CLEAN UP RURAL BEACHES (CURB) PLAN FOR BIG CREEK AND OTHER WATERSHEDS IN THE ESSEX REGION CONSERVATION AUTHORITY

FINAL REPORT

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ABSTRACT

Big Creek, draining into Lake Erie just west of Holiday Beach Conservation Area, was selected as the study watershed for the Clean Up Rural Beaches (CURB) program. The study determined fecal coliform and phosphorus loadings from upstream sources within the watershed using CURB algorithms and ranked the relative impact of these sources. In addition, the impact of the Detroit River and shoreline homes located west of Big Creek outlet, were assessed for their impact on water quality at Holiday Beach. A water and sediment sampling monitoring program was used to verify algorithm rankings.

Improperly functioning septic systems within the watershed were identified from CURB algorithms as having the greatest fecal coliform loading of 1.04×10^{13} FC-yr^{-1}, or 73% of the total 1.42×10^{13} FC-yr^{-1} loading. Sediment samples taken at the watershed outlet confirmed the presence of human fecal contamination. Similarly, elevated fecal coliform counts of human origin were measured at the Detroit River. However, the distance of the Detroit River from Holiday Beach was sufficient to minimize the impact of this source on water quality at the Beach, under normal lake conditions.

Improper manure management practices accounted for approximately 23% of the total fecal coliform loading. CURB algorithms estimated winter spreading and spring/summer/fall overspreading to have significant fecal coliform loadings to Holiday Beach. Relatively insignificant fecal coliform loadings were associated with the other agricultural sources.

Soil erosion within the watershed was identified as contributing the greatest phosphorus load of 7358.4 kg.yr^{-1}, or 83% of the total load from the watershed as estimated by the CURB algorithms. High suspended solids and phosphorus concentrations measured at the watershed outlet confirmed sediment loading from upstream sources.

A cost-effectiveness analysis determined that restricting livestock stream access, improving septic system operation and expanding manure storage facilities would result in the greatest fecal coliform load reductions. It was also determined that remedial measures directed at these sources will lower phosphorus loadings. Additional phosphorus loading reductions can be secured through the promotion of soil conservation practices.

Water quality problems exist at other beaches throughout Essex County. The rural watersheds effecting downstream water quality have been identified and are considered to be eligible for the CURB Implementation Program.

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CHAPTER ONE

INTRODUCTION

1.1 HISTORY

During the past decade, recreational water quality of Ontario's beaches has been of major public concern. Seemingly consistent closures of public beaches due to poor water quality has prompted the Ontario Ministry of the Environment to initiate the Provincial Rural Beaches Strategy Program (PRBSP) to address this problem. Through this initiative, local Conservation Authorities have carried out studies to identify rural sources of fecal coliform contamination to surface waters, estimate their impact on downstream beaches, propose abatement strategies and provide assistance in administering these strategies at the local level.

In 1989, Phase I of the Essex Region Rural Beaches (ERRE) program was initiated with the selection of Big Creek as the study watershed. During Phase I of the ERRB program a survey of livestock operations in the watershed and a preliminary water quality monitoring schedule were conducted. Details of Phase I of the ERRB program are available in the 1989 Summary Report.

During 1990, phase II of the ERRE program continued water quality monitoring and conducted some experimental trials on bacteria transport within the creek and the marsh and bacteria survival in marsh sediment. Details of Phase II of the ERRB program are available in the 1990 Summary Report. The results of the final phase of the ERRB program, conducted during 1991, are outlined in this report.

1.2 OBJECTIVES

The objectives of Phase III, of the ERRB program are firstly, to continue water quality monitoring in order to expand the existing database. Secondly, to estimate fecal coliform and phosphorus loadings to Holiday Beach from various sources within the Big Creek watershed, from Westside homes and from the Detroit River. Thirdly, a Clean Up Rural Beaches (CURB) plan will be prepared which outlines remedial actions for the reduction of fecal coliform and phosphorus loadings from identified sources. Included in the plan is a cost/benefit evaluation of the remedial actions and an implementation strategy to be followed to improve water quality at Holiday Beach. Additional watersheds in Essex County are described for their inclusion into the CURB Implementation Program.

