* are all examples of indicator bacterial groups. They are found predominantly in the feces of warm blooded animals. If these microorganisms are found in the water, then fecal contamination from humans or animals has occurred. In addition, it is very likely that the associated pathogenic organisms which cause diseases are also present (Pipes, 1982). *Pseudomonas aeruginosa* was the only pathogenic bacteria measured directly in this study.

These indicator organisms are found almost exclusively in the intestines of warm blooded animals and are thus termed intestinal bacteria. The fecal coliform group is the one exception as it may contain non-animal sources. *E. coli* can also be found in the soil but these particular cells do not survive the warm incubation process used in the lab. Thus, only the intestinal *E. coli* remain and are measured and recorded here.

There is a health risk to swimmers and bathers when the geometric mean density of these bacteria exceeds the MOE objectives for a series of water samples taken from a beach or bathing area. The most common concern with infected waters is the risk of eye and ear infections. However, other communicable diseases associated with pathogenic organisms in water include bacillary and amoebic dysentery, cholera, typhoid and paratyphoid fever, bacterial gastroenteritis, leptospirosis, infectious hepatitis and diarrhea (Inland Waters

Directorate, 1979).

Table 2 summarizes and describes each of the four bacterial groups, the MOE objectives designated for them, and their effects on the environment and humans.

3.2 CHEMICAL PARAMETERS

The quality of water can also be measured by testing for the presence and concentration of various nutrients and elements which are suspended in the water. The presence of these parameters may give insight into the sources of the pollution and the threat to aquatic wildlife.

For example, four different forms of nitrogen and two forms of phosphorus were tested for in this study. Some forms of nitrogen are toxic to fish and excessive amounts of phosphorus can cause unsightly algal blooms and eutrophication.

Table 3 summarizes and describes each of the chemical parameters used in this study.

Table 2: Description of the bacteriological parameters

PARAMETER	MOE OBJECTIVES (#/100 ml)	DESCRIPTION	EFFECTS
fecal coliform group	100	• a subgroup of the coliform group • a group of intestinal bacteria found primarily in the intestines and feces of warm-blooded animals • some non-animal sources • more numerous in humans than other animals • most commonly used indicator of water safety	• can cause disease transmission to swimmers either directly or through the other bacteria often present with it
Escherichia coli	100	• a member of the fecal coliform group • a bacterium generally found in the intestines of warm-blooded animals • more numerous in human gut than animal • may have non-animal sources but these are killed in lab • a more restrictive determinator of water safety than fecal coliforms	• causes illness to swimmers at high concentrations • commonly associated with food poisoning in unrefrigerated foods
fecal *Streptococci*	100	• a resistant, intestinal bacterium found primarily in the intestines and feces of warm-blooded animals • more numerous than coliforms in animal feces	• as above
Pseudomonas aeruginosa	4	• an opportunistic pathogen • appears to be associated with human rather than animal feces • indicates presence of other infectious bacteria • concentrations over 20 may indicate human waste pollution	• can cause eye, ear nose, throat and skin infections to swimmers

Table 3: Description of the chemical parameters

PARAMETER	MOE OBJECTIVE	DESCRIPTION	EFFECTS
Temperature	---	• water temperature in degrees Celsius • oxygen is less soluble in warm water • many chemicals are more soluble in warm water	• high temperatures or quick changes can be dangerous to fish • dissolved chemicals can be dangerous to fish
Biological Oxygen Demand (BOD)	----	• amount of oxygen consumed by microbial decomposers to break down organic matter in the water	• high levels are dangerous to fish and other aquatic life
Suspended Sediment (S.S.)	----	• measures clarity • sediment includes silt, clay, organic matter, and organisms	• reduces aesthetics • destroys fish spawning areas and reduces photosynthesis
Unionized Ammonia	0.02 mg/L	• most reduced form of nitrogen • sources: normal biological activities, and fertilizers • non-persistent, non- cumulative, but toxic • soluble in water	• eutrophication • toxic to fish at levels between 0.02-0.20 mg/L and lethal over 0.20 mg/L • pH and temperature dependent
Total Kjeldahl Nitrogen (TKN)	0.5 mg/L	• measures organic nitrogen and ammonia together	• eutrophication

Table 3 (continued)

Nitrate	drinking water objective is 10 mg/L	• the primary combined form of nitrogen • reduced from ammonia • highly soluble + stable • sources: human and animal waste and inorganic fertilizers	• stimulates plant and algal growth
Nitrite	for nitrate plus nitrite	• an intermediate form between ammonia and nitrate • sources: animal rumens and moist feeds • usual range 0.001 mg/L	• toxic to aquatic life
Total Phosphorus	0.03 mg/L	• a nutrient • sources: erosion, fertilizers, milk- house waste water, industrial cleansers	• encourages algal blooms and eutrophication
Soluble Phosphorus	----	• amount of total phosphorus in solution	• as above
pH	6.5-8.5	• measures the balance between the acids and bases in solution • influenced by sun and water temperature	• can cause *eye* irritation to swimmers
Chloride	----	• measures the salt content of the water	• disrupts the ionic balance in fish • can be corrosive
Conductivity		• numerical expression of a water's ability to conduct electrical current • increases with levels of dissolved solids such as magnesium, sodium and sulfur	• --------

3.3 DATA ANALYSIS AND PRESENTATION

Pollution levels in open watercourses tend to follow an annual cycle (Ron Griffith, pers. comm., 1989). Certain seasons experience higher pollution loadings than others. For example, levels tend to be higher in the early fall and lower in the winter in response to temperature, cloud cover, rainfall and farming practices. All of these influence the survival rates of the bacteria and the amount of pollutants discharged into open watercourses.

As a result, it is more useful to examine the data one season at a time to avoid the between-season differences. The summer data has been chosen for analysis here as this is the season when recreational waters are impacted. However, since bacteria can live for several months, it is still important to gather and examine information year round.

Geometric means, maximums and minimums are used to describe and summarize the data. Because of the uneven distribution of bacteria in space and over time, occasional samples may be far above or below the usual range of bacteria levels. For example, the number of *E. coli* bacteria at Station 1 ranged from 10 to 5500 per 100 ml of water. However, most of the figures were in the 100 to 500/100 ml range. A simple arithmetic average calculation yields a value of 1043/100 ml because of the influence of a few very high samples. This is an unrealistic estimate. The geometric mean, however, yields a value of 347/100 ml which is much closer to the normal range of levels recorded for that station.

Geometric means are thus used to get a more accurate estimate of the number of bacteria in the water over time. Occasional unrepresentative samples do not unduly influence the mean. Furthermore, the MOE objectives for water quality are expressed in geometric means.

The formula for geometric mean (G_X) is as follows:

$$G_x = x_1 \; x_2 \; x_3 \ldots x_n$$

where x_1, x_2, x_3 up to x_n, are individual sample values which are multiplied together and then taken to the nth root. In other words, the geometric mean of n readings is the n^{th} root of their product (Carruthers, no date).

CHAPTER 4

RESULTS

Over the 9 month sampling period (late June 1988 to late March 1989), approximately 38 samples per station were collected and analyzed. The results for this entire period are contained in Appendix B. In total 386 samples were collected and analysed.

4.1 SEASONALITY IN BACTERIA LEVELS

The geometric mean of the 4 groups of bacteria were calculated for each station over the course of the study. The between-season differences are apparent when the geometric means are calculated separately for each season. Table 4 lists the geometric means for each station and each season.

Figure 15 illustrates the marked differences in bacteria levels over the 3 season period for station 1. Station 1 was located at the mouth of Bear Creek just before the water enters the Warwick Reservoir. The trend in levels was similar for the other stations with a few minor exceptions. Figure 16 illustrates the concentration of each bacterial group each week over the study period.

During the summer from mid-June to mid-September, bacteria levels in the creek were consistently above acceptable levels. The concentration of fecal coliforms, *E. coli*, and fecal *Streptococci* were commonly five times above the MOE objectives. The pathogenic *Pseudomonas aeruginosa* was also regularly present in the stream after the drought ended in mid-July.

The worst months appeared to be between July and October. Fecal *streptococci* levels remained high later into the fall and even into the winter (Figure 16c.).

TABLE 4: Summary of geometric means of bacterial populations by season

i) SUMMER	f. colif	*E. coli*	*Pseudom*.	F. STREP	No. of samples
Objectives	100	100	4	100	
Station 1	785	495	7	537	13
Station 2	856	549	41	1005	13
Station 3	288	135	47	1293	11
Station 4	179	94	3	474	12
Station 5	884	686	7	556	13
Station 6	554	458	4	512	13
Station 7	917	482	15	503	13
Station 8	693	556	9	816	13
Station 9	804	631	5	922	13
Station 10	1042	666	3	1592	13
Station 11	544	400	13	974	11

ii) **FALL**	f. colif	*E. coli*	*Pseudom*.	F. STREP	No. of samples
Objectives	100	100	4	100	
Station 1	357	306	1	560	13
Station 2	675	618	4	566	13
Station 3	156	114	9	820	11
Station 4	357	251	4	408	12
Station 5	430	340	2	530	13
Station 6	483	395	2	495	11
Station 7	839	495	2	353	13
Station 8	193	145	1	279	13
Station 9	1567	1094	5	1495	13
Station 10	412	340	1	654	13
Station 11	876	506	3	813	13

Table 4 (continued)

iii) **WINTER**

	f. colif	*E. coli*	*Pseudom*.	F. STREP	No. of samples
Objectives	100	100	4	100	
Station 1	158	156	1	236	11
Station 2	218	119	1	94	11
Station 3	246	150	1	467	10
Station 4	336	224	1	169	11
Station 5	433	265	4	1109	5
Station 6	1086	694	6	2760	4
Station 7	106	80	0	71	13
Station 8	415	301	2	426	11
Station 9	401	298	1	1116	9
Station 10	54	31	1	80	10
Station 11	236	152	4	145	11

iv) **SUMMER, FALL AND WINTER**

	f. colif	*E. coli*	*Pseudom*.	F. STREP	No. of samples
Objectives	100	100	4	100	
Station 1	347	267	2	409	38
Station 2	505	352	6	379	38
Station 3	216	130	6	756	35
Station 4	276	175	2	304	37
Station 5	527	400	3	597	32
Station 6	593	422	3	660	29
Station 7	446	256	2	233	38
Station 8	348	262	3	436	36
Station 9	696	522	3	1162	37
Station 10	450	292	1	771	38
Station 11	431	281	4	478	36

