THE HIGHLAND CREEK WATERSHED
WATER QUALITY STUDY
1989-90

Prepared by:
Ann Marie Weselan, BscH

ST. CLAIR REGION CONSERVATION AUTHORITY
AND THE
MINISTRY OF THE ENVIRONMENT

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SUMMARY

During the summer, fall and winter of 1989-90, the St. Clair Region Conservation Authority, together with the Ministry of the Environment, conducted a water quality study of the Highland Creek watershed. It was thought that the creek was contributing high levels of bacteria to the beach at the Highland Glen Conservation Area.

Results revealed that bacteria, total kjeldhal nitrogen and phosphorus levels in the creek were in excess of MOE guidelines. The bacterial pollution, however, was the most extreme and therefore of the greatest concern. Concentrations were highest in the fall when runoff from field tiles was the greatest and contaminated sediments were being disturbed. Levels peaked along the mid-section of the creek where the greatest concentration of livestock farms was found and cattle access was the most prevalent. A few hog farmers upstream of this area were also suspected of bacterial pollution caused by the overspreading of manure. The majority of the bacterial pollution was from animal sources but one polluted tile was found which originated from a house. This was adding considerable amounts of fecal coliform to the creek as well.

Although the creek had high bacteria levels, it was not reaching the beach at the time of the beach closure. Past studies of the Plympton Township lakeshore that were carried out by MOE revealed that septic tanks in this area were not functioning properly. Leakage from these tanks could have been contributing to the bacterial contamination. In the fall, a walking survey of the cottages along the lakeshore uncovered two polluted tiles and high bacteria counts at the mouth of Aberarder Creek. Since most of the cottages were not occupied at this time, another survey will be completed in the summer of 1990. The Authority will also keep up to date with the steps that the Ministry of the Environment in taking to remedy this problem.

INTRODUCTION

Over the past few years beach closures, manure spills, industrial spills and increased media attention have increased the general public's concern over water pollution. More and more people are aware of the need to protect our valuable water resources. There have been complaints and concerns from the public regarding water quality degradation within the St. Clair Region Conservation Authority's watersheds. Beaches at Conservation Areas have been closed for parts of both 1988 and 1989 due to elevated bacterial counts.

The S.C.R.C.A.'s involvement with water quality began in 1970 in response to public concerns. To date, in cooperation with the Ministry of the Environment, the Authority has collected water quality information in two sub-watersheds which have affected beach conditions at the Coldstream and Warwick Conservation Areas.

More recently concern has been raised over the effects of polluted streams on the natural beaches along Lake Huron. Little is known about streams in the northwestern part of the Authority and baseline water quality data is needed.

The beaches along Lake Huron have a high public profile. There are only 1,500 meters of public beach located between Sarnia and Kettle Point and 900 meters of these are owned by this Authority, 610 meters at the Highland Glen Conservation Area and 240 meters at Charles J. McEwen Conservation Area.

The beach at the Highland Glen Conservation Area was closed for parts of 1988 and 1989 due to high bacteria counts. Since Highland Creek abuts the beach, it was felt that the creek may have been contributing to the beach closures. Other studies have shown correlations between beach closures and pollution levels in the streams which feed into beach areas (UTRCA 1984, ABCA 1988, MVCA 1988, SCRCA 1988).

To tackle this problem the St. Clair Region Conservation Authority, together with the Ministry of the Environment, have undertaken a Rural Beaches Study known as the CURB plan (Clean Up Rural Beaches). It involves a mathematical model which is designed to determine possible sources of pollution and evaluate the most cost-effective method of cleaning them up.

This report summarizes the first stage of a 2-stage CURB plan. Stage One involved monitoring the creek and collecting field data on the surrounding area. Interviews were carried out to determine farm management practices in the watershed. Stage Two will be completed in 1990-91 and will involve using the mathematical model to establish possible pollution sources and determine the most cost-effective method of clean-up for the watershed. Forums will then be held to publicize the findings.

BACKGROUND

Location and Land Use

The Highland Creek Watershed is situated in the northwest corner of Lambton County (Fig. 1). The creek and associated drains total 42 km and drain from Warwick Township across Plympton Township in a northwesterly direction. The creek empties into Lake Huron at the Highland Glen Conservation Area. The watershed is approximately 45 square km in size.

The Highland Creek watershed is intensively farmed. The farm types found in the watershed are as follows:

38 cash crop	9 sheep/horse
13 pig	5 poultry
10 beef cattle	2 dairy

As Fig. 2 illustrates, the majority of the livestock buildings are located on the east - west roads in the Township of Plympton. Those buildings not in the watershed, but represented on the map, have land in the watershed.

Soils and Drainage

Highland Creek watershed and Lambton County in general are characterized by low relief. Highland Creek has a change in elevation of only 20 m from its headwaters to its mouth (2.75 km).

Fig. 3 illustrates that approximately 80% of the Highland Creek watershed is clay loam, while 11% is clay, 4% is loam and 2% is sandy loam. The heavy clay and clay loam soils found in this watershed require artificial underground drainage to increase productivity.

Climate

Air temperatures in the Highland watershed average 22°C in the summer and -4°C in the winter. The watershed is subject to the moderating effects of Lake Huron which provides an excellent source of atmospheric moisture and can add or take away large amounts of heat from any air mass which crosses it. As a result the Highland watershed experiences more cloud, more precipitation and more moderate temperatures than areas farther inland. These conditions also cause heavy snowfalls in winter and suppress thunderstorms in early summer (City of Sarnia 1972). The past two summers have had less than average rainfall (<235 mm). As a result, water levels in Highland Creek have been low during the summer months.