1.3 STUDY AREA

The Big Creek watershed, approximately 60 km^2, comprises of Big Creek and its tributaries draining into Big Creek marsh, which then discharges into Lake Erie west of Holiday Beach Conservation Area (Figure 1). This watershed was chosen for the CURB study because land use within the watershed was predominately agricultural,

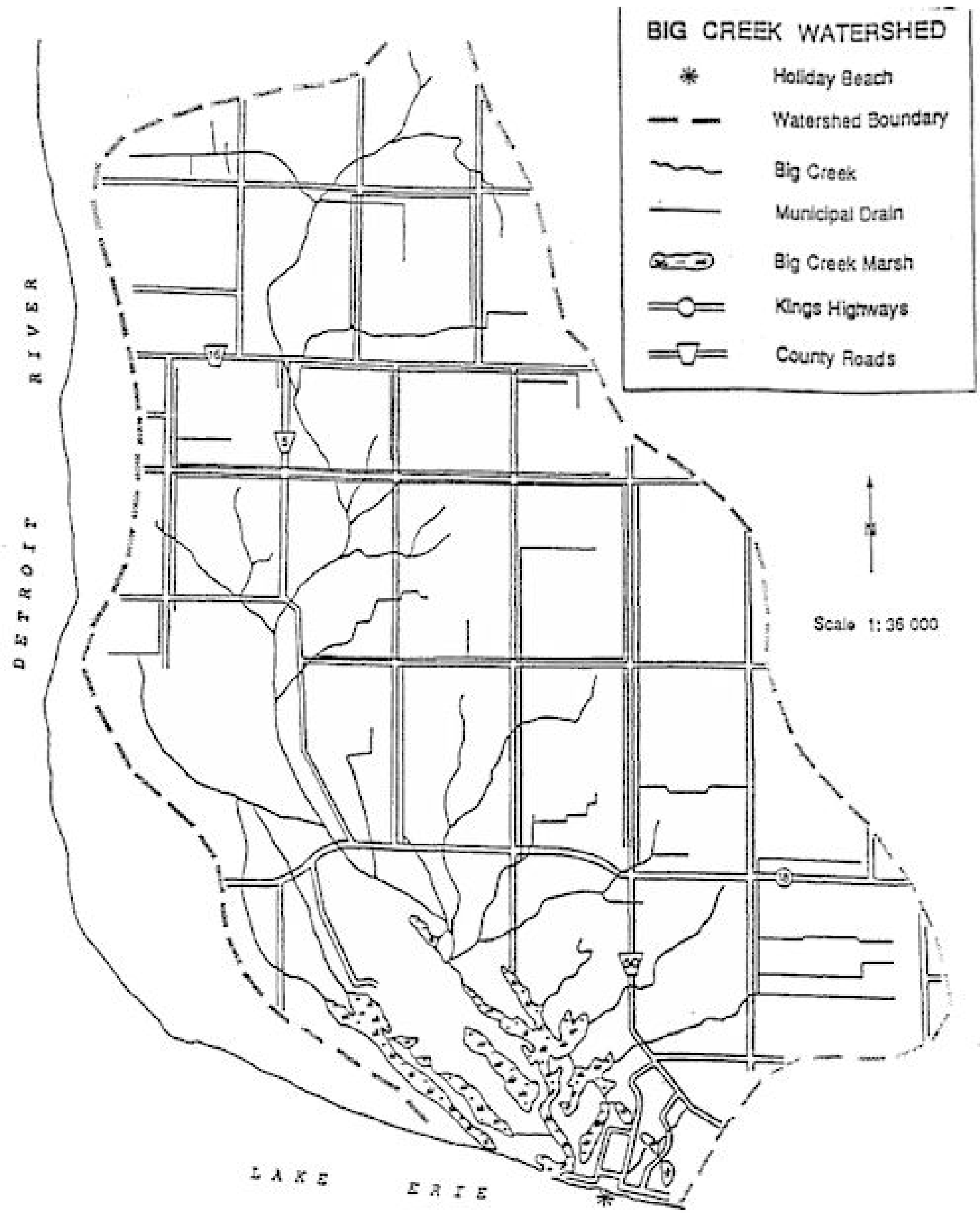

Figure 1. A map showing the area of the Big Creek watershed.

with approximately 120 cash crop farms and 17 livestock operations. In addition, the presence of a 16 km^2 marsh at the mouth of Big Creek provided an unique opportunity to investigate the survival and movement of bacteria in the marsh and the impact of the marsh on bacteria levels at Holiday Beach. Located throughout the watershed were numerous rural dwellings, as well as, a subdivision situated along the Lake Erie shoreline west of Holiday Beach, hereafter referred to as the Westside homes (Figure 1).