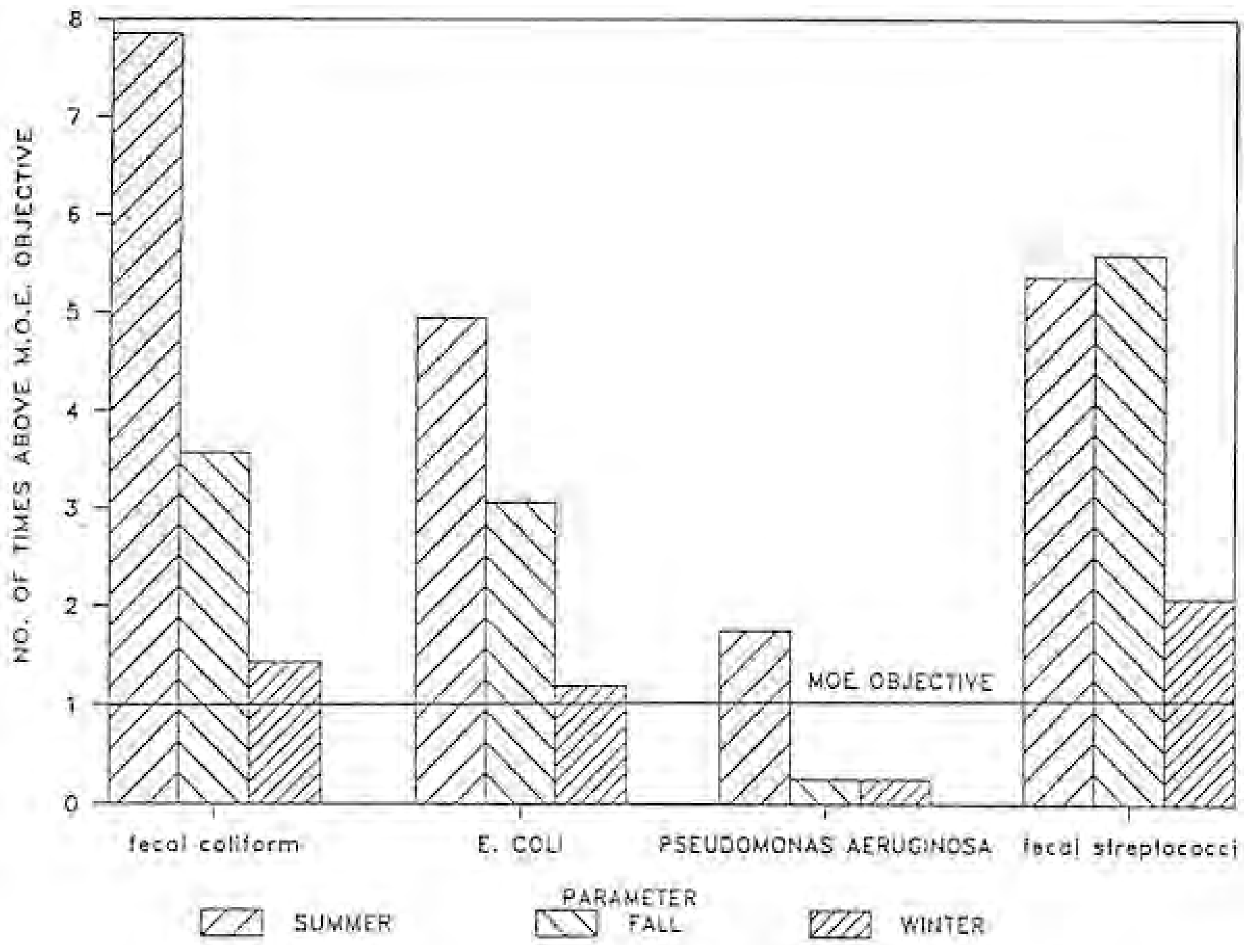
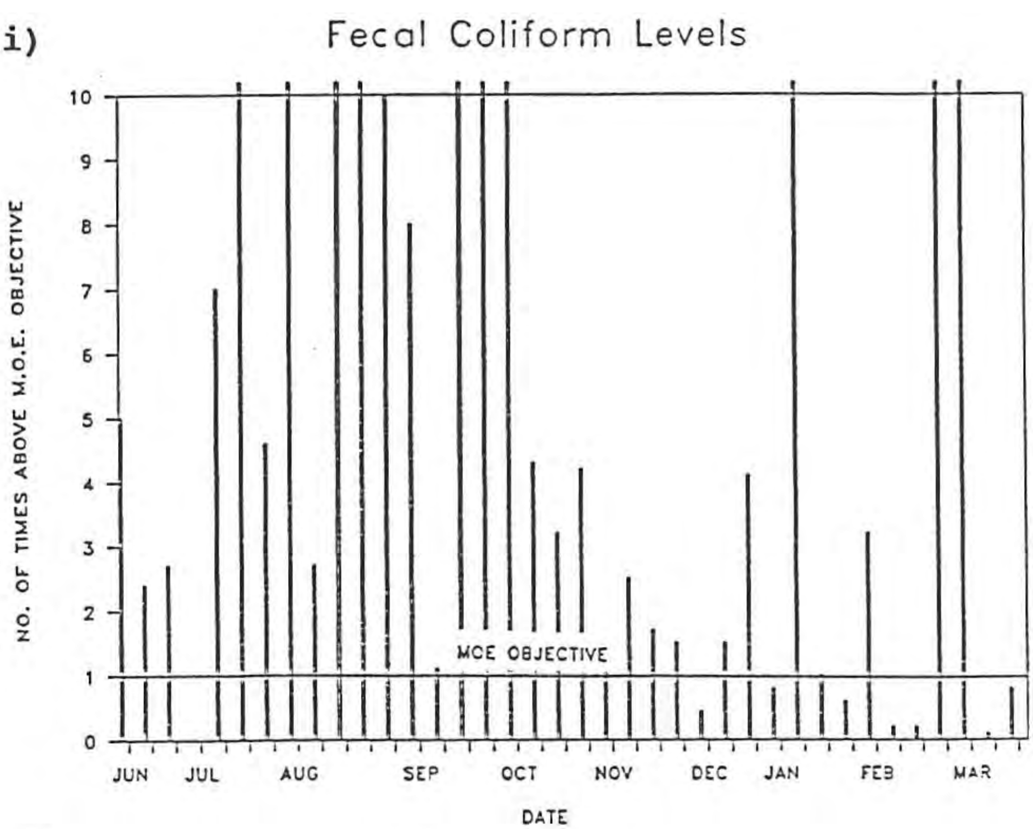


Figure 14: Seasonality in bacteria levels - Station 1

i)



ii)

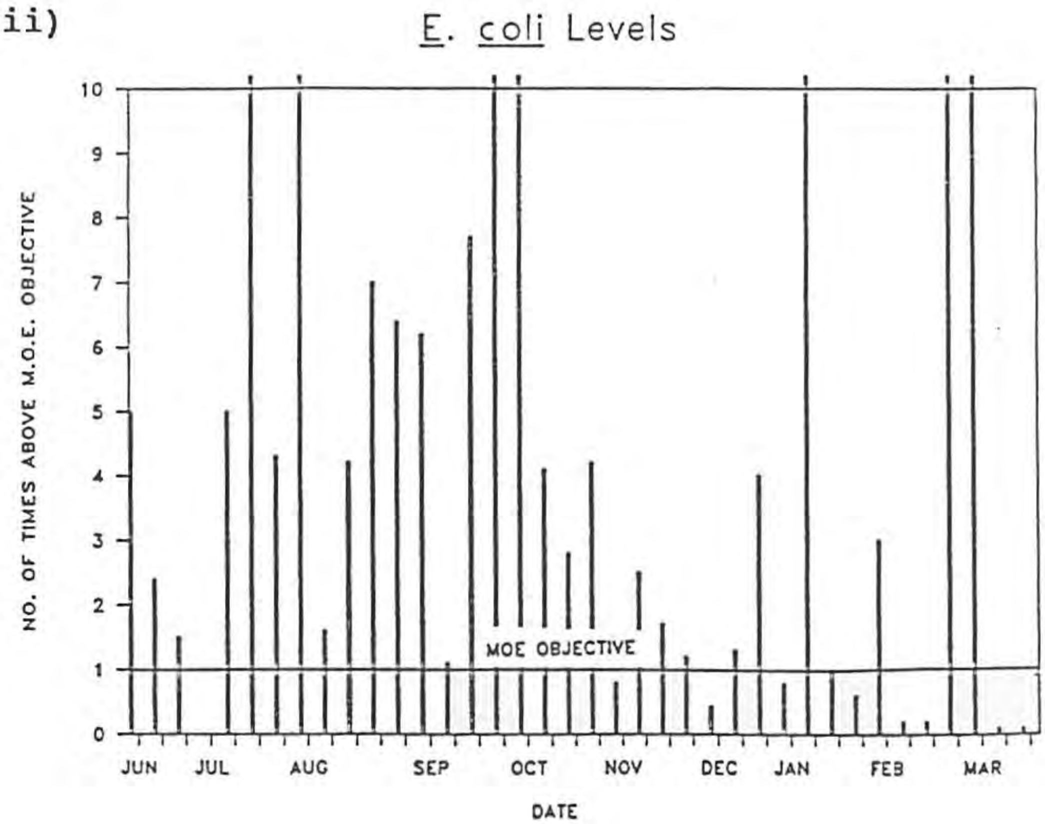
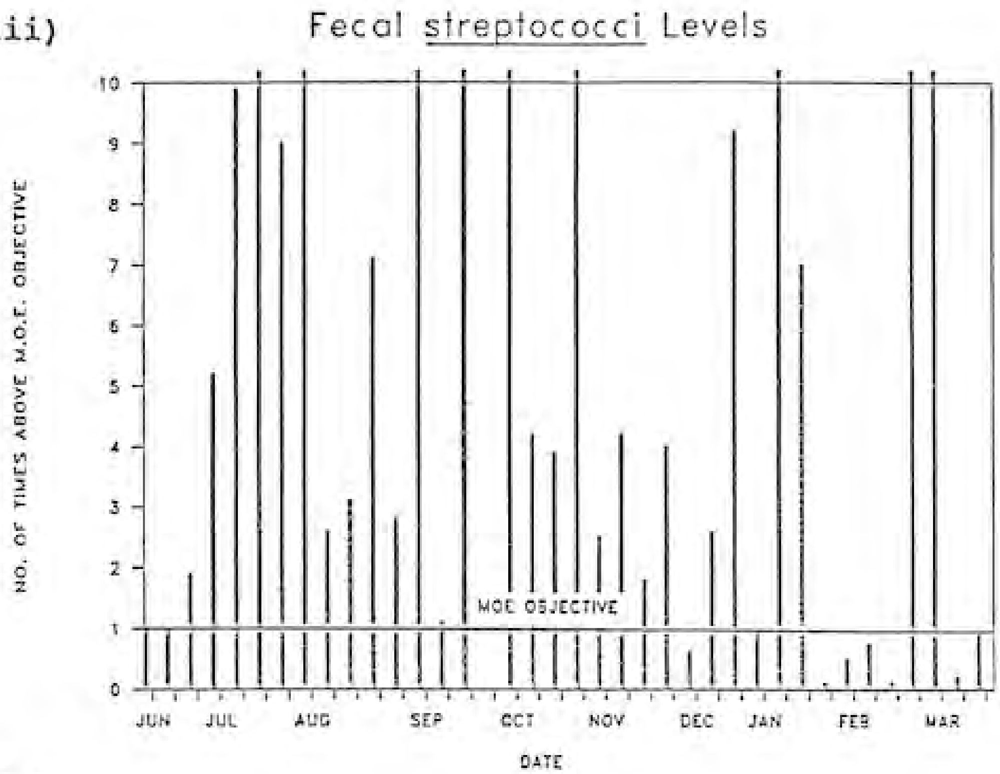


Figure 15: Bacteria levels at Station 1

iii)



iv)

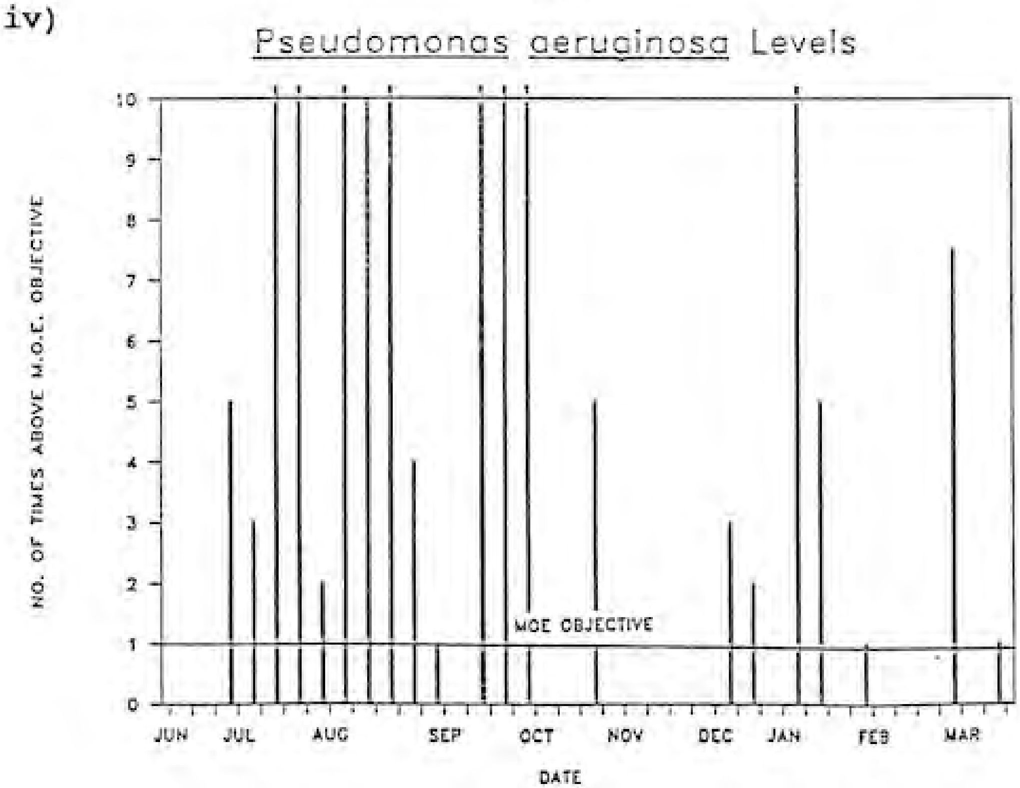


Figure 15: continued

Over all 3 seasons, 81% of the samples exceeded safe levels of fecal coliform, 75% for *E. coli*, 80% for fecal *streptococci* and 61% for *Pseudomonas aeruginosa*.

4.2 WARWICK BEACH

Eight samples were taken at Warwick Beach by the Sarnia-Lambton Health Unit between June and August. Figure 17 illustrates the results of the analysis for fecal coliform bacteria for the beach and Station 1 on Bear Creek just above the reservoir. The full data record is in Appendix D.

Fecal coliform levels in the beach were excessive throughout most of the summer, especially after the mid-July rainfall which ended the drought. In general, levels in the creek reflected levels in the reservoir. Since the beach and creek samples were not taken the same day, a direct correlation cannot be made. Bacteria levels in the reservoir were, in general, lower than those in the creek.