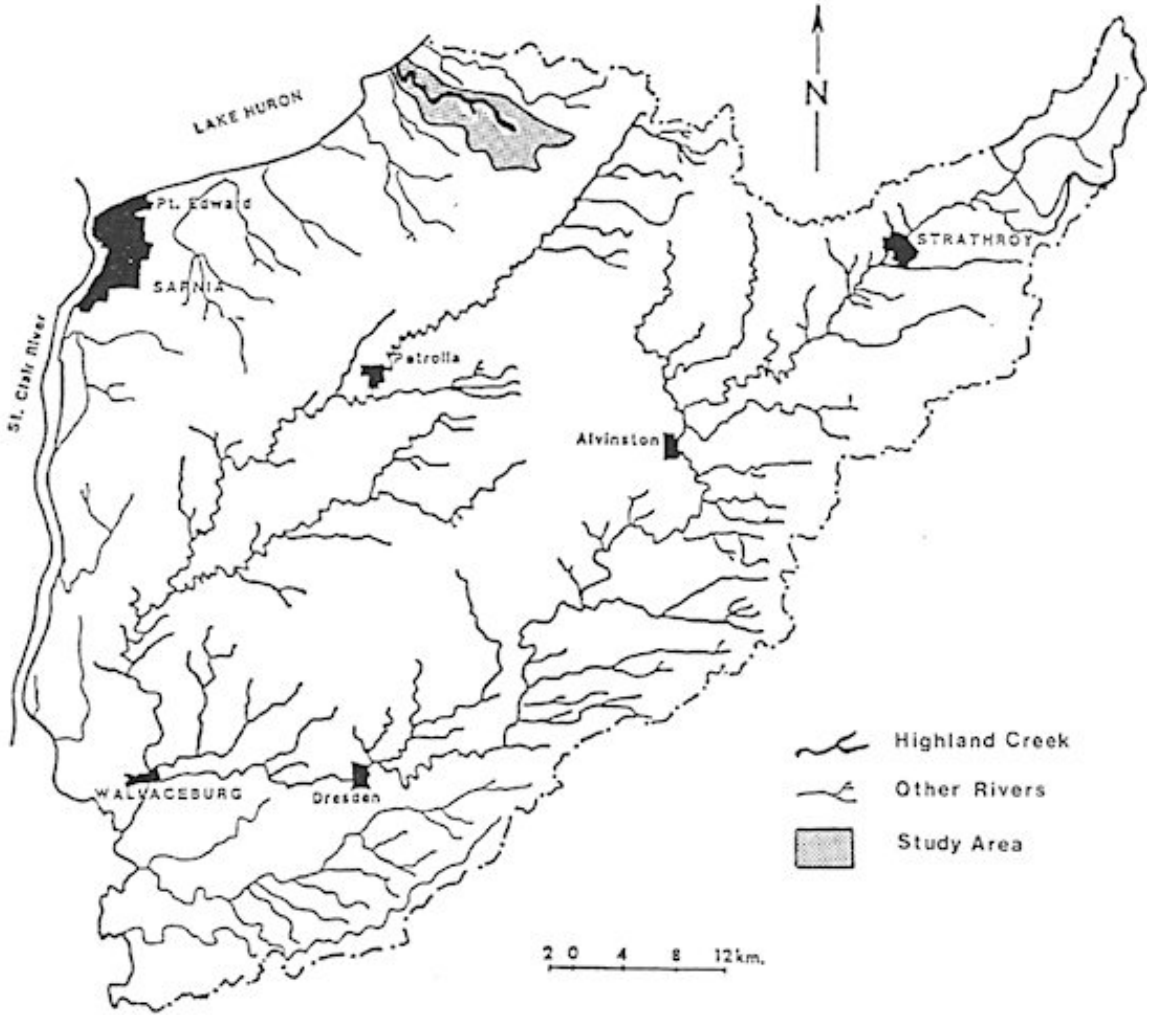

Fig. 1: Location of the Highland Creek Watershed Within the St. Clair Region Conservation Authority.