The topography of the study area is flat with occasional gentle slopes. There is an elevation change of five metres in the watershed from the headwaters of Big Creek to the outlet, with a 0.5% slope over this distance. The dominant soil types in the watershed are Perth clay loam and Brookston clay, with a small number of sand and gravel deposits. The combination of flat topography and high clay content of the soil in the watershed has resulted in poor natural drainage. As a result, drainage in the watershed has been improved in order to sustain agricultural activity and prevent flooding of residential homes and buildings. Thus, extensive private and municipal drains have been created to assist the natural drainage in the watershed.

The climate in the watershed was classified as being humid continental, with hot summers and mild winters. There were an average of 167 frost free days in the area and a growing season of 220 days. The mean annual precipitation for the area was estimated to be 792 mm Sanderson, 1980).

CHAPTER TWO

CURB ALGORITHMS USED TO ESTIMATE FECAL COLIFORM AND PHOSPHORUS LOADINGS

2.1 METHODOLOGY

2.1.1 Livestock Operators Questionnaire

A Livestock Operators Questionnaire was designed to evaluate the agricultural practice within the watershed which have the potential to degrade water quality. Each livestock operator in the watershed with the exception of one, was visited and a survey of the livestock operation was completed. A copy of the questionnaire was shown in the 1989 Summary Report (Kelly, 1989). A brief summary of the results effecting water quality follows

Ten operators in the watershed have solid manure storage and the remaining seven have liquid manure storage Seven of the solid manure storage operators stock pile their manure on concrete or earthen pads. Four of the operators with this system do not have liquid runoff containment and have manure stacks located within 150 m of a watercourse, which was the critical distance for fecal contamination of a watercourse.

The minimum acreage requirement for manure application based on nitrogen requirements for loamy to clayey soils planted to corn was two animal units/acre (Ontario Ministry of Agriculture and Food *et al.*, 1976). Based on this guideline used in the CURB Manure Storage/Barnyard Runoff, Section B of the Water Quality Improvement Plan, two of the 10 operators with solid manure and two of the six operators with liquid manure overapply manure to their fields.

Of the 16 livestock operators surveyed, 15 grow cash crops. Of these 15 operators, 14 do not determine the nutrient value of their manure. Five and eight operators determine the nutrient content of their soil annually and bi-annually, respectively. The remaining two operators do not determine the nutrient content of their soil. A better understanding of the nutrient requirements of the land and the nutrient content of the manure applied, will prevent unnecessary manure spreading or overspreading and potential fecal coliform and phosphorus contamination of a nearby watercourse.

The two dairy operations in. the watershed do not have waste water treatment facilities. A tile leads directly from the milkhouse to a watercourse for both operations. The milkhouse waste water is a source of both phosphorus and bacteria contamination and direct discharge of this waste water to a watercourse should be avoided.

Seven livestock operations in the watershed pasture livestock near a watercourse. Five of these seven operations have unrestricted access of livestock to a watercourse while the remaining two operations have restricted access. All five of the operators stated that the livestock will not drink from these watercourses if clean water is available, but will continue to wade into the water to cool down. Two of these seven livestock operations were dairy. Milk production from these operations increased after the watercourse was no longer used as the source of water, indicating the poor water quality of the watercourse.

All of the 17 livestock operators surveyed have a septic tank to handle their sanitary waste. The age of these tanks varied from 3-30 years. The majority of the tanks were serviced on a problem basis. Indicative of this approach to septic system maintenance three septic systems have never been serviced and eight have not been serviced in the last 10-15 years.

Only six systems were serviced during a 3-10 year period. Proper maintenance of the septic system will optimize its function of controlling fecal coliform discharges. The information contained in the questionnaire was used in the CURB algorithms to estimate fecal coliform and phosphorus loadings from various sources within the watershed.