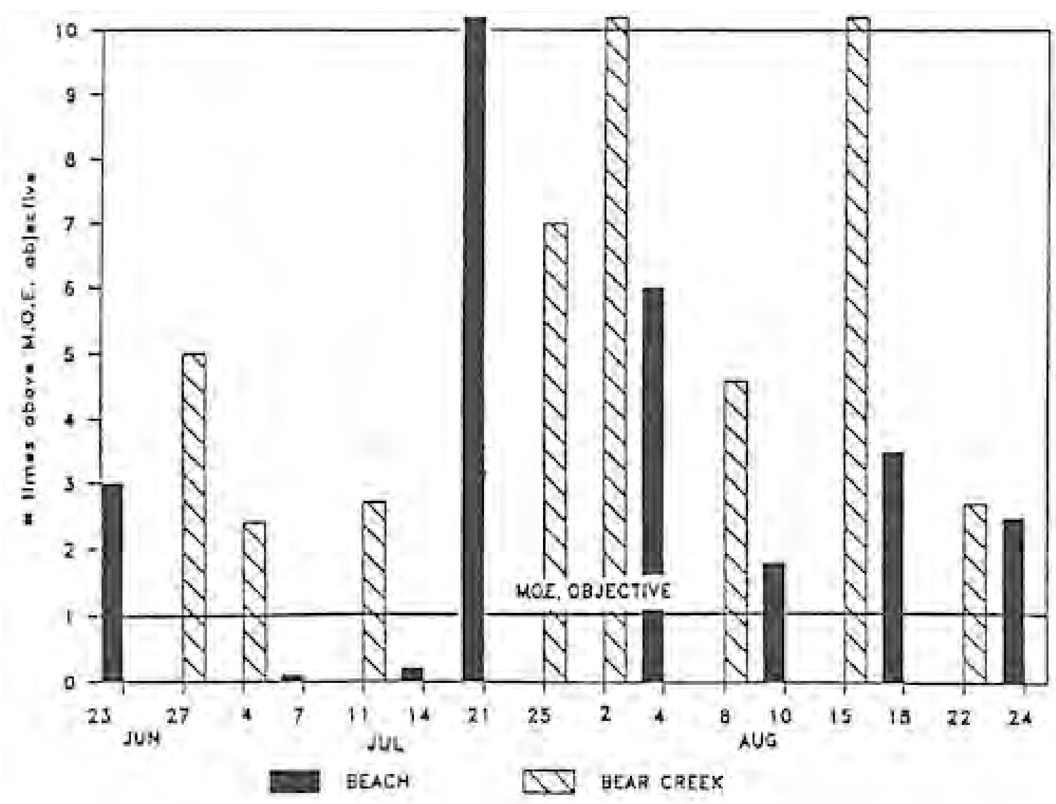


Figure 16: Fecal coliform levels at Warwick Beach and Bear Creek, Station 1

4.3 SPATIAL VARIATION IN BACTERIA LEVELS

The data collected at the 11 stations along the watercourse provided an opportunity to see where the water quality was poorest in the watershed. The data was quite variable and caution must be exercised when making conclusions about in-stream conditions. There is still not a clear understanding of how far bacteria can travel in streams, how long they survive and how they interact with other bacterial cells. A few generalizations can be drawn, however.

The data from Table 4i has been plotted on watershed maps in Figure 17 to illustrate the spatial distribution of the pollution loadings. Four symbols have been used to denote the geometric mean concentration of each bacterial group at a station along the creek over the summer period. The open circles indicate acceptable levels at or below MOE objectives. The open triangles denote polluted conditions (2 - 4 times MOE objectives) and the solid diamonds represent levels which were 5 - 7 times acceptable concentrations. The solid squares represent levels of over 8 times MOE objectives.

Fecal coliform and *E. coli*:

Since *E. coli* bacteria are a major component of the fecal coliform group, these two organisms will be examined together. In general, levels of these organisms were very high throughout the watershed. Station 10 on the Ross-Hall drain at the upper end of the watercourse recorded the highest overall levels (10 times MOE guidelines). There was consistent flow in this drain. Just downstream at Station 9 levels were somewhat lower, although still 8 times guidelines.

High concentrations of fecal coliforms were also recorded at Station 7 on the Zavitz Drain near Birnham. Despite its short length and small drainage area, this drain had steady

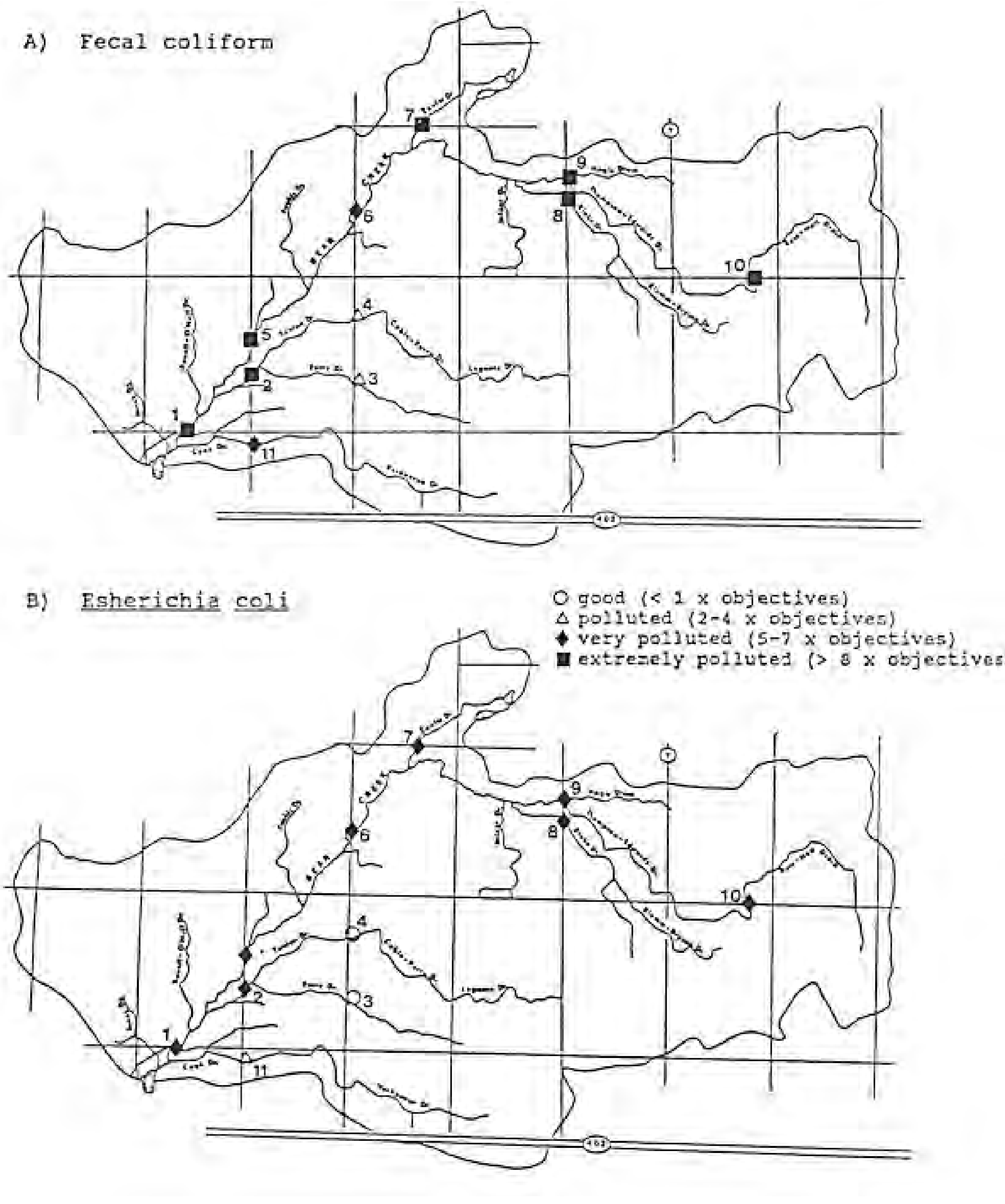
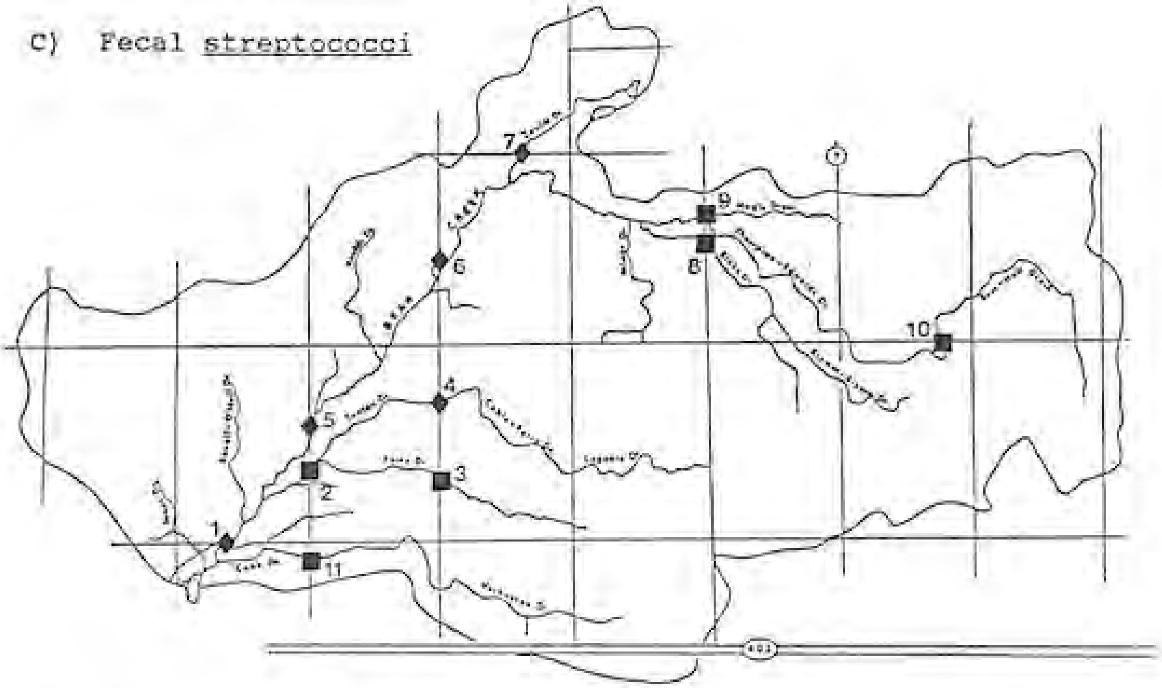


Figure 17: In-stream bacteria levels at station sites (summer 1988)

C) Fecal streptococci



D) Pseudomonas aeruginosa

○ good (< 1 x objectives)
△ polluted (2-4 x objectives)
◆ very polluted (5-7 x objectives)
■ extremely polluted (> 8 x objectives)

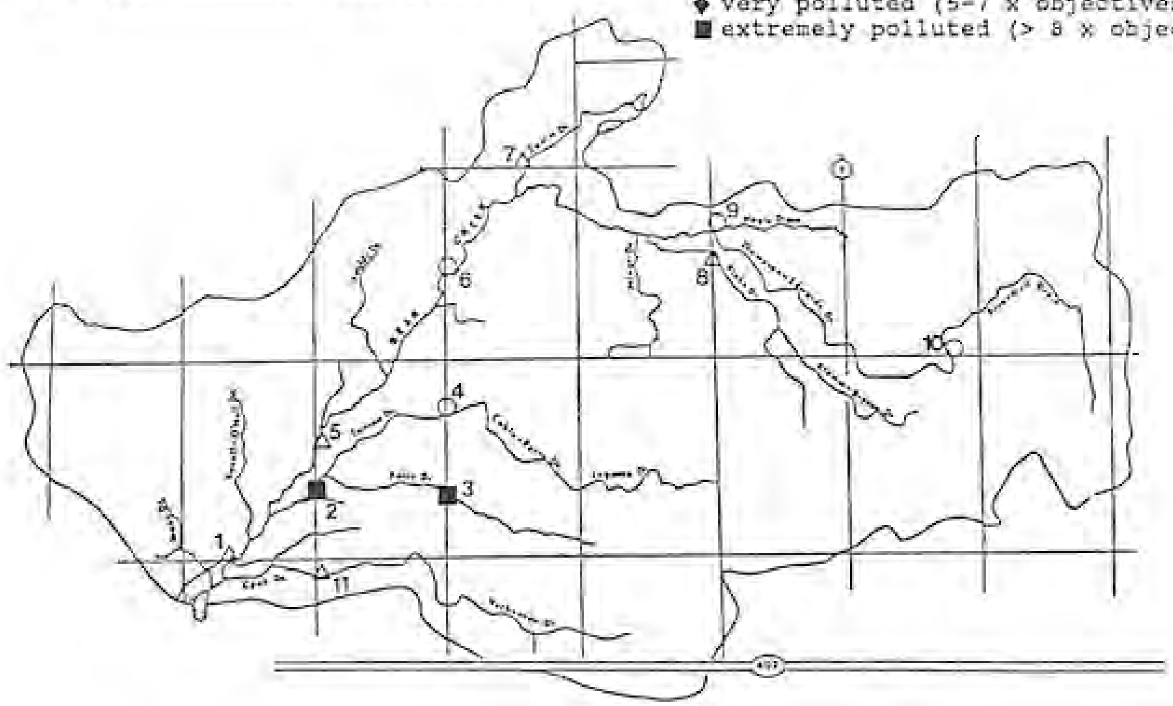


Figure 17: (continued)

flow throughout the summer period partially due to the fact that it drained a quarry.

Station 5 along Bear Creek just upstream of Station 1 also experienced regularly high levels of fecal coliforms. Levels, in fact, appeared to be on the increase compared to Station 6, its nearest upstream neighbour.