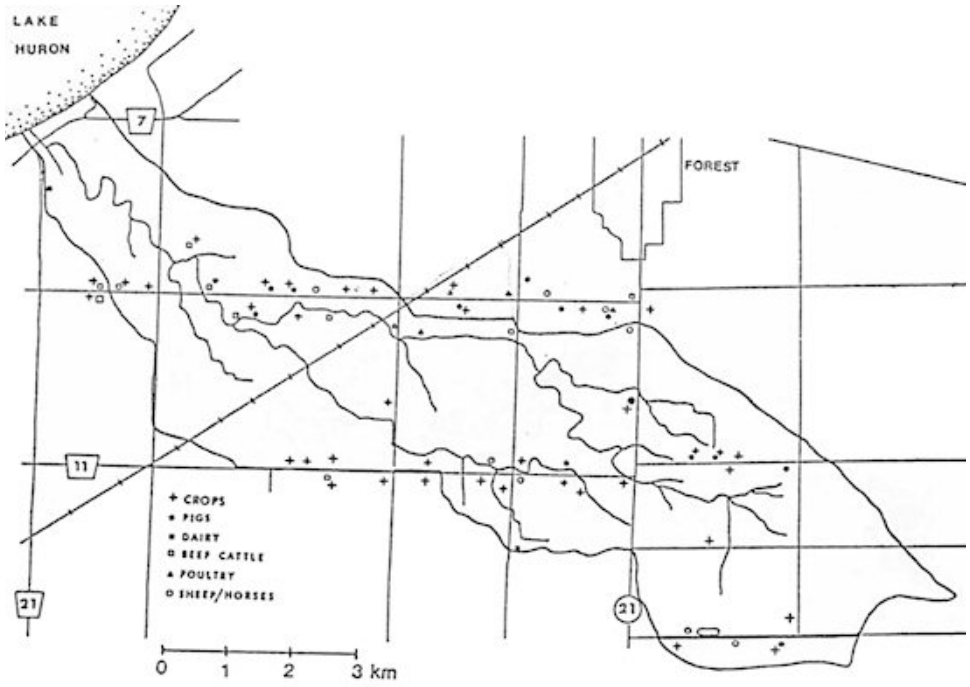

Fig. 2: Livestock Buildings in the Highland Creek Watershed

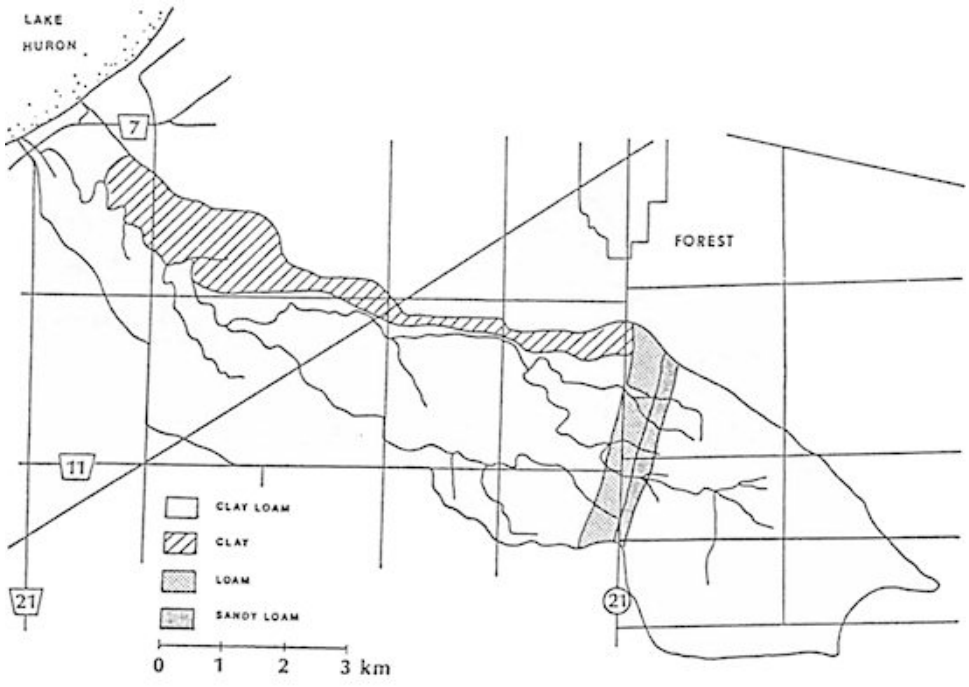

Fig. 3: Soil Types in the Highland Creek Watershed

Population

Plympton Township has a population of 4,931 and 53% of these people live in Forest (Ontario Ministry of Revenue 1985). There is also a large population concentrated at the mouth of Highland Creek in the cottage communities of Gallimere, Hillcrest, Invercairn and Hillsborough Beach. Many of these cottages are now being converted into permanent homes. The rural community comprises the rest of the population.

METHODOLOGY

Water samples were taken once a week from six stations along the creek and its associated drains. Fig. 4 illustrates the location of the stations. Five stations were chosen along the creek and one at the beach.

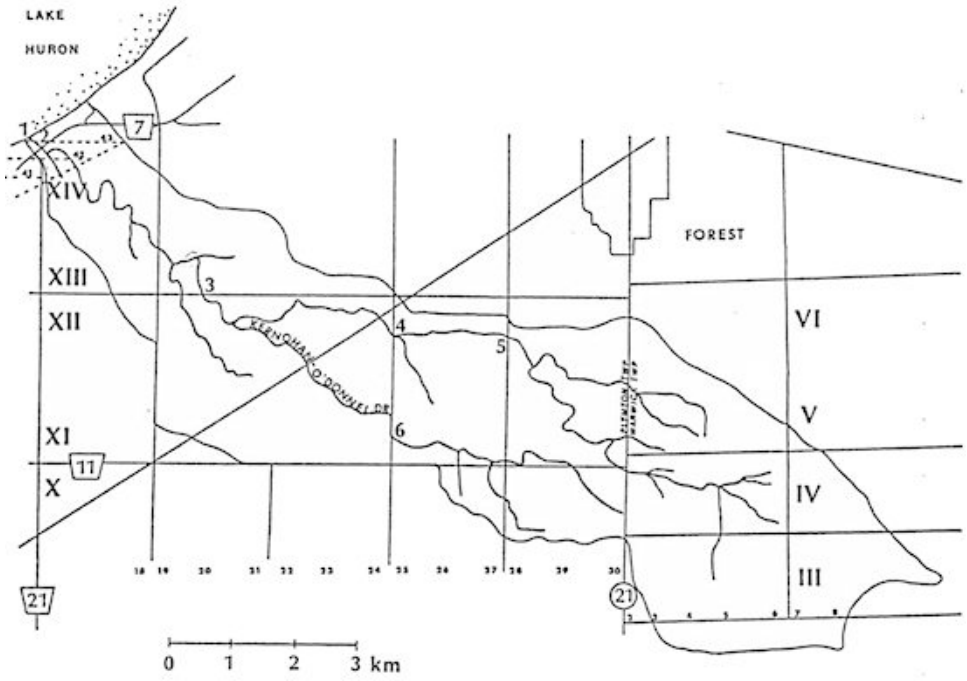

Fig. 4: Water Sampling Station Locations

Samples were collected between June 22, 1989 and January 23, 1990. However, relatively few samples were collected through the summer months because of extremely dry conditions. Stagnant pools were encountered at most of the sampling stations from late July - early August. After August the creek was flowing but was not breaching the sand dam at the beach, and did not do so until the week of November 14, 1989. This must be considered when the beach data is examined. Sampling was also sporadic in December due to the frozen conditions.

All samples were analyzed by the Ministry of the Environment lab in London for the following parameters:

Chemical	Bacteriological
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	

A description of the in-lab procedures can be found in a Handbook published by the Ministry of the Environment (MOE 1983).

Appendix A lists the objectives for the bacterial and chemical parameters. In cases where an MOE objective did not exist, upper limits were taken from the Inlands Water Directorate manual (Inland Waters Directorate 1979) (*). Geometric means were used to summarize the data. This way extreme and unrepresentative samples do not influence the mean.

The formula for determining geometric mean (G_x is as follows:

$$G_x = \sqrt[n]{x_1 \, x_2 \, x_3 \, \ldots x_n}$$

where x_1, x_2, etc. are individual sample values which are multiplied together and taken to the n^{th} root.

The Lambton-Sarnia Health Unit also sampled the water at the beach at the Highland Glen Conservation Area during the summer. It was on the basis of their results that the beach was closed for two weeks during the summer. This information was used in the Authority's analysis of possible sources of lakefront contamination.