2.1. Fecal Coliform nd Phosphorus Loadings to a Watercourse

Fecal coliform and phosphorus loadings to a watercourse from specific sources were calculated using algorithms for each subbasin within the Big Creek watershed. The subbasins and the location of the Westside homes are outlined in Figure 2. The sources of potential fecal coliform and phosphorus pollution were faulty septic systems livestock stream access milkhouse waste barnyard/feedlot runoff, manure stack runoff, winter spread manure and spring/summer/fall manure overspreading. The algorithms used to estimate relative fecal coliform and phosphorus loadings were a modification of a computer model called Pollution from Livestock Operation Predictor (PLOP developed by Ecologistics Ltd. (Ecologistics Ltd., 1988).

Participants in the Provincial Rural Beaches Strategy redefined PLOP and provided additional formulae to correctly estimate fecal coliform and phosphorus loadings (Bos, 1988) . Where possible components and parameters of the algorithms were modified to represent unique conditions of each subwatershed.

2.1.2.1 Faulty Septic Systems

The septic system algorithm estimated the total annual fecal coliform and phosphorus loadings to watercourses as a consequenc of faulty or improperly maintained septic systems.

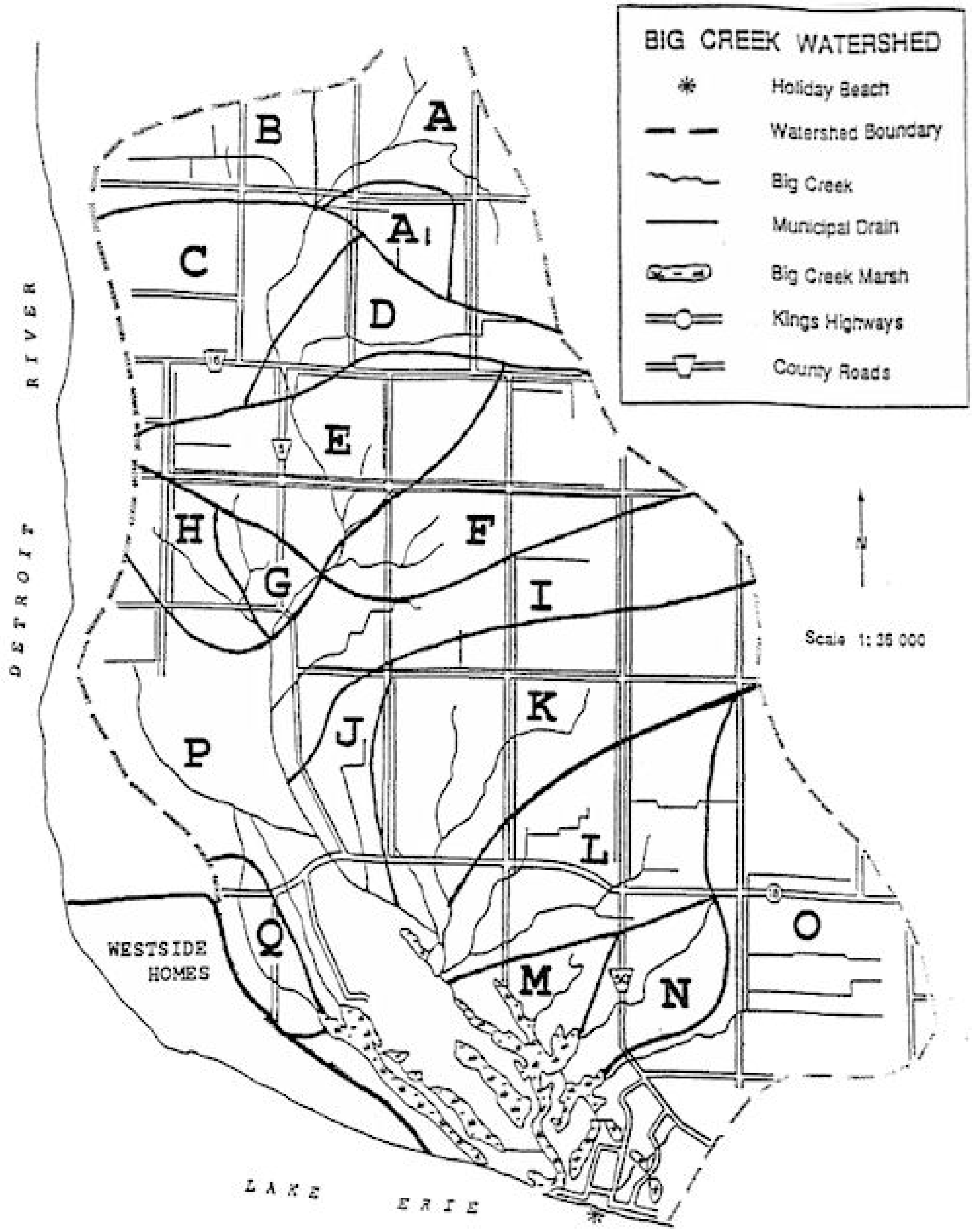

Figure 2. Outline of subbasins in the Big Creek watershed and Westside homes used in the CURB algorithms to determine fecal coliform and phosphorus loadings to Holiday Beach.

Load = parameter concentration x Volume H_20 used/person/day x number of homes in subwatershed x average family size x % faulty septic systems x delivery to watercourse x 365 days.

A number of assumptions were made in order to calculate the septic system load. They were as follows:

1) The parameter concentrations are listed in Appendix 1.

2) Volume H_2O used/day/person was 240 L (Malden Township Clerk per. comm., 1991).

3) Number of homes in the subwatersheds were determined from property assessment records.

4) Average family size was 2.5 persons.

5) The percentage of potentially faulty septic systems with inadequate domestic waste disposal was estimated from property assessment records. Homes built prior to 1974 were assumed to have inadequate septic waste disposal (G. Pillon, per. comm., 1991). From the property assessment records it was estimated that 83% of the septic systems were installed prior to 1974 and considered to be operating inadequately. However, it was suggested that between 1974 and 1991 improvements were made on these old septic systems. Thus, a faulty septic system value of 70% was used (M. Strong, per. comm., 1991).

6) A delivery rate to a watercourse of 50% or 0.5 was used (Fuller and Foran, 1989).

2.1.2.2 Livestock Stream Access