The water at Station 2 was also regularly polluted with fecal coliform and *E. coli* bacteria. Stations 3 and 4 which merge and flow into Station 2 recorded much lower concentrations. Thus, the source of the bacteria at Station 2 appeared to be located along the stretches of drain between Station 2 and Stations 3 and 4.

Fecal streptococci:

Levels of fecal *streptococci* were quite high across the watershed. In fact, all stations recorded geometric means over 500 bacteria/100 ml. Once again, Station 10 on the Ross-Hall drain showed the highest geometric mean. Station 3 was also highly contaminated with fecal *streptococci* despite the fact that it showed moderate to low levels of *E. coli* and fecal coliforms. Station 11 along the Cook drain experienced levels of fecal *streptococci* 10 times the MOE objectives as well.

Pseudomonas aeruginosa:

This pathogenic bacteria was present at elevated levels sporadically throughout the summer period. Geometric means were fairly low compared to the other bacterial groups but humans have a very low tolerance to it. Its presence at any concentration is considered unacceptable.

Station 3 on the Perry Drain showed very high levels of *P. aeruginosa*. Station 2 which was downstream of Station 3 also experienced high levels, but this was probably a reflection of the pollution at Station 3 which travelled downstream to this point. Station 7 on the Zavitz Drain also showed comparatively high levels of this bacteria.

Between-Station samples:

At stations where bacteria levels were particularly high, additional samples were taken upstream or between stations to narrow down the location of the pollution source. These additional samples were taken along with the regular weekly sampling. Due to heavy load submission to the MOE lab in London, only a few samples from each site were collected.

Figure 18 illustrates the results of this between-station sampling. Other areas were sampled as well but results were inconclusive and so these stations were not mapped. Follow-up work is still needed in these areas.

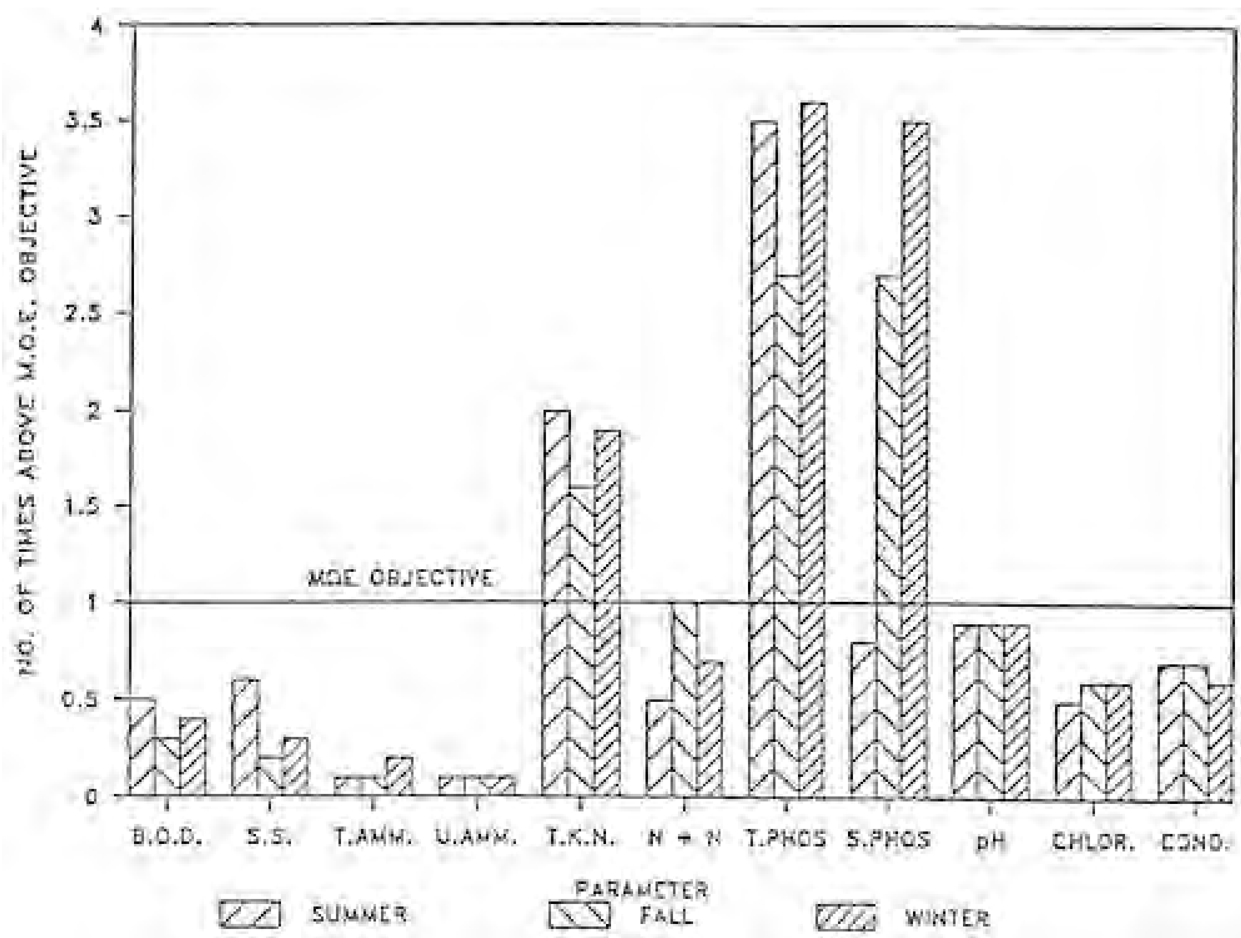


Figure 19: Between-Station sample locations and results.

The stretch of the Ross-Hall Drain between Stations 9B and 10 (see Figure 19) was sampled. Five samples were taken to compare levels at Stations 9, 9B and 10. The results indicate that levels of fecal coliform, *E. coli*, and fecal *streptococci* were 10 to 13 times higher at Station 9B compared to its upstream neighbour at Station 10 and *Pseudomonas aeruginosa* levels were twice as high at Station 9B. This suggested a source of bacterial contamination existed along this stretch of the drain between Station 9B and 10.

Four samples were taken at Station 7B which was located just upstream of Station 7 on the Zavitz Drain near Birnham. The results of the comparison revealed levels of fecal coliform and *E. coli* were 5 to 9 times higher at Station 7 than at its upstream neighbour at Station 7B. Levels of *Pseudomonas aeruginosa* were 14 times higher at Station 7. Levels of fecal *streptococci* showed little change. The source of most of the elevated bacteria levels at Station 7 appeared to be located somewhere between the two stations along this very short stretch of drain. In addition, field tiles contributed a lot of water volume between these two sites.

Three paired samples were taken at Station 5B which was located half way between Stations 5 and 6 along Bear Creek. As stated earlier, Station 5 recorded higher levels of bacteria than Station 6 which is just 2 concessions upstream. Although the number of samples taken were small, these preliminary results show a significant rise in *Pseudomonas aeruginosa* levels at Station 5B compared to its upstream neighbour at Station 6. Fecal coliform and fecal *streptococci* levels also showed increases. This appeared to suggest that the source of the elevated pollution levels at Station 5 were originating somewhere upstream of Station 5B but downstream of Station 6. Further sampling is required.

Finally, Station 6B was set up along Bear Creek downstream of Stations 8 and 9 and upstream of Station 6. Only two samples were taken, but the results indicated significant increases in levels of fecal coliforms, *E. coli*, and *Pseudomonas aeruginosa* at Station 6B compared to levels at Station 8 and 9. Further sampling is required as well to verify this source.

4.4 CHEMICAL RESULTS

Figure 19 illustrates the geometric mean concentration of each chemical parameter over the 3 season study period. Levels appeared to remain constant over time. Only Total Kjeldahl Nitrogen (TKN) and phosphorus (total and soluble) were excessive regularly throughout the period. In cases where an MOE objective did not exist, upper limits were taken from the Inlands Water Directorate manual (Inland Waters Directorate, 1979) (*) or were arbitrarily chosen based on the range of data (+). The upper limits for each parameter are as follows:

BOD = 4*	TKN = 0.5	pH = 6.5-8.6
SS = 50*	Nitrite + Nitrate = 10.00	Chloride = 50
T. AMMONIA = 0.50+	Total phosphorus = 0.03	Conduct. = 1000
U. AMMONIA = 0.02	Soluble phosphorus = 0.015	

There was very little spatial variation in TKN levels across the watershed as levels ranged only between 1 and 2 times the MOE objective. Figure 20 illustrates the moderate spatial variation of the total phosphorus levels across the watershed. Stations 8 and 9 displayed the highest overall levels, while stations 2, 7 and 10 had the lowest. This contrasts the bacteria loadings which did show marked spatial differences.

There was not a great deal of correlation between the stations with the highest bacterial concentrations and those with the highest nutrient levels. For example, Stations 7 and 10 were high in bacteria but low in nitrogen and phosphorus.

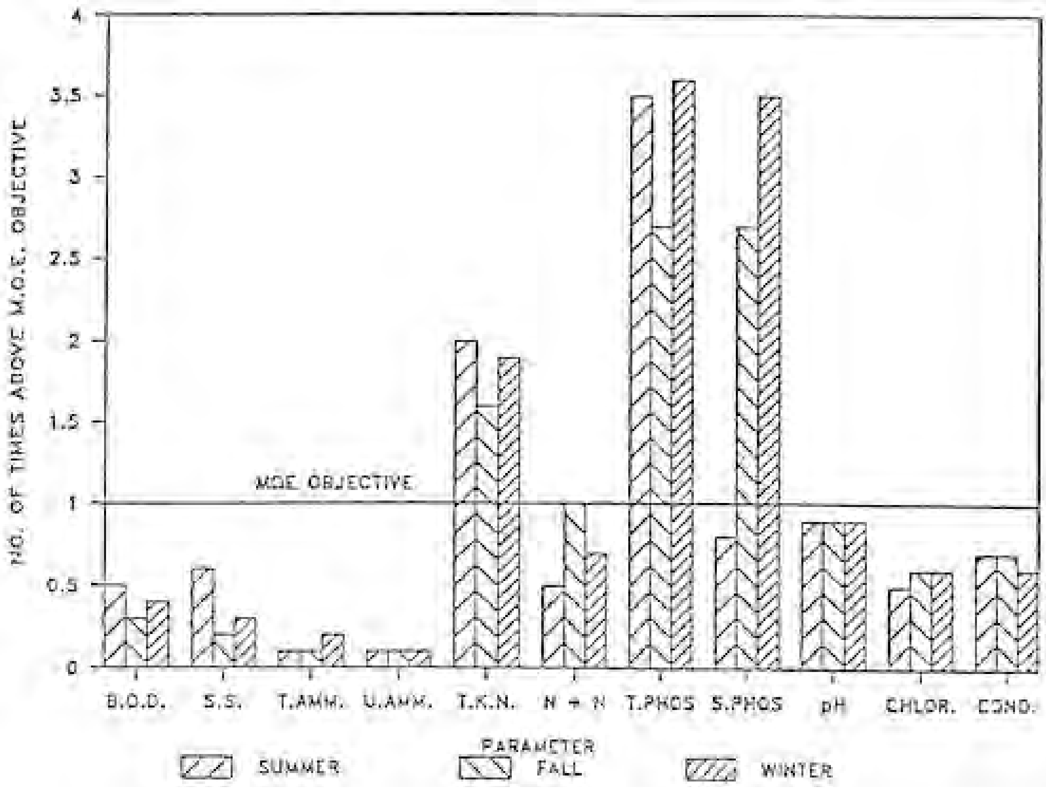


Figure 19: Seasonality in chemical parameters

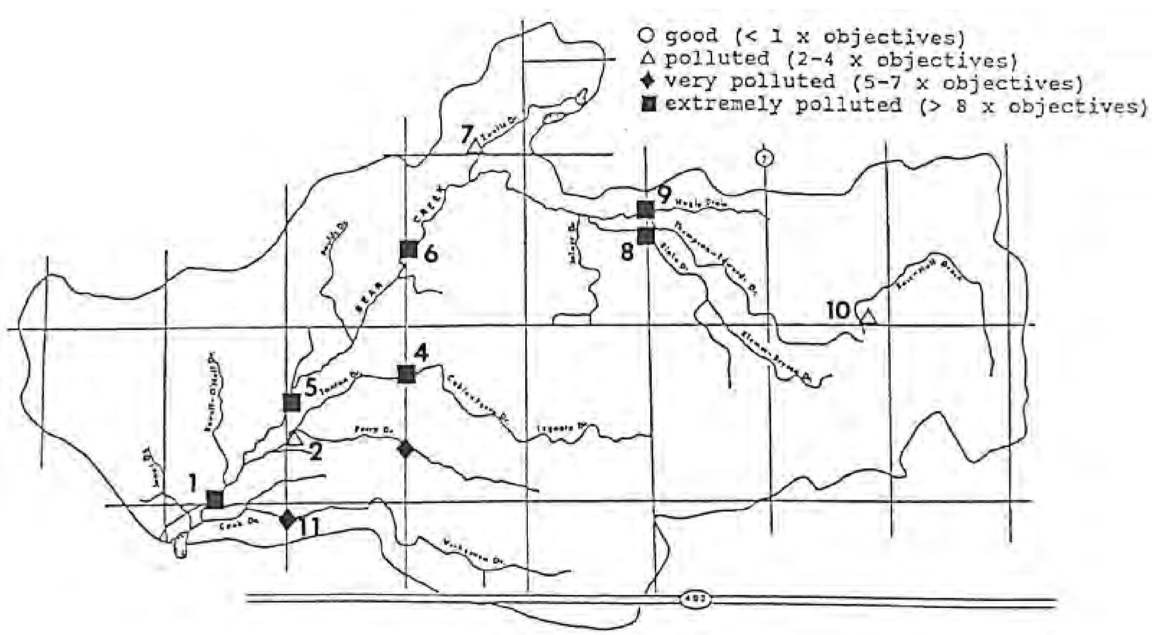


Figure 20: Spatial distribution of total phosphorus levels (summer 1988).