The locations and types of all livestock operations in the watershed were mapped as well. Where animals were not visible, the types of livestock operations were determined from the buildings.

A walking survey of the beach, creek and associated drains in the watershed was also carried out. Tile outlets were mapped using 1972 aerial photographs at a scale of 1:15,840. Samples were taken from tiles that were suspected of being polluted, either due to their colour or smell.

It seemed possible that the cottages along Lake Huron, just north and south of Highland Glen beach, may also have been contributing to the beach closures. Before commencing our own study of the area, research was done to discover what types of studies have already been done on this portion of the shoreline. An investigation was carried out at the Ministry of the Environment office in Sarnia (1989).

A four page questionnaire was given to farmers in the Highland Creek watershed to verify the type of livestock operations and determine the specific farm management practices in the area. These interviews allowed farmers to voice their concerns on water quality in the rural area. Letters explaining the questionnaire were sent out beforehand and telephone calls were made to arrange meeting times. Thirty-six interviews had been completed at the time of this report. Approximately 12 will be completed subsequently.

On February 2, 1990 a Water Quality Information Day was held in Watford. This is an annual event hosted by the Water Quality Program of the S.C.R.C.A. to exchange ideas with the public and present the results of the Authority's studies. Five people gave presentations on various topics relating to rural/agricultural water pollution. Mr. James McGuigan (M.P.P. for Essex-Kent) was the keynote speaker. The audience also heard from representatives of the Ontario Ministry of Agriculture and Food, University of Guelph, Ontario Ministry of the Environment, Ontario Federation of Agriculture and the St. Clair Region Conservation Authority. The audience found the afternoon very informative and many interesting questions were raised.

RESULTS - BACTERIAL AND CHEMICAL

Bacterial - General

The geometric means of both fecal *Streptococci* (fecal *Strep*.) and fecal coliform bacteria were calculated and divided up according to summer, fall and winter data. This was done to illustrate how levels changed with each season.

Levels of both fecal *Streptococci* and fecal coliform were above the Ministry of the Environment objectives at stations 2, 3, 4, 5, and 6 during the time of the study. Concentrations of fecal *Strep*. were usually higher than those of fecal coliform.

Mean levels of fecal *Streptococci* peaked in the fall (Fig. 5) at extremely high concentrations of 25 times MOE objectives. Summer and winter levels averaged between 2 and 6 times the MOE guidelines.

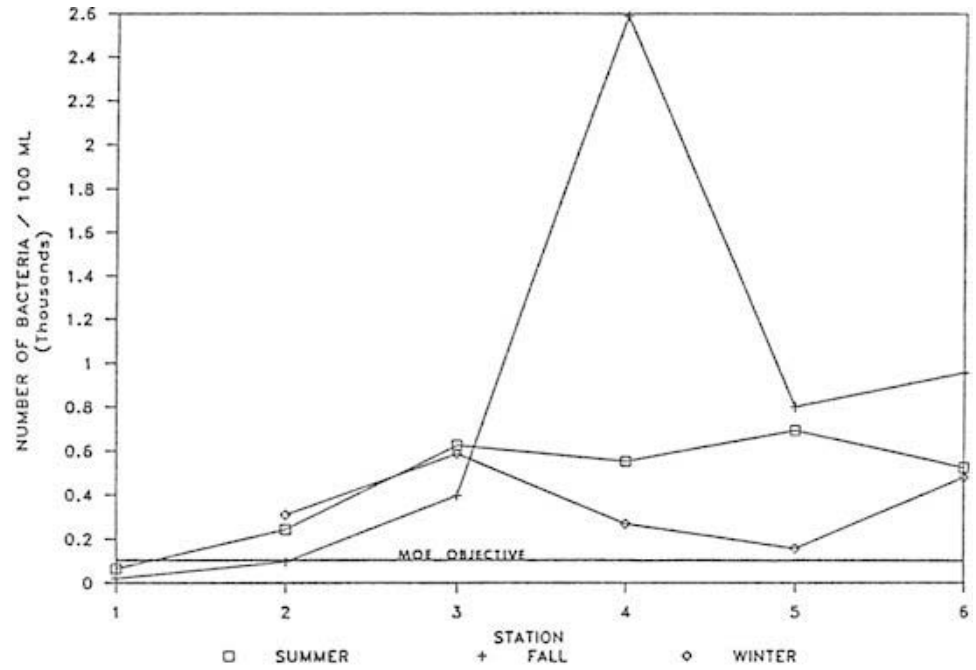

Fig. 5: Mean Fecal *Streptococci* Levels in Highland Creek

Fecal coliform concentrations in the creek were highest in the fall as well (Fig. 6). In this case, the geometric mean peaked at 17 times MOE guidelines. Summer and winter concentrations were similar to those of fecal *Strep*. and remained high at 2-6 times MOE objectives. For raw bacteria data, see Appendix B.