This algorithm estimated the fecal coliform and phosphorus load from livestock having access to a stream

Load = parameter concentration/defecation x EAU x probability of defecating x number of access events/day x location factor x number of animals in pasture x number days in pasture.

A number of assumptions were made in order to calculate the livestock stream access load. They were as follows:

1) The parameter concentrations are listed in Appendix 1.

2) Equivalent animal units (EAU) are listed in Appendix 2.

3) A probability of 0.18 for an animal defecating in the watercourse during an access event was used (Demal, 1982).

4) The number of access events/day/animal was 2.5 (Demal, 1982)

5) The location factor was 1.0 if the watercourse was not on a major travelled pathway leading to a barn or daily feeding area. A location factor of 1.6 was used if the watercourse was located on a major travelled pathway leading to a barn or daily feeding area or if the watercourse was the only source of water (Ecologistics, 1988).

6) The number of animals in pasture and the number of days livestock were in pasture were calculated from Livestock Operators Questionnaire (Kelly, 1989).

2.1.2.3 Milkhouse Waste

The milkhouse waste algorithm estimated the total annual fecal coliform and phosphorus loads delivered to nearby watercourses as a result of mismanagement of milkhouse waste water.

Load = parameter concentration x volume of waste water/cow/day x livestock number x lactation period x delivery of waste water to tile system.

A number of assumptions were made in order to calculate the milkhouse waste load. They were as follows:

1) The parameter concentrations are listed in Appendix 1.

2) A volume of 13 L/cow/day was used (Fuller and Foran, 1989).

3) The number of milking cows per livestock operator was taken from the Livestock Operators Questionnaire (Kelly, 1989).

4) The lactation period was assumed to be 365 days.

5) The delivery of waste water to the tile system and accounting for growth of bacterial in the tile system was 50,000% or 500. A 100% or one delivery factor was used for phosphorus (Fuller and Foran, 1989).

2.1.2.4 Barnyard/Feedlot Runoff

The barnyard/feedlot runoff algorithm was used to calculate the total annual fecal coliform and phosphorus loads delivered to a watercourse that was 150 m or less away from the barnyard/feedlot. The average manure accumulated (AMA in kilograms, average manure pack (AMP) and volume of runoff were determined for each feedlot.

Load = parameter concentration in runoff x AMP x runoff volume x delivery to watercourses

A number of assumptions and calculations were made in order to calculate the barnyard/feedlot runoff load. They were as follows:

1) The parameter concentrations are listed in Appendix 1.