4.5 TILE OUTLET SAMPLE RESULTS

Samples were taken of the water emerging from fourteen different tile outlets. Figure 20 illustrates the location of each of these and Table 5 lists their condition as either acceptable, polluted or very polluted. The detailed results of the laboratory analysis are included in Appendix C.

Four of the fourteen samples revealed pollution levels below the MOE objectives and were termed acceptable. Three samples were termed polluted as the bacteria levels were approximately 8 - 30 times above MOE objectives and several of the chemical parameters were also excessive. The remaining seven were termed very polluted as their bacteria levels were on the order of 100 times the MOE objective for safe water.

Approximately 310 tile outlets of various sizes were located during the field survey. While this is a small percentage of all of the tile outlets found (4 - 5%), many of the tile outlets were dry during inspection.

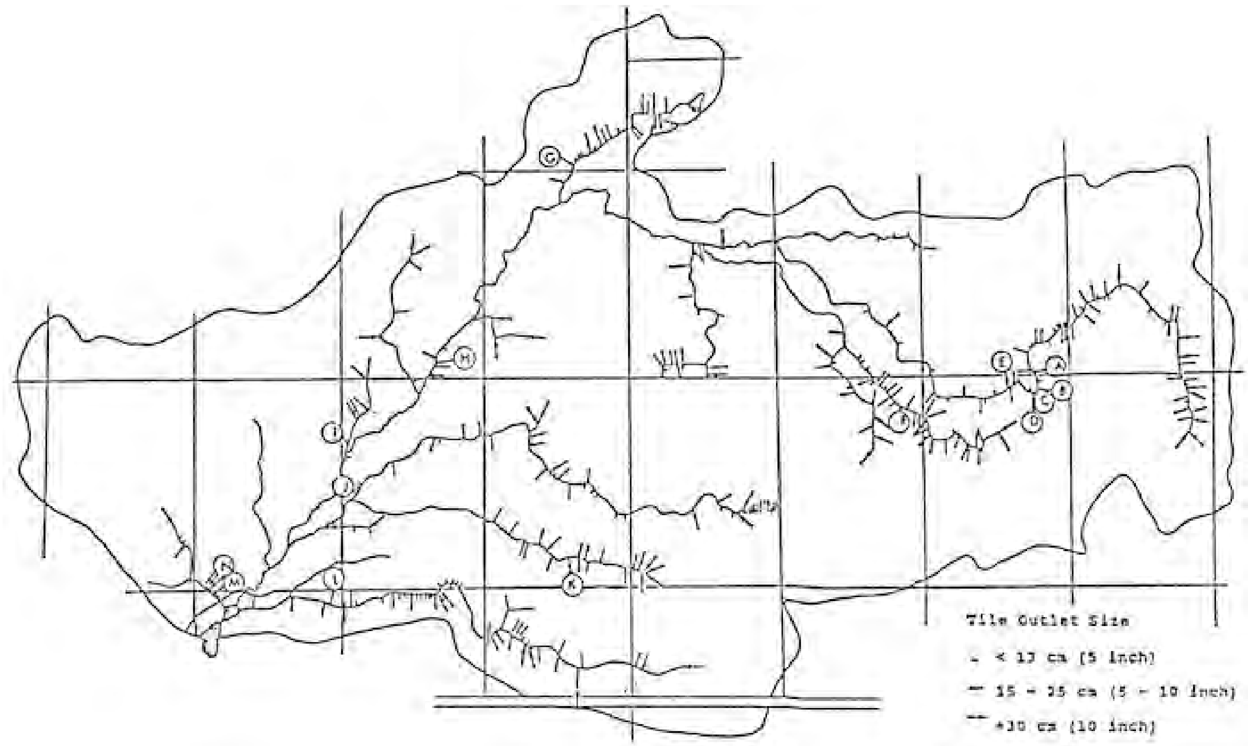


Figure 21: Location of tile outlet samples.

Table 6: Suspected sources and pollution levels of sampled tile outlets.

LOCATION	SUSPECTED SOURCE OF TILE	POLLUTION LEVEL
A	agricultural field	acceptable
B	agricultural filed	very polluted
C	laundry tub	acceptable
D	agricultural field	polluted
E	agricultural field + barnyard	very polluted
F	agricultural field + barnyard	very polluted
G	agricultural field	polluted
H	septic overflow	very polluted
I	irrigation pond	acceptable
J	agricultural field	acceptable
K	agricultural field	very polluted
L	septic overflow	polluted
M	septic overflow	very polluted
N	septic overflow	very polluted

4.6 SUMMARY OF THE LANDOWNER QUESTIONNAIRE RESULTS

The results of the questionnaire are in Appendix A. This section summarizes the key points.

In total, 29 landowners were interviewed. Of these 25 were livestock farmers. This was not a completely random sample as farms with livestock were targeted. Almost all of these were very willing to cooperate. A few seemed hesitant of answering questions.

Type of livestock and manure storage system:

Of the 25 livestock farmers, 15 raised pigs, 7 raised dairy cattle, 3 raised poultry, another 3 raised goats/sheep and 3 raised beef cattle. A few farmers kept 2 to 3 different types of livestock and so the numbers do not add up to 25.

Liquid manure storage was much more common than solid manure storage in this watershed. Eighty-eight percent of the farmers had liquid manure systems, some in conjunction with solid manure systems. Only 33% dealt solely with solid manure. This is quite different from the situation in other watersheds where water quality work has been carried out where solid manure is the most common type (ABCA, 1988; SCRCA, 1988).

Of the liquid storage systems, 60% of the farmers stored their manure in in-ground, covered concrete pits, 50% in in-ground, open concrete pits and 5% in earthen manure pits. Again, several farmers had more than one type of pit and so the figures do not add up to 100%.

Most of the liquid systems were around 10 years old and 65% of the farmers had received grants for their construction. About half are considering expanding their storage capacity but are waiting for finances to improve before doing so.

Milkhouse wash water treatment:

Of the 6 farmers with wet dairy operations, half of these had no treatment facility and simply let the waste water run through the drains. Two of the farmers stored the liquid in a septic bed and the other stored the waste water in a manure pit.

Soil testing and chemical fertilizers:

Sixty-three percent of the farmers test their soil regularly, about once every 3 years. About 60% use the recommended rate, 27% use more than the recommended rate and 13% use less. Sixty-eight percent go through a private fertilizer company, and the other 32% use the Guelph Soil Testing Lab. Only eight percent have ever had their manure tested for fertilizer value.

Conservation tillage:

Thirty-three percent of the farmers interviewed said they employ some conservation tillage or land stewardship methods. Green manure or seeding down to clover was the most common type. An additional 17% said they tried conservation tillage but were unsuccessful and returned to moldboard plowing.

About two-thirds of the farmers said there were windbreaks on their properties, but most of these were old and not consistent rows. Buffer strips along drains were minimal (0 - 5 feet or about 1 meter).

Household septic tanks:

Only 21% of the landowners said they had trouble with their septic systems. Twenty-one percent also said their washing machine wash water was not connected to the septic system, but instead entered the tiles and drains directly.

Fines:

When farmers were asked what they felt was the best way to clean up farm pollution, 65% said stiffer fines for deliberate offenders was the answer. Another 35% said higher grants would be helpful to farmers with leaky systems. Twenty-three percent said more information was needed and 12% had no opinion.

A little over half of the farmers admitted that there was some room for improvement on their farms to prevent water pollution. Forty-two percent thought their present practices were adequate.

Fishing and swimming:

Of the 46% of landowners who said they enjoyed fishing, 42% of these fish in Bear Creek. Carp, suckers, catfish, small mouth bass and the occasional pike and perch were the usual catch.

Of the 50% of the people who said they like to swim, 24% currently swim at the Warwick Conservation Area. A few more said they swam there in the past when the water was cleaner, but no longer. Thirty-six percent of the non-swimmers use the park for picnics only.

In total, 28% of the local farmers interviewed use the Warwick Conservation Area for swimming and or picnicking.

4.7 MANURE APPLICATION RATES (CALCULATED VS. FARMER)

One of the goals of the landowner interview program was to determine what 'normal farming practices' were in this community. There has been very little work carried out to determine how and much manure farmers are actually applying to their fields. There is still a need to determine if the guidelines laid out by OMAF in its Agricultural Code of Practice are being followed and if they are stringent enough to control water pollution.

Since the majority of farmers in this watershed dealt with liquid manure, application rates in gallons per acre could be calculated. This was not converted into metric as the imperial measurements are still most commonly used. Information was collected from each farmer regarding livestock type and population, size and type of manure pits, frequency of spreading, field size on which manure is applied and application rates. Given this information, a farmer's estimation of his application rate and manure pit storage capacity was compared with figures derived empirically using OMAF charts (OMAF, 1983, FACTSHEET). Table 6 summarizes the farmer versus calculated responses to these questions. The full table is included in Appendix D.

All of the farmers interviewed knew the dimensions of their manure pits. However, only 60% knew the capacity in gallons. Of those who knew most were fairly accurate although many slightly over estimated the capacity by a few thousand gallons.

Storage capacity in months was calculated by determining annual manure production from the number of livestock in gallons per year, adding annual rainfall of 3 feet for open pits, and then dividing this by the storage capacity of the pit(s).

Of the 16 farmers who said they knew their storage capacity in months, 10 over-estimated, 4 were accurate and two underestimated the capacity of storage. Approximately half of the farmers claimed to have 6 months storage, but the calculated results indicate only about one third of the farmers had 6 months storage.

Application rates (R) were determined by dividing total manure and rainfall production per year (M) by the product of the number of times they spread per year (T) and the number of acres on which they spread (A):

$$R = M/(T \times A)$$

The resulting figures are only approximations and are only as accurate as the figures supplied by the farmers. Most farmers seemed to be quite sure of their pit sizes and livestock numbers, while somewhat less certain about storage capacity, acres on which they spread and application rates.

Table 6: Manure application rates (farmer vs. calculated).

FARMER	PIT CAPACITY IN MONTHS		APPLICATION RATES IN GALLONS/ACRE	
	FARMER	CALCULATED	FARMER	CALCULATED
1	7-8	3	?	4,3000-15,000
2	?	3+12	2,000	1,200
3	5-6	4	2,000	1,400-2,000
4	3-4	2	3,000	1,000
5	4	9	4,000-5,000	1,300-1,600
6	6	1	?	2,800
7	6	6	?	5,100
8	4-5	2	3,000	2,300-7,600
9	?	3	4,000-5,000	4,900-5,800
10	4+6	4	1"(22,000)	4,100
11	6+12	12	1"(22,000)	6,400
12	8	2+7	6,000	2,000
13	8-12	7	?	4,300
14	6	6	3,000	850
15	?	2	6,000-8,000	4,600-5,700
16	12	3-4	1"(22,000)	1,000-5,400
18	4	4	3,000	1,600-5,400
19	4+4	3	?	5,000-6,000
21	8	4	2,000	6,700-9,900

Note: a (+) plus sign indicates 2 pits, eg. 4+6 means 4 months for one pit, 6 months for the other.
a (?) question mark indicates the farmer did not know or did not give an answer

A little over half of the farmers knew their approximate application rate. The range reported was 2,000 to 8,000 gallons per acre. The average was 3,600 gallons/acre. Another quarter of the farmers said they didn't know their application rates but estimated the amount spread was about 1 inch on the soil's surface. This was calculated to be approximately 22,000 gallons per acre. This seemed to be an exaggeration as the calculated results did not support this.

The calculated application rates ranged from 700 to 15,000 gallons per acre. The average was 3,300 gallons per acre. This was very close to the farmers' estimates. Of the 15 farmers who quoted an application rate, 10 over-estimated their rates, 3 were very close and one was putting on more than he reported. In general, most were actually applying a little less than they thought, based on a comparison with the calculated figures.

The average field size on which the farmers spread ranged between 30 and 150 acres, with the average being 66 acres. In the cases where the farmer did not know the field size, the application rates were determined for field sizes of 30 and 100 (65 acres average).

Application rates varied significantly depending on field size. In one case, a farmer said he applied manure to 30 to 70 acres. This translates to an application rate of between 4,300 gallons per acre on 70 acres to 15,000 gallons per acre on 30 acres. This is a significant difference.

In total, 59% of the farmers said they spread manure during the winter months. Most knew this wasn't the ideal time but said it was often necessary because tanks were full.