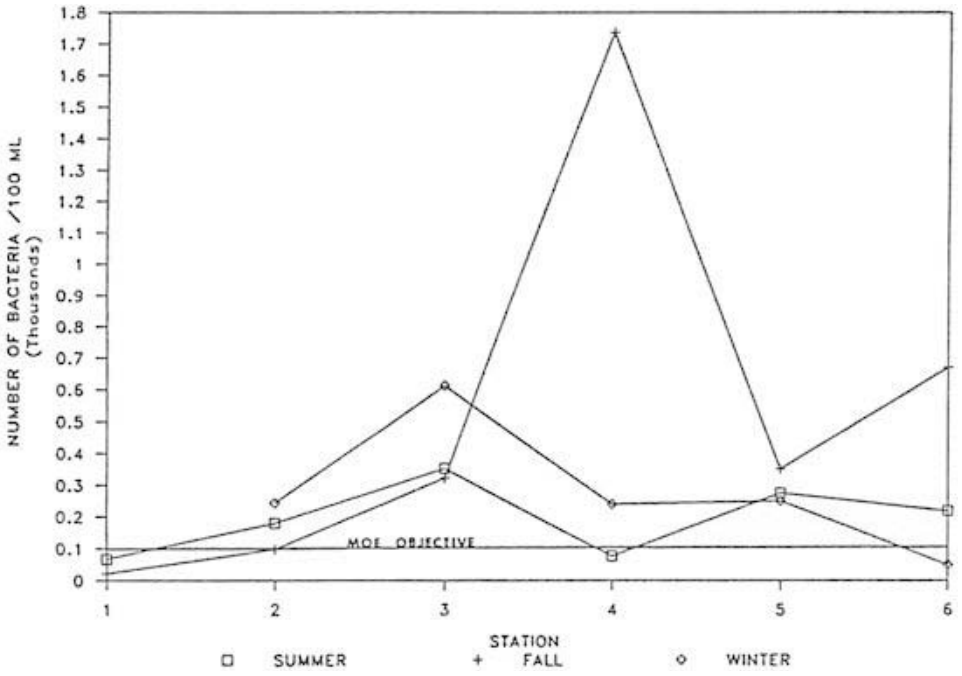

Fig. 6: Mean Fecal Coliform Levels in Highland Creek

Station Locations

Fall concentrations of fecal *Streptococci* were highest along the mid-section of the creek, between stations 5 and 3. A walking survey of the creek revealed that most of the livestock farms in the watershed are located in this area. Furthermore, the creek runs directly through the pasture on the majority of these farms. Downstream of this region as the creek approaches the beach, bacterial levels decreased dramatically (95%). Levels also decreased Between station 6 on the Kernohan-O'Donnel Drain and station 3. During the summer months of this study, station 5 averaged the highest concentration of fecal *Streptococci.* Levels dropped slightly between stations 5 and 4 during this time, but increased between stations 4 and 3. It should again be noted that stagnant pools were encountered along much of the watercourse at this time. This may have affected results and should be considered when analyzing the data. In the winter, mean concentrations of fecal *Strep*. grew steadily from station 5 to station 3 but decreased further downstream. Levels decreased for both summer and winter months between stations 6 and 3 of the watercourse.

Geometric means for fecal coliform were greatest in the fall at station 4. It should be noted that a polluted tile was found just upstream of this station. The lab results of the number of bacteria per 100 ml of water were as follows:

fecal coliform	fecal *Strep*.	*P. aeruginosa*	*E. coli*
3,800,000,000	1,000	1900	3,800,000,000

The tile appeared to originate from a household. MOE was alerted to the problem but results of the investigation were not known at the time of printing. A total of 170 tiles were mapped but this was the only one that was found to be polluted. Downstream of station 4 levels dropped dramatically until they reached 19 fecal coliform per 100 ml of water at the beach. Summer and winter concentrations of this bacteria were generally lower than those in the fall. Trends in data were also very similar between the summer and winter months. In both cases the highest concentration of fecal coliform was found at station 3. Downstream of this station, levels slowly decreased toward the beach. Bacterial counts increased between stations 4 and 3 of the stream, but dropped between stations 5 and 4. Levels at station 3 were higher than its upstream neighbour, station 6.

Lakefront

Fig. 7 illustrates the results of samples taken by the S.C.R.C.A. and the Lambton-Sarnia Health Unit from the beach at the Highland Glen Conservation Area. The Authority began sampling the beach on June 26, 1989. Over the course of the summer, bacterial counts averaged 61 fecal coliform per 100 ml of water. Seven samples were above the MOE guidelines of 100 fecal coliform per 100 ml of water. The Lambton-Sarnia Health Unit

sampled the beach from June 12, 1989 to September 26, 1989. Their results indicated bacterial levels of 32 fecal coliform per 100 ml of water. There were, however, three samples over the course of the summer which were in excess of the recommended guidelines. It was on the basis of the high count on July 10, 1989 that the Lambton-Sarnia Health Unit closed the beach at the Highland Glen Conservation Area from July 13, 1989 to July 26, 1989.

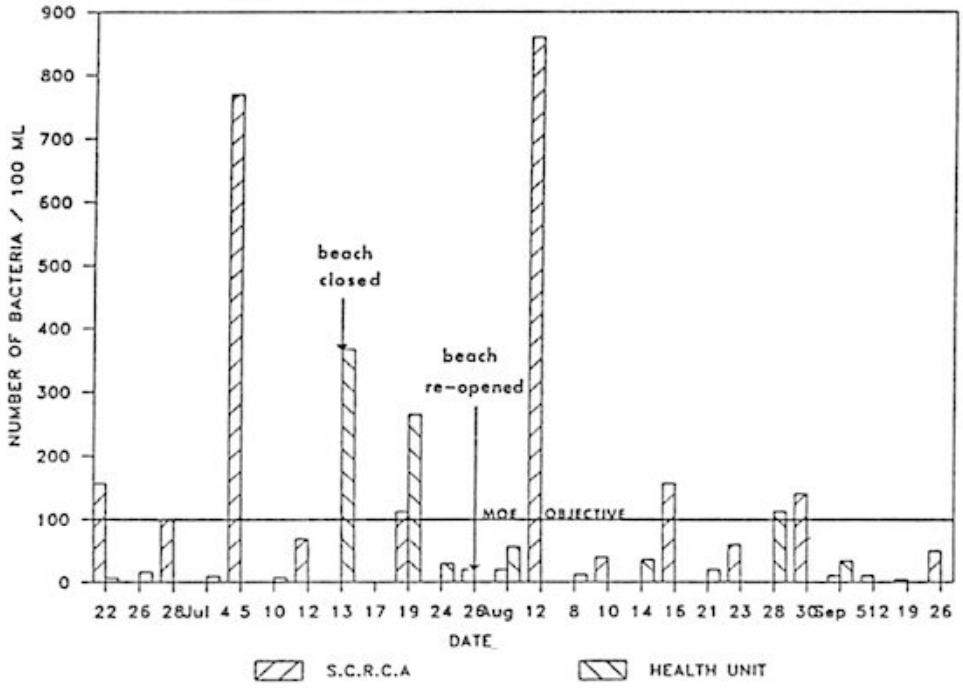

Fig. 7: Mean Fecal Coliform at the Highland Glen Beach

During the months of August and November 1989 a walking survey was done of the cottages along the Lake Huron shoreline between Blue Point and Hillsborough Beach. A total of 54 tiles, as well as the mouth of Aberarder Creek and the beach at Highland Glen were mapped. Samples were taken from four tiles, Aberarder Creek and Highland Glen beach. Of these, two tiles and Aberarder Creek had excessive fecal coliform and fecal *Strep*. counts. Fig. 8 shows their locations. Tile "a" was traced up the bluffs and appeared to be a storm sewer outlet. Not all tiles were followed in this manner as climbing was treacherous in most spots.