2) The AMP (kg) was calculated, by first calculating AMA as follows:

AMA = (number of animals in feedlot x EAU x 1.31 kg/hr x hours/day animals in feedlot x number of days between scraping)/2.

a) The number of animals in the feedlot was gathered from the Livestock Operators Questionnaire (Kelly, 1989).

b) Equivalent animal units are listed in Appendix 2.

c) An average excretion of 1.31 kg/hr of fecal material was used

(Ecologistics, 1988).

d) In a feedlot operation it was assumed that the cattle were out on the open lot for an average of 16 hours/day for half the year and 3 hours/day for the other half of the year. In a dairy operation with an open feedlot or exercise yard, the cows were on the open lot for 1 hour/day/year (Fuller and Foran, 1989).

e) The number of days between scraping was determined from the Livestock Operators Questionnaire (Kelly, 1989).

3) The AMA was used to calculate the AMP.

AMP = (AMA/barnyard area)/manure pack size.

a) The barnyard area was calculated from the Livestock Operators Questionnaire (Kelly, 1989).

b) The manure pack size was assumed to be 67,180kg/ha (Ecologistics, 1988).

4) The volume of runoff from the barnyard/feedlot area was calculated as follows:

Runoff volume = barnyard area x annual precipitation x percent runoff x proportion of year barnyard/feedlot used.

a) The barnyard area was calculated from the Livestock Operators

Questionnaire (Kelly, 1989).

b) The annual precipitation was estimated to be 792 mm Sanderson, 1980).

c) It was assumed that the runoff from the yard area was 60% of the annual precipitation (Coote and Hore, 1978).

d) The proportion of the year the barnyard/feedlot was used was estimated from the Livestock Operators Questionnaire (Kelly, 1989).

5) A delivery of 80% to the watercourse was used if the barnyard/feedlot was within 150 m of the watercourse and runoff flowed toward the watercourse

2.1.2.5 Manure Stack Runoff

The total annual fecal coliform and phosphorus loads originating from a solid manure stack with no runoff containment located within 150 m of a watercourse were calculated. For each calculation average stack volume (ASV) in m and average yard area (ASA) in ha covered by the manure stack were calculated.

Load = parameter concentration in stack runoff x ASA x runoff volume x delivery to watercourse.

A number of assumptions and calculations were made in order to calculate the manure stack runoff load. They were as follows:

1) The parameter concentrations are listed in Appendix 1.

2) The ASA (ha) was calculated, by first calculating the ASV as follows:

ASV = (1/1+ number of cleanouts) x (number of animals in barn x volume of manure/animal/day x number days in barn/year) - (% of day in pasture x number of animals in pasture x volume of manure/animal/day x number days in pasture/year).

a) The number of cleanouts was gathered from the Livestock Operators Survey (Kelly, 1989).

b) The number of animals in the barn which go out to pasture was determined from the Livestock Operators Survey (Kelly, 1989).

c) The volume of manure/animal/day was taken from Appendix 3.

d) The number of days in the barn/year was estimated from the difference of the number of days animals were in pasture from 365 days.

e) The percent of day livestock were in pasture was assumed to be 75 for dairy cows and 100 for beef cows (Fuller and Foran, 1989).

f) To determine the number of animals in pasture see 2(b).

g) To determine the number of days in pasture see 2(d).

3) The ASA was determined from the ASV using the following calculation:

$$ASA = [\ ((ASV\ m^3 - 14.3\ m^3)\ /7.36\ m^3)\ x\ 5.36\ m + 18m^2]\ /10000m^2/ha.$$

4) It was assumed that manure stack runoff was 60% of the annual precipitation (Coote and Hore, 1978).

5) A delivery to the watercourse of 80% was assumed if the manure stack was located within 150 m of the water course and runoff flowed toward the watercourse.

2.1.2.6 Winter Spread Manure

This algorithm estimated the total fecal coliform and phosphorus loads delivered to watercourses from manure spreading during the winter season.

Load = parameter amount in winter spread manure x drain density x critical distance to watercourse x delivery to watercourse x bacteria decay in stack x bacteria decay in field.

A number of assumptions and calculations were made in order to calculate the winter spread manure load. They were as follows:

1) The parameter amount in