CHAPTER 5

DISCUSSION AND CONCLUSIONS

In general, there is a year round pollution problem in Bear Creek. The original intent of the study was to determine the effect of hog operations on water quality. Unfortunately, we were unable to isolate any obvious impacts directly related to hog operations, aside from overspreading of manure which will be discussed below. Therefore, as a follow-up to this study, it will be necessary to carry out a PYOSIN typing experiment to determine the extent that each type of livestock operation has on water quality. This will involve sorting out and selecting specific bacteria cells for analysis.

The pollution levels were highest between July and October. Bacteria levels were in the range of five to eight times acceptable levels in the summer months. Levels of Total Kjeldahl Nitrogen and phosphorus were also excessive. They probably account for the usual amounts of algal growth in the drains. Other chemical parameters such as Biological Oxygen Demand, Suspended Solids, Ammonia, pH, and Chloride and conductivity were acceptable overall with only occasional excessive levels.

The peak in pollution levels in the summer also coincided with peak recreational usage of the water at Warwick Conservation Area. This area brings in tourists and is also used by about a quarter of the local population. The questionnaire responses indicated that use of the area by the local population has dropped off over the years due to pollution levels.

Bacteria levels remained low at the beach during the early summer drought of 1988, but quickly became excessive with the return of the rain. Levels closely reflected conditions in Bear Creek which is the main water source for the reservoir.

The sources of the contamination were widespread. There were several stretches of the watercourse which had regularly higher levels than others. Figure 22 illustrates the combination of Station and between-station results and the location of the problematic tile outlets discovered to date. The upper-east section of the watercourse along the Ross-Hall Drain and midsections of Bear Creek experienced elevated pollution loadings and were also near a large number of intensive livestock operations. The lower section of the watershed along Perry Drain also showed excessive levels despite fewer farms. There is need to further define and isolate the pollution sources.

The bacteria appeared to be coming from both human and animal sources. The high levels of the fecal coliform bacteria suggested a human source and the equally high levels of fecal streptococci which suggest an animal source. There was also a need to determine if the bacteria was from hog, cow or human sources.

Farmers appeared to be acting in good faith by applying manure within OMAF guidelines for manure spreading for nitrogen requirements (OMAF, 1976). The average was 3,000 to 4,000 gallons per acre. However, these were only averages. Given the difficulty many farmers had with answering questions about the number of times they spread and on what acreage of land, these figures are bound to vary. It is probably safe to assume that application rates may occasionally fluctuate over the course of the year or years.

The application rates originally quoted by OMAF of 6-8,000 gallons per acre were set up for optimal nutrient levels for crops, not environmental concerns. Since farmers seem to be applying within this range, there is a need to redefine and publicize acceptable application rates.

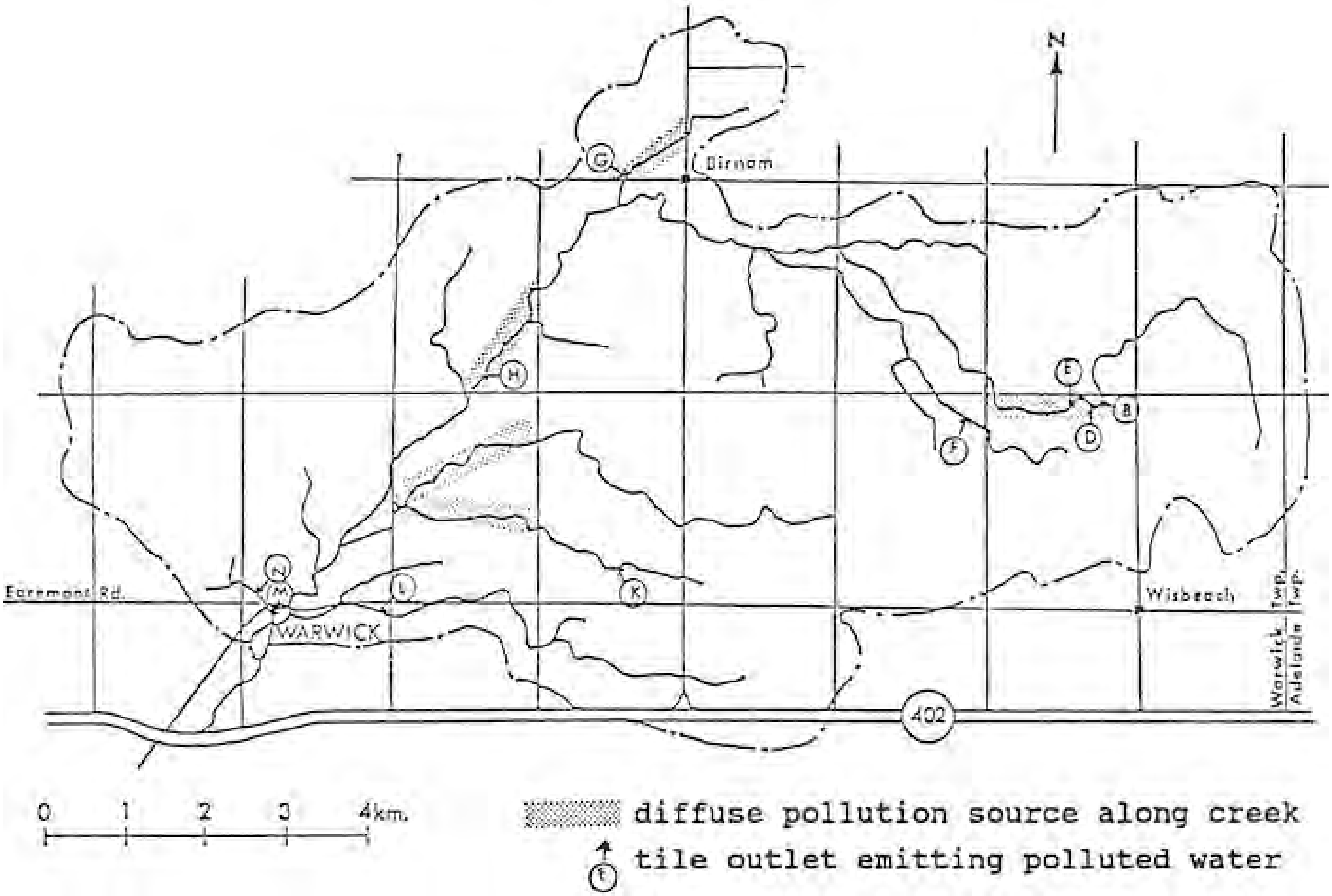


Figure 22: Summary of point and diffuse pollution sources.

The dense network of tile drains needs to be considered as well since the drains provide easy access for manure to the open creeks. Moisture and soil texture factors need to be calculated into the derivation of acceptable application rates as well.

In reality it will always be up to the farmer's discretion to apply less or more than the quoted amount depending on the climate and soil conditions (Harold House, personal communication, 1989).

Problems arise when farmers have a full tank and must dispose of their excess. More storage and a large land base are probably the best safeguards so the farmer has the time to make the right decisions and not just react to a critical situation.

More than half of the interviewed farmers did not have 6 months storage and almost 60% still apply in the winter months on frozen ground. Also, only half of the dairy farmers had wash water treatment facilities. These activities, combined with the heavy clay and silt soil, probably accounted for the manure and other nutrients gaining access to the open watercourse. Also, conservation tillage techniques were not commonly used in this watershed. Buffer strips along creeks and drains were also minimal.

Based on the interviews, a little over one-quarter of the farmers were applying more than the recommended amount of fertilizer. Most farmers use the soil test results of independent fertilizer companies instead of the University of Guelph facility.

There is some evidence that the independent companies recommend greater amounts of fertilizers than the University of Guelph lab for the same soil sample (Henry Olechowski, personal communication, 1989). This is especially true for potash, phosphorus, and micronutrients such as zinc. The University of Guelph facility backs up their recommendations with field calibration. The private companies, however, are often American-based and their calibrations are done on predominantly non-glaciated soils in their northern corn-belt regions. These soils are different from those found here in southwestern Ontario. Hence, the American recommendations may not be the most accurate for farmers in this region.

The over-fertilization of phosphorus in this part of Southern Ontario has been well documented (Shelton *et al*, no date). Farmers have built up their soils with fertilizers over the years to the point that many do not need very much of certain nutrients. However, farmers find it difficult to change old or traditional farming methods and see fertilizing as an assurance and not a detriment.

The reason farmers may use the private companies over Guelph is that Guelph is a free government service. Many feel that you do not get something for nothing and prefer to pay a private company to come in and do the sampling for a fee. They may also feel that the Americans are ahead of the Canadians in this field. In fact, Canadian research into fertilization is on equal footing with our Americans counterparts, if not ahead in many ways (Henry Olechowski, personal communication, 1989).

Another source of pollution to Bear Creek is household septic system hook-ups in the rural watershed and in the Village of Warwick. Grey water from washing machines were also being connected directly to the creeks. Other studies have shown this to be a source of bacterial contamination (ABCA, 1989).

Most farmers have consideration for the environment but feel dealing with the day-to-day problems of farming including financial constraints, weather and full manure tanks prevents them from running a pollution-free farm (if that is possible).

Many farmers favour heavy fines for deliberate polluters, although many encourage financial and educational aid as well.

The Bear Creek watershed is a farming-intensive community. Several farmers mentioned a desire to expand livestock numbers in the future. While technology and finances may enable many farmers to house and feed the extra animals, there will be a growing problem with land base. This should be a serious consideration for approvals of expansion in the future. Many farmers were aware of the desperate situation farmers in Holland are facing with this right now.

Farmers appear to be more aware of their liability in polluting the open watercourse than in years past. There has been a drop in the number of confirmed pig manure spills over the last year or two. There were a number reported in late 1987, and only one in 1988 in Lambton County. All of the reported spills have occurred in Warwick, Plympton and Bosanquet Townships.

Following the Rural Water Quality Information Day conducted for this study, local OMAF staff members noted farmers in the area were more nervous and cautious about potential threats to water quality. The presence of Authority and Ministry staff in their communities is undoubtedly a big part of this (Meyers, 1989, pers. comm.). They feel the Conservation Authorities are a help-oriented agency and the MOE is the one who tickets.

Ninety percent of all pig manure spills originate from irrigation system failures (Hutt, MOE, 1989, pers. comm.). The gun and reel system is most often to blame. It is either due to mechanical failure or the fact that application rates are too high as farmers tend to leave the systems running longer than needed. There is a small but growing number of farmers using this system in this watershed (6/15 liquid systems use irrigators). The users feel it is very safe, but other farmers see this system as being too risky and don't support it.

The calculated application rates from the farmers who used irrigation systems were somewhat higher than those using tankers on average (4,250 vs 3,300 gallons per acre). Also half of the irrigation system users did not know their application rates and one third thought they were applying one inch on the soil which is excessive.

More research is needed to determine the environmental consequences of this system. This may involve looking into the ways the system is used by farmers and their understanding of how it operates and the need to design safety shut off valves. A study comparing large numbers of farmers and their methods of spreading and application rates may reveal the true use/misuse of this system.

CHAPTER 6

RECOMMENDATIONS

To improve water quality in this watershed there needs to be continued presence in this area in terms of research and education. There are several specific activities which can be carried out to help the pollution situation as well as several general policy considerations for use at the provincial level.

1. All identified point pollution sources (eg. tile outlets) should be reported to MOE Abatement and the Sarnia-Lambton Health Unit for clean up.

2. There is a need to determine how much of the bacteriological pollution is coming from hog operations as opposed to human or other animal sources. This will involve conducting a Pyosin-typing experiment with MOE. This will give direction to future cost/effective remedial measure programs.

3. There is a need to continue to provide landowners and farmers with literature and information on the ways farming activities and human wastes can gain access to watercourses and swimming areas. Farmers should be encouraged to adopt soil conservation practices, manure and livestock management and septic system maintenance. They should also be sent information on how to calculate application rates so that they know if they are within safe/acceptable limits. Landowner interviews reveal the best way to reach farmers is through farm newspapers and magazines since virtually all farmers subscribe to these publications.

4. Given the erratic nature of sampling at Warwick beach in the past as well as last summer's high bacteria levels (and no postings) there is a need to monitor the reservoir on a regular basis. There is also a need to monitor water quality throughout the reservoir and beach area to determine local impacts from bathers.

5. There is a need for more research into manure application rates to determine environmentally safe levels taking into account soil and moisture levels as well as the tile drainage network.

6. In conjunction with the above, there is a need to set standards and determine the environmental safety record of manure irrigation systems. The cause of the spills associated with the use of this equipment needs to be determined as well.

7. Municipalities need to seriously consider the land base situation before permitting livestock expansions. This may be achieved by developing a by-law restricting the number of animal units on an acreage basis. Alternatively, a Registered Manure Agreement may be used for farmers wishing to expand livestock numbers where there is already minimal acreage upon which to spread.

8. OMAF or local farmer groups should be encouraged to form a network or agreement system between farmers which would enable farmers to spread manure on the field of a neighbour who does not have livestock. This will provide an alternative to over-spreading or applying in the wrong season when manure tanks are becoming full.

9. The federal government should legislate the reduction and/or removal of phosphorus in all industrial cleansers including milkhouse washing cleaners. This would make it consistent with the present legislation regarding household detergents and speed attempts at reducing phosphorus in our rivers and the Great Lakes.