The discovery of these polluted tiles led to an investigation of the cottage community along this stretch of the shoreline. Preliminary unpublished studies of this area had been carried out by the Ministry of the Environment in the 1970's. They revealed that the septic tanks in this region of Plympton Township were faulty and could indeed be contributing to beach closures. It was also learned that another study is currently underway to determine the best possible solution for cleaning up the area. As a result, the Conservation Authority decided not to pursue the matter further but keep up to date on the proceedings.

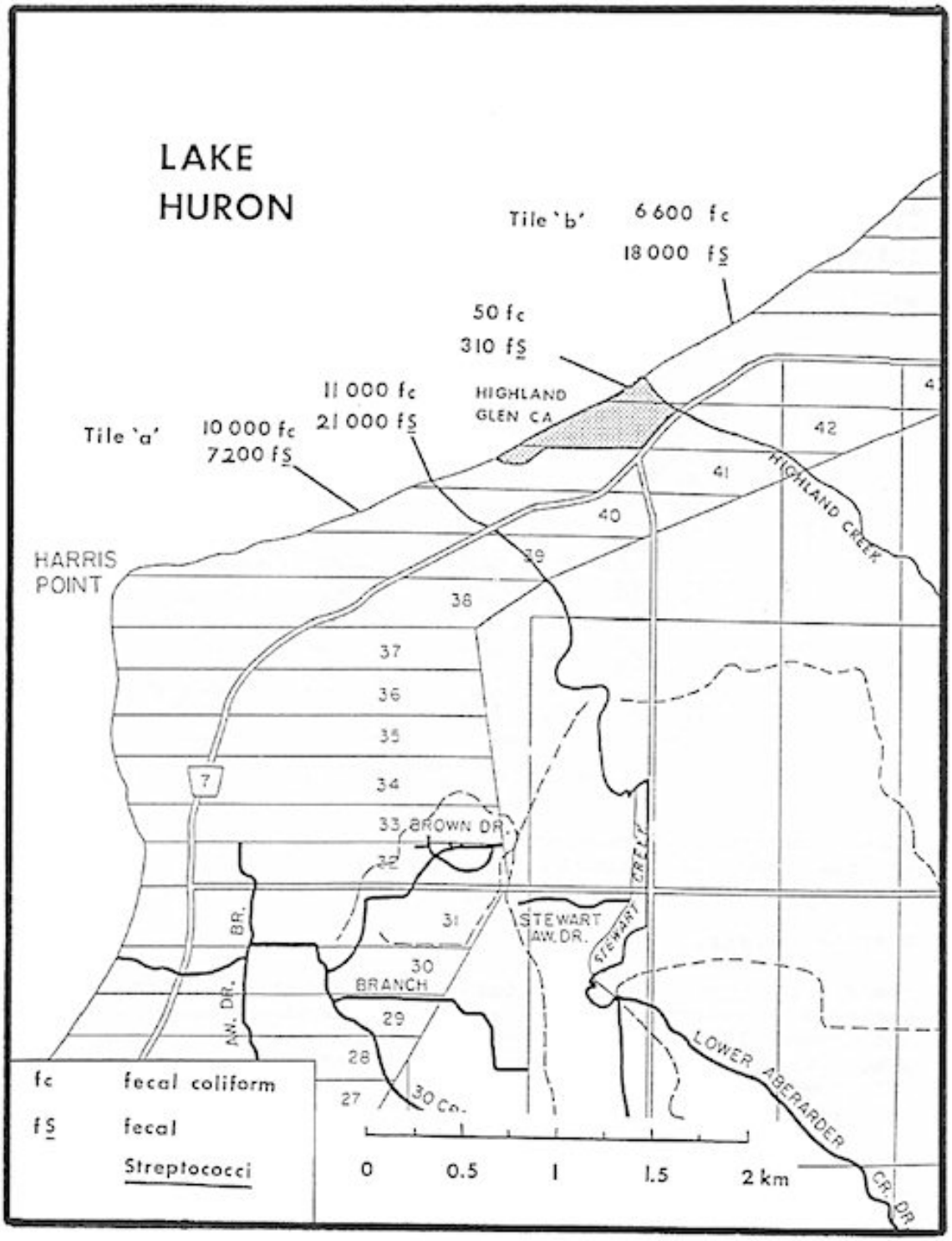

Fig. 8: Possible Pollution Sources on the Lake Huron Shoreline

Chemical - General

Levels of the chemical parameters remained fairly constant over the course of the study. Total Kjeldahl Nitrogen (TKN) and total phosphorus levels were excessive year round. Values for TKN ranged from 1 - 4 times MOE objectives while phosphorus levels were 1 - 6 tines objectives. Soluble phosphorus levels were 3- 5 times MOE objectives in the fall and winter at most stations. Chloride levels were excessive in summer and fall, fluctuating anywhere from 1 - 3 times guidelines. The winter months had the highest nitrite and nitrate concentrations. They varied from 1- 1.5 times MOE guidelines (see Fig. 9).

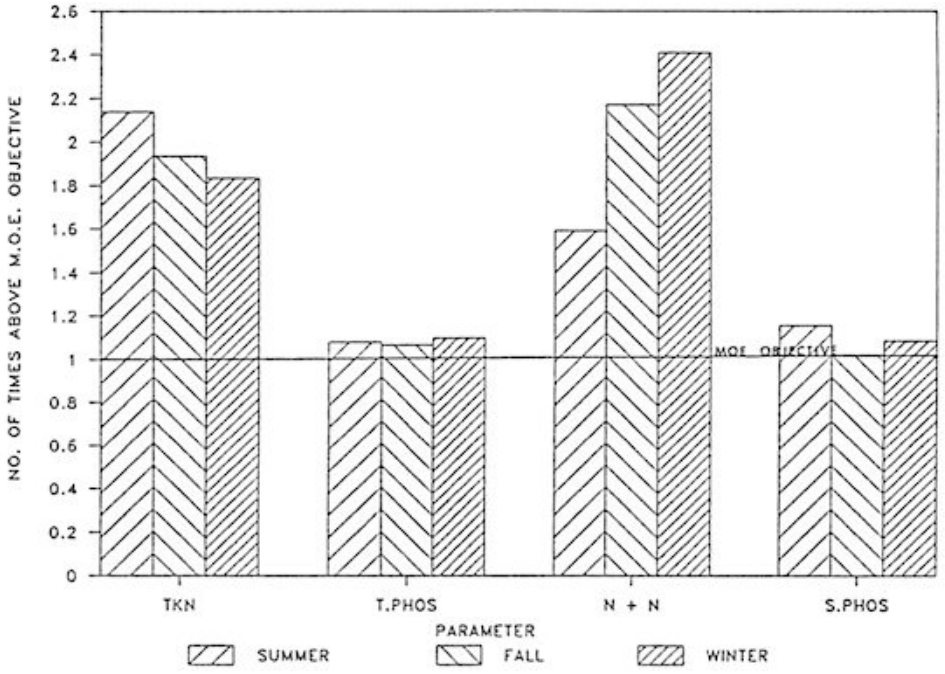

Fig. 9: Excessive Chemical Parameters in Highland Creek

Other chemical parameters such as BOD, suspended sediments, ammonia, pH and conductivity were at acceptable concentrations throughout the season with only occasional excessive levels.

Station Locations

There was some variation between the stations with respect to parameter concentrations. Levels of TKN were lowest at the beach and gradually increased when moving towards the headwaters. The same was true of total and soluble phosphorus concentrations. Chloride levels behaved similarly but peaked at station 4 and not at the source of the creek.

Time constraints did not allow for a detailed review of the landowner questionnaire. Those results will be included in the report for Stage 2 of the CURB plan.

DISCUSSION

Fecal *Streptococci* and fecal coliform are types of bacteria that can be used to indicate the presence of sewage or fecal matter. Their densities in the water are directly related to the risk of contracting a disease from the pathogens associated with them. These two bacteria can be used in conjunction to indicate the nature of the potential fecal source (Appendix A).

Summer bacteria levels in the creek were difficult to assess as stagnant conditions were encountered from late-July to mid-November. As a result, samples were not taken as they would not accurately represent the conditions of the creek as a whole. Winter sampling was sporadic as well as the creek was frozen for most of December and January. Late fall had the highest concentrations of bacteria as this was a time of relatively high flow volume.

Results indicate that there is bacterial pollution occurring in the Highland Creek watershed. Fecal *Streptococci* levels exceeded those of fecal coliform, suggesting that animal waste was the primary source of pollution.

Elevated fecal *Streptococci* levels were detected at station 5. Through an interview, it was learned that a large hog operation existed upstream of this area. The farmer in question did not possess adequate manure storage. As a result he was spreading every month. If this was done in the dry conditions of 1989 the manure may have run directly into the tiles through the cracks in the soil. Most of the landowners directly upstream of this hog farmer claimed that they used only chemical fertilizers on their land. Thus, they would not have been contributing to the bacterial pollution. To help remedy the pig farmer's situation, the S.C.R.C.A. has found a cash crop farmer who is willing to take some of the excess manure. It is hoped that this type of "manure-sharing network" can be set up in more of our watersheds.

Bacterial levels of fecal *Strep*. were highest in the mid-section of the creek where the greatest concentration of livestock farms was found. Unrestricted cattle access was quite prevalent along this stretch of the watercourse. This may have been a significant source of bacterial pollution. Fecal bacteria deposited between May and September would not have survived in the warm, stagnant pools of the creek but may have survived in the sediment (Gary Palmateer pers. comm.). These sediments would have been stirred up in the fall because of the increased water volume. Contaminated tiles may also have had increased flow in the fall. Both of these factors could have contributed to the inflated counts during that season.

Downstream the creek flowed through a woodlot and the levels of bacteria were much lower (95%). Field tiles were not found in this area. Instead they stopped short of the woodlot and released water into the soil. This allowed the water to filter out before reaching the creek.

Furthermore, farms were not as concentrated along this portion of the watercourse as they were upstream. Both of these factors would account for the low bacteria counts found along this part of the creek.

Elevated counts of fecal *Strep*. were also found at station 6 on the Kernohan-O'Donnel Drain. Directly upstream of this station there was a fairly large hog operation which may have been contributing to the contamination. Residents in the area have complained of the odours and, although it is not always the case, overspreading of manure may be the culprit in this instance.

Although not as extreme as fecal *Streptococci.,* fecal conform bacteria also occurred at elevated concentrations in Highland Creek. This was especially true at station 4, a site downstream of a polluted tile. Judging from the fecal count, the tile was septic in nature. Such a point source would not only contribute to the closure of the beach at Highland Glen, but may also pose a potential health hazard to livestock watering downstream. The Ministry of the Environment has been notified of the problem.

Levels of fecal conform varied between stations during the summer and winter. Counts were consistently above MOE guidelines at station 3 in both cases, possibly because Highland Creek and the Kernohan-O'Donnel Drain met at this point. Downstream of this station levels slowly decreased. Again, this could have been because the tiles ended short of the woodlot and the water could filter through the soil.

The S.C.R.C.A. has had beach closures at the Highland Glen Conservation Area for the past two years (1988-89). The Lambton - Sarnia Health Unit is responsible for sampling this beach, as well as those from Grand Bend to Sarnia to Port Lambton. On July 13, 1989 the beach at Highland Glen was closed for two weeks. Samples taken by the Health Unit on July 10, 1989 had shown very high counts of fecal coliform bacteria. It was learned that other beaches along the Lake Huron shoreline had also experienced elevated counts at that time. It was on the basis of all of these readings, as well as rainfall events and the history of the area that the beach at Highland Glen was posted (Clayton Wardell pers. comm.).