10. Farmers in southwestern Ontario should be made aware of the serious phosphorus buildup in their soils. Use of Ontario Government approved soil testing laboratories should be promoted to support this. Manure testing should also be promoted.

11. This watershed should be brought into the Beaches Program and a CURB Plan be laid out to direct remedial work in the future. Flows should be measured at station sites along the watercourse to determine loadings of bacteria and nutrients so the data can be compared to other studies.

12. Provincial agencies should set up a program to investigate and correct faulty septic and other household hookups. There also needs to be a decision as to which agency, MOE or the Health Units will be responsible for this.

GLOSSARY OF TERMS

ANIMAL UNITS - a measure of nitrogen equivalents in livestock manure one animal unit equals the amount of nitrogen produced by one dairy cow plus calf or 1 horse or 4 sheep and lambs the full table can be found in the Agricultural Code of Practice (1976)

APPLICATION RATE - The amount of manure (this could be manure plus precipitation and milkhouse wash water) applied to one acre of land in gallons per acre or pounds per acre.

BACTERIA - plural of bacterium - microscopic plants having round, rod-like, spiral, or filamentous single-celled or noncellular bodies which often group into colonies
- they live in soil, water and organic matter in plants and animals and they break down food in the gut
- some cause disease

EUTROPHICATION - the nourishment of a body of water with dissolved nutrients such as phosphates
- often associated with shallow lakes
- oxygen depletion is common due to an overgrowth of plants and algae which feed on the nutrients and use up oxygen when they decompose

MOLDBOARD PLOWING - a common method of primary tillage whereby a plowshare is pulled through the soil to cut, lift and turn over a furrow slice - the bare soil beneath the previous crop is exposed leaving no crop residue on the surface

PATHOGEN - a specific agent, usually a bacterium or virus which causes disease

RUMEN - the large first compartment of the stomach of a ruminant (mammal that chews the cud) in which cellulose is broken down by microscopic organisms

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APPENDICES

APPENDIX A
RESULTS OF THE LANDOWNER QUESTIONNAIRE

Demographics

Total Number of Respondents : 29

Tenant 1 Owner 24 Retired 4

Cash Crops Only 2 Crops + Livestock 23 Livestock Only 2

Average Farm Size 190 acres (77 hectares)

SECTION 1. CASH CROP PRODUCERS

No. of Respondents	Percent	Crop	Acres (per farmer)
24	89	corn	93
15	56	winter wheat	36
16	59	beans (soy +white)	45
9	33	hay	71
4	15	pasture	50
7	26	grains	39
12	44	bush/woodlot	22

8% Practice Conservation Tillage or Land Stewardship.

25% Practice some Conservation Tillage, usually green manure.

38% Practice no Conservation Tillage.

17% Tried but were unsuccessful and returned to old ways.

3% Are thinking of adopting Conservation Tillage.

96% Have heard of the Land Stewardship Grant Program.

8% Wanted to get into the program but it was full.

68% Have some windbreaks on their property to protect their fields but most were not consistent rows.

63% Have their soil tested regularly, about every 3 years.

37% Do not test their soil. Of these 22% plan to start soil testing next year; 44% used to test their soil, but became disillusioned and quit; and 33% gave no reason.

13% Use less than the recommended amount of fertilizer.

27% Use more than the recommended amount of fertilizer.

60% Use approximately what is recommended.

32% Use the Guelph Soil Testing Lab.

68% Use private Fertilizer Company Labs.

8% Have had their manure tested, but only once (liquid only).

SECTION 2. DRAINAGE

Tiling system:

Systematic Only 48% Random Only 19%

Systematic + Random 22% Self Draining 11%

16% Use surface drains or grassed waterways in their crop fields to carry away surface water in low lying areas.

40% Said there are areas where they might be able to use them.

79% Have an open drain or stream on their property.

18% Said some eroding had occurred.

18% Said some flooding had occurred onto their fields.

9% Commented on the poor smell and appearance of the drain.

59% Said there were no problems.

3-5% Was the average buffer width along the drains and creek.

6' Was the average distance farmers keep back when spreading.

10% Know about the grants available to use grassed waterways and to leave buffers along drains.

SECTION 3. TYPE OF LIVESTOCK ENTERPRISE

No.of Respondents	Percent	Livestock Type	Aver. # Head
15	60	Pigs	970
7	28	Dairy	134
3	12	Poultry	8,000
3	12	Goats + Sheep	18
2	8	Horses	3

SECTION 4. TYPE OF MANURE AND MANURE STORAGE SYSTEM

SOLID 33% LIQUID 83% SOLID + LIQUID 17%

13% Have a Runoff Containment Tank or Pond for their solid manure.

Solid Manure Storage:

25% pile on earth 25% pile on concrete 50% in barn

Liquid Manure Storage: (some farmers have more than one type)

50% have in ground, open concrete pits

60% have in ground, covered concrete pits

5% have an open earthen pit

6 Months manure storage (Average)

Milkhouse Washwater:

7 landowners have Dairy Operations
1 stores milkhouse washwater in the manure pit
2 store it in a septic bed
3 let it run through the drains
1 is a dry operation

SECTION 5. MANURE APPLICATION

Type of Spreader or Applicator:

Liquid: 10% Use an irrigation system
20% Use an irrigation system plus a tanker
70% Use a tanker

Solid: 75% spread with a box spreader
25% shovelled out by hand

Time of Application:

41% spread manure in all 4 seasons
18% spread in the spring or summer, fall and winter
36% spread in the spring and fall and occasionally summer
5% spread only in the summer
* in total, 59% spread in the winter

Amount of Manure Applied:

68 acres - average size of field spread in one season

Half of the farmers knew their rate of spreading:
3,700 gallons/acre = average rate
or
1 inch = average covering of liquid manure on the ground which is 22,000 gallons per acre.

14% Work the manure into the soil
36% Usually work the manure in
50% Sometimes do depending on the crop
68% Said the manure paid for itself as a fertilizer
32% Said the cost of handling it was more than its benefits

SECTION 6. PRESENT MANURE SYSTEM

10 years Was the average age of the manure systems.

Most Had switched to liquid manure systems for ease.

65% Received financial assistance.

20% Would not have made the change without the grant.

55% Are thinking of some change, primarily more storage.

77% Know about the OSCEPAP II grants to correct manure systems.

SECTION 8. HOUSEHOLD SEPTIC SYSTEM

ALL respondents had a septic system.

35% Had their septic system been changed or expanded in the 15 years, mostly a new tank or bed.

10% Had extra facilities added to their homes such as extra tubs, toilets, washing or dishwashing machines.

21% Have had problems with their system, primarily back-up or tree roots breaking tiles.

21% Washwater enters tiles/drains and not septic tank.

55% Rarely if ever get their tanks pumped.

45% Have it cleaned regularly on an average of every 4 years.

SECTION 9. GENERAL QUESTIONS

The best way to clean up farm pollution:

65% Stiffer fines for deliberate polluters/offenders

35% Higher grants

23% More information

12% No opinion

The 2 best sources of information to farmers concerning farm management:

100%	Farm Newspaper/Magazines	12%	Factsheets
28%	Government Staff	20%	Demonstrations
28%	Neighbours	3%	A bit of everything

42% Felt their present farm management practices were adequate for controlling water pollution.

54% Felt there was room for improvement.

4% Said it probably was not adequate.

28% Were familiar with the general guidelines of the Ontario Agricultural Code of Practice.

84% Had heard of the Certificate of Compliance.

Swimming and Fishing in Bear Creek:

<u>46%</u> Do go fishing for sport; <u>42%</u> of these also fish in Bear Creek.
Type of fish caught: carp, suckers, one pike, catfish, one perch, smallmouth bass, large clams

<u>50%</u> Enjoy swimming for pleasure; <u>24%</u> of these currently swim at Warwick C.A.

<u>35%</u> Of those who swim, swam at Warwick in the past when the water was cleaner.

<u>36%</u> Of the non-swimmers go to the park for picnics

*28% of those interviewed use the park for swimming and/or picnicking

SECTION 10. GENERAL COMMENTS FROM LANDOWNERS

One farmer had no success with minimum tillage 6 years ago and so reverted to his old ways. Another farmer had heard negative things about conservation tillage.

Two farmers thought stiff fines to farmers were bad as it breaks up families. Therefore, first time offenders shouldn't be fined so hard. Contradicting this, another farmer thought fines are still cheaper than building new pits or cleaning up their act. He thought polluters should be closed down for a short term.

Three farmers said it is hard NOT to pollute due to timing and weather problems. One of them noted that all farmers are guilty of polluting to some degree so only the 'real' polluters should be prosecuted.

One farmer got in trouble with an overflowing manure tanker and didn't know who to call and the phone book didn't list the agencies back then. Another farmer admitted to an accident he had about 12 years ago related to a herbicide sprayer tanker. Another farmer is angry at his current prosecution related to irrigation spreading when manure came out the tiles. He feels it wasn't on purpose and therefore he should not be fined.

One farmer said he had seen manure spills and dead fish in Bear Creek in the past. Another landowner said he had seen young pigs and chemical drums in the creek as well. Another said that he knew of a hog farmer who had connected the tank to the creek and the neighbours 'squealed' on him.

One farmer commented that Bear Creek had significantly deteriorated over the last 20 to 30 years. Before that, there was less liquid manure, more pasture and hay and less fertilizer usage. One retired farmer said he missed the old days of farming and is now suspicious of big hog operators and 'desk farmers'. Another farmer noted that farmers ruined the surface and ground water in their areas and therefore should pay for it's clean-up.

Five farmers thought liquid manure irrigation systems were bad as the manure gets on the land too quickly. It is hard to keep control of and the heavily applied manure can run through the tiles. One farmer noted that he guards his irrigation system very closely. Another commented that it does not apply manure too quickly, as so many believe.

With regard to fertilizers, one farmer thought most farmers should reduce the amount of phosphorus they use. Two farmers commented that they now use less fertilizers because of the manure added.

One farmer has mentioned that it has come to the point that now one can buy Pollution Coverage in an Insurance Policy (eg. East Williams Mutual in Kerwood). One farmer noted, that in 1970 there was a Pollution Regulation in progress which was never passed yet he felt it should have been. This regulation stipulated the distance that barns and buildings had to be set back from roads and open water channels (600' from stream, 300' from road). Another farmer had heard there was no longer a Certificate of Compliance needed in Warwick Township because the Council didn't want it (i.e. it interfered with something they wanted built).

Two farmers commented that they thought that surveys and studies like this one are a good idea. The C.A. can keep an eye on the situation and are open to farmers' opinions and problems.

Concerning Land Stewardship, one farmer commented that it is too difficult to think of everything you want when you apply. He missed out on getting trees as a result. He'd like to *see* more incentives for planting windbreaks. Another farmer tried planting trees but had poor survival. One farmer said he would like to rent a chisel plow locally and see more local demonstration plots. Two farmers said they wanted to get into Land Stewardship but the money ran out. Another farmer said he was frustrated with the system as he couldn't collect the grant money because he already had too much land in clover. This seemed to him to penalize the farmers with initiative and was not equal to all.

One farmer thought grants were ineffective because construction companies raise their prices when they know people have grant money. For those who don't get the grants, it is very expensive. Furthermore, the public pays for these changes one way or another and he would rather have the money for his crop and not in the form of a handout. Yet another farmer thought grants were great because they help everybody. Another heard that farmers in the A.B.C.A. were getting more grant money and he would like that extra as well.

Four farmers commented that there were no erosion problems on their properties because of the flatness of the land. However, four farmers did mention they though compaction in this region was a problem. One farmer knew of a company called Airways which makes a plow that lifts up the ground to increase porosity. This allows the soil to take in and hold more manure and water.

One farmer did not think that milkhouse waste going into drains was a problem. Another farmer commented that he would correct his milkhouse waste water problem if he was TOLD he had to. Another dairy farmer would like to *see* more research into ways to handle milkhouse waste and manure together. He was concerned about the different bacteria interacting poorly together.

On the topic of education, one farmer thought it would be a good idea to bring speakers on water quality into Hog and Poultry Meetings. Another farmer thought that all farmers should attend at least one demonstration or seminar per year to keep in touch with the latest news. Another farmer thought that the Agricultural Code of Practice should be in all farmers' hands to increase awareness.

A farmer thought that everyone should have at least one year of manure storage and that they be required to get a new pit if they expand their herd size. Another farmer commented that he wouldn't have built his pit so big if it were not for the OSCEPAP stipulations.

In the bush along Bear Creek, one farmer was happy to see painted turtles, frogs, garter snakes, herons and Canada geese using the area. He was upset about the situation where pheasants were introduced into the floodplain woodlot and hunters with dogs came in and shot them all. None have returned or been reintroduced. Another farmer thought it was a shame about the poor forest cover in this township. He said there was good cover until the recent farmers settled here and cleared so much for their large hog operations.

Three landowners thought Warwick was a beautiful park. Another farmer said the family stopped swimming in the reservoir about 23 years ago because of geese droppings. Another landowner said her children enjoy swimming at Warwick but always end up with ear infections. Another farmer finds the water at Warwick too muddy because the carp stir it up. Three other farmers commented that they enjoyed swimming at the conservation area when their children were young but no longer go because they feel they are too old. Lastly, a landowner commented that he did not think that a swimming pond on the Bear Creek would work because of the high intensity livestock operations upstream.