As was previously mentioned, two polluted tiles were found on the beach which may have contributed to the fouling of the water at Highland Glen. One of these sources was traced and appeared to be originating from a storm sewer. It is quite possible that faulty septic tanks in this area are leaking into this sewer.

A sample from Aberarder Creek also showed high levels of bacteria. Yet when data between Highland Glen and Aberarder was compared, the latter seemed to be having no effect on the conditions at Highland Glen. However, this may not always be the case. Shifts in the wind direction can alter wave direction, making it difficult to assess the origin of the pollution.

It should also be noted that, at the time of the beach closure, Highland Creek was beginning to encounter stagnant conditions. A few samples were taken from the creek at that time and bacteria levels were excessive. However, the creek was not breaching the sand dam at the beach. A certain amount of polluted water may have filtered through the sand but it may not have been sufficient to close the beach. The source of pollution may have originated from somewhere else.

The Ministry of the Environment (Sarnia) has been investigating the faulty septic tanks in the cottages along Lake Huron. They feel that they may be contributing to the beach closures. The Ministry has awarded a joint contract for a Class Environmental Assessment to Monteith, Ingram & Graham and DeLCan. Once this is completed, they hope to have the best alternative to resolve the problem (Chris Hutt, pers. comm.).

Not only were bacterial levels excessive in Highland Creek, levels of TKN, total phosphorus and soluble phosphorus also had concentrations well above MOE guidelines. This type of pollution is caused by erosion, excess fertilizer application, untreated milkhouse waste water and industrial cleansers entering the watercourse. Such an environment is ideal for algal blooms and can lead to eutrophication. The high chloride levels also found in the creek can disrupt the ionic balance in aquatic life. All of these create a poor aquatic environment and can lead to fish kills.

Recommendations

1. A "manure-sharing network" should be set up in the Highland Creek watershed. Most farmers near the headwaters of the creek are crop farmers and do not have manure to spread on their fields. Agreements could be made between them and livestock farmers in the watershed whereby the excess manure is shared.

2. Farmers should be encouraged to adopt farming practices which would reduce bacterial pollution. If possible, public forums should be set up whereby those who practice this type of farming can speak to those who do not. An annual bus tour should also be arranged so that local farmers can see these practices in action. Farmers are more likely to listen to other farmers than government officials and this would encourage them to share knowledge.

3. Landowners must be made more aware of the ways human and animal waste can enter into watercourses. Presently, the S.C.R.C.A. is taking a Water Quality Display to different malls/libraries in the watershed to increase peoples' awareness. More information could also be made available in newspapers, magazines and more Water Quality Information days.

4. Further investigation is needed of the area upstream of station 5. The creek branches at this point and it is difficult to determine which branch is the greater source of pollution. There are four hog farms which may be possible contributors. Sampling directly up- and downstream of these sources would help determine the problem farms.

5. Further investigation is needed of the region upstream of station 6. Residents in the area have been complaining of odours from a large hog operation. Overspreading may be the source of bacterial pollution in this case.

6. Intensive summer sampling should be done along the beach, both updrift and downdrift of the Highland Glen Conservation Area. Together with wind data, this may help to pinpoint where the source of pollution is located.

7. Results from samples taken by the S.C.R.C.A. will be sent to the Lambton-Sarnia Health Unit as this would help them "fill in" any holes in their data and give them a more a more accurate picture of the beach conditions.

8. There should be a mandatory clean out of septic tanks every three to four years in this watershed. Septic tanks do not function properly in clay soils and this is one way to help alleviate the problem of backups and leakage into creeks.

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APPENDICES

Appendix A

Description of bacteriological parameters

PARAMETER	MOE OBJECTIVE (#/100 ml)	DESCRIPTION	EFFECTS
fecal coliform group	100	• subgroup of the coliform group • group of intestinal • bacteria found primarily in 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	• disease transmission to swimmers either directly or through other bacteria present with it
Escherichia coli	100	• 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 coliform	• illness to swimmers at high concentrations • 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	• causes eye, ear, nose, throat and skin infections to swimmers

Appendix A (continued)

Description of chemical parameters

PARAMETER	MOE OBJECTIVE	DESCRIPTION	EFFECTS
Temperature	---	• water temperature in degrees Celcius • oxygen is less soluble in warm water • many chemicals are more soluble in warm water	• high temperature or quick changes can be dangerous to fish • dissolved chemicals can be dangerous to fist"
Biological Oxygen Demand (BOD)	4*	• 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.)	50*	• 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, temperature dependent
Total Kjeldahl Nitrogen (TKN)	0.5 mg/L	• measures organic nitrogen and ammonia together	• eutrophication

* objectives taken from Inland Waters Directorate manual (1979)

Appendix A (continued)

PARAMETER	MOE OBJECTIVE	DESCRIPTION	EFFECTS
Nitrate (N)	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 (N)	for nitrate plus nitrite	• an intermediate form of ammonia and nitrate • sources: animal rumens and moist feeds • usual range 0.001 mg/L	• toxic to aquatic life
Total Phosphorus (T. Phos.)	0.03 mg/L	• a nutrient • sources: erosion, fertilizers, milk-house waste water, industrial cleansers	• encourages algal blooms and eutrophication
Soluble Phosphorus (S. Phos.)	---	• amount of total phosphorus in solution	• as above
pH	6.5-8.5	• measures the salt content of the water	• disrupts the ionic balance in fish • can be corrosive
Conductivity	---	• numerical expression of the waters ability to conduct electrical current • increases with levels of levels of dissolved solids such as magnesium, sodium and sulfur	• ----

Source: "Bear Creek Water Quality Study", S.C.R.C.A., 1989.

APPENDIX B

MEAN BACTERIA COUNTS FOR HIGHLAND CREEK

	MEAN FECAL COLIFORM			MEAN FECAL STREPTOCOCCI		
Station	summer	fall	winter	summer	fall	winter
1	67	21	---	64	19	---
2	180	98	244	244	96	310
3	353	323	614	626	397	589
4	77	1737	241	553	2589	269
5	276	351	251	696	803	156
6	219	671	50	526	958	480