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

November 14, 1988

MEMORANDUM TO: All landowners in the Bear Creek Watershed

As you may be aware, the St. Clair Region Conservation Authority and the Ministry of the Environment have been conducting a Water Quality Study of the Bear Creek watershed upstream of Warwick. The purpose of this study is to identify the possible sources of pollution which have led to beach closures, fish kills and other complaints from landowners in this area.

The preliminary results of this study indicate that our drains and rivers are becoming carriers of soil, nutrients and bacteria in concentrations that impair water quality and present a potential risk to livestock and people. To the farmer, this reflects a loss of productivity of the land.

Since the problems and solutions to water pollution affect everyone in the community, we will be attempting to contact all landowners over the next few weeks. We hope you will be willing to meet with our Water Quality Technician, Cathy Quinlan, at a convenient time to you, to answer a brief questionnaire. This should only take about 5 to 20 minutes of your time. We think it is very important to obtain YOUR views and concerns and to discuss the types of activities which may or may not be contributing to water pollution and the grants available to correct them. This information will, of course, be treated as confidential.

If you have any questions or comments, please feel free to contact this office. We appreciate you cooperation and look forward to hearing your views.

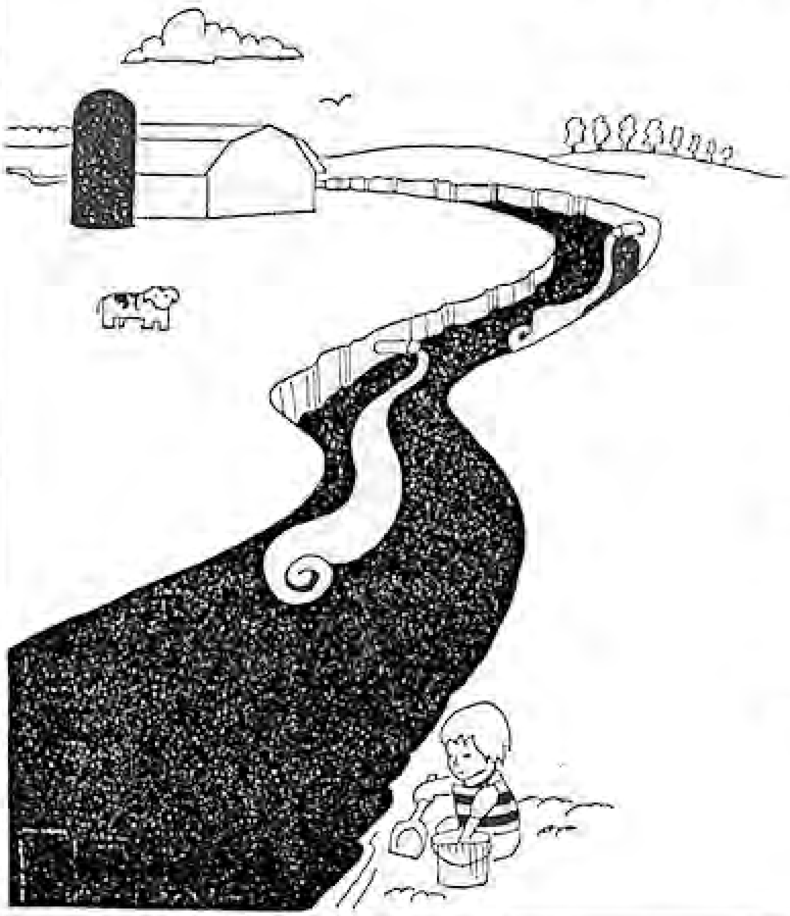
Yours truly,
Donald Craig
Conservation Services Supervisor

DCC/cmq

APPENDIX B

RURAL WATER QUALITY INFORMATION DAY

RURAL WATER QUALITY INFORMATION DAY



Tuesday, February 21, 1989
12:45 - 4:00 p.m.
Taxandria Community Hall
1/2 Mile South of Arkona on Highway 7

FREE ADMISSION
Free Coffee and Doughnuts
EVERYONE IS WELCOME

Keynote Speaker: Art Bos
Ministry of the Environment

"SOIL MANAGEMENT AND WATER QUALITY"

Other Topics:
- Manure Storage and Spreading Practices
- Pesticides in the 1990's
- Rights and Responsibilities
- Clean-up in the Parkhill Cr. Watershed
- Water Quality in the Sydenham River

Sponsored by the St. Clair Region Conservation Authority, Ausable-Bayfield Conservation Authority and Ministry of the Environment.

RURAL WATER QUALITY INFORMATION DAY

Date:	Tuesday, February 21, 1989
Time:	12:45 to 4:00 p.m.
Place:	Taxandria Community Centre Half Mile South of Arkona on Highway 7

Tentative Agenda

12:45	Registration
1:10	Opening Remarks - Ken Brooks Vice Chairman of the St. Clair Region Conservation Authority
1:15	SOIL MANAGEMENT IMPACTS ON WATER QUALITY Keynote Speaker - Mr. Art Bos, Co-ordinator, Diffuse Source Control Program Ministry of the Environment
1:45	RIGHTS AND RESPONSIBILITIES Murray Blackie, Agricultural Specialist Ministry of the Environment
2:05	MANURE STORAGE AND SPREADING: RECOMMENDED PRACTICES Ron Fleming, Agricultural Engineer Ontario Ministry of Agriculture and Food
2:30	BREAK FOR COFFEE AND DOUGHNUTS
2:50	PESTICIDES INTO THE 1990'S Wray Lampman, District Pesticides Officer Ministry of the Environment
3:15	WATER QUALITY STUDIES IN THE SYDENHAM RIVER Cathy Quinlan, Water Quality Technician St. Clair Region Conservation Authority
3:25	CLEAN-UP IN THE PARKHILL CREEK WATERSHED Doug Hocking, Rural Beaches Program Supervisor Ausable-Bayfield Conservation Authority
3:50	QUESTIONS AND WRAP UP

APPENDIX C

LABORATORY RESULTS
(COMPUTER PRINTOUT)

Fecal coliform levels at Warwick Lake and Bear Creek

A) Fecal coliform levels at Warwick Beach. (Analysis by Sarnia-Lambton Health Unit)

DATE D M Y	CENTRE BEACH	SOUTH BEACH	NORTH BEACH	GEOMETRIC MEAN
23/06/88	300			300
07/07/88	10	10	10	10
14/07/88	20	20	20	20
21/07/88	8100	3700	3600	5166
04/08/88	600	600	600	600
10/08/88	300	100	200	182
18/08/88	400	500	220	353
24/08/88	400	300	130	250

B) General comparison of fecal coliform levels between Warwick beach and Bear Creek at Station 1

SAMPLING DATE		FECAL COLIFORM LEVELS	
BEACH	BEAR CREEK	BEACH	BEAR CREEK
23 JUN	27 JUN	300	500
7 JUL	4 JUL	10	240
14 JUL	11 JUL	20	270
21 JUL	25 JUL	5166	700
4 AUG	2 AUG	600	2500
10 AUG	8 AUG	182	460
18 AUG	15 AUG	353	3600
24 AUG	22 AUG	250	270

Tile outlet sample results

TILE	# SAMP.	FECAL COLIF.	E.COLI	FECAL STREP.	PSEUD. AERUG.	BOD	S.S.
(Obj.)		(100)	(100)	(100)	(4)		
A	2	44	44	28	4	7.29	5.0
B	2	36946	32863	959	452	10.06	7.7
C	1	20	20	10	4	11.20	5.0
D	2	2540	866	1068	57	1.35	3.2
E	2	130000	100000	2324	290	2.22	5.0
F	1	5400000	4600000	19000	4700	72.00	270.0
G	3	3235	2384	557	6	1.68	8.1
H	2	271662	144492	11292	2258	6.48	5.0
I	3	7	7	13	0	2.00	6.4
J	1	10	10	10	0	0.47	5.0
K	2	16000	11402	7785	111	9.65	23.9
L	2	155	65	715	1		
M	2	1612451	1341641	6372	6	53.81	19.8
N	1	11000	10000	1000	144		

TILE	T.AMM	U.AMM	TKN	NITRATE + NITRITE	T.PHO	S. PHOS	pH	CL	COND
(OBJ.)		(0.020)	(0.50)	(10.00)	(0.03)		(6.5-8.5)		
A	0.010	0.000	0.09	0.11	0.016	0.005	7.66	19.2	700
B	5.700	0.033	7.17	1.65	2.037	1.517	7.50	44.7	981
C	0.001	0.000	0.35	58.53	0.023	0.013	7.99	33.9	1224
D	0.155	0.001	0.75	12.43	0.377	0.116	7.56	34.3	822
E	1.076	0.005	1.74	19.51	0.554	0.534	7.64	48.4	1042
F	0.013	0.000	41.00	0.11	7.800	0.001	7.29	58.3	1070
G	0.345	0.001	1.26	14.26	0.190	0.131	7.52	20.7	710
H	3.400	0.023	4.30	6.68	1.200	1.030	7.50	36.3	910
I	0.120	0.000	0.71	7.52	0.035	0.014	8.00	16.1	665
J	0.003	0.000	0.36	17.22	0.002	0.001	7.36	13.8	735
K	0.834	0.010	357.18	0.86	1.442	0.973	7.54	59.7	994
L	----	---	---	---	---	---	---	---	--
M	44.833	0.265	50.58	0.22	7.014	6.663	7.72	328.5	1815

TABLE 5. MANURE APPLICATION RATES -- FARMER VERSUS CALCULATED RESPONSE

A) HOG FARMS

Farmer No.	No. Of Animals	Type Of Pig (Other)	Pit Type (*)	No. Of Pits	Pit Size (Feet)	Capacity Gallons (Farmer)	Capacity Gallons (Call).	Capacity In Months (Farmer)	Capacity In Months (Calc.)	Manure Production (Gal/yr) (Calc.)	Rainfall In Pit (Gallon) (Calc.)	Manure + Rain (Gallon)	No. times Spread Per Year	Field Size Spread (Acres)	Application Rate (Farmer) (Gal./acre)	Application Rate (Calc'd) (Gal./acre)
1	1500	Fattening	I.C.O.	2	60 X12	250,000	212,000	7 - 8	3	852,840	52,000	904,800	2- 3	30-70	?	4,300-15,000
2	550	?	I.C.O.	1	50 X 8	98,000	98,000	?	3	312,700	36,000	348,700	2	150	2,000	1,200
	8600	(Laying)	I.C.C.	1	87 X 8	291,000	291,000	?	12	172,000	N/A	172,000				
3	300	Feeder	I.C.C.	2	36 x 40 x8	?	71,000	5 - 6	4	284,000	N/A	284,000	2	70-100	2,000	1,400-2,000
					20 x 8	?	15,400									
4	1000	Farr-finish	I.C.O.	1	50 x 8	100,000	98,000	3 - 4	2	568,600	36,000	604,600	4	150	3,000	1,000
5	150	Sows	I.C.O.	1	70 x 8	230,000	192,000	4	9	192,000	70,000	262,004	4	40-50	4,000-5,000	1,300-1,600
6	650	Sow-weaner	I.C.O.	1	30 x12	70,000	53,000	6	1	295,000	13,000	308,000	3	37	?	2,800
7	1,800	Sow-weaner	I.C.C.	1	50 x100	?	394,000	6	6	816,400	N/A	816,000	2	80	?	5,100
8	1,200	Farr-finish	I.C.C.	1	30 x 8	30,000	35,000	4 - 5	2	682,000	N/A	682,000	3	7	3,000	7,600/ 30 ac.
				1	50 x 8	96,000	98,000									2,300/100 ac.
9	1,500	Fattening	I.C.O.	2	55 x 8	240,000	232,600		3	852,800	21,800	874,700	3	50-60	4,000-5,000	4,900-5,800
10	2,500	Sow-weaner	I.C.O	2	60 x 8	?	141,000	4	4	1,134,000	52,000	1,230,000	3	100	1" = 22,000	4,100
				1	130 x 36	?	231,000	6			43,000					
11	500	Farr-finish	I.C.C.	1	40x40x 8		78,800	6	12	284,000	98,000	382,000	2	30	1" = 22,000	6,400
			I.C.O.	1	100x100x10	?	887,000	12								
12	650	All	I.C.O.	1	30 x 8	?	35,300	8	2	260,000	13,000	273,260	3	85	6,000	2,000
	5500	(Turkey)	SOLID	1	60 x 8	?	141,100		7	204,000	13,000	233,800				
13	100	Farr-finish	I.C.C.	1	30 x 8	34,000	35,300	8 - 12	7	56,900	N/A	56,900	2	40	?	4,300 or
	100	(Dairy)	SOLID	0	N/A	N/A	N/A	N/A	N/A	3,406,800 lb	N/A	339,000				42,640 lb/ac
										339,000 L						
14	450	Fattening	I.C.C.	1	50 x10	120,000	122,000	6	6	255,900	N/A	255,900	3	100	3,000	853
15	1,500	Farr-finish	I.C.O.	1	50 x 8	96,000	98,000	?	2	852,900	36,000	910,900	4	40-50	6,000-8,000	4,600-5,700
				1	40 x 8	54,000	62,700				22,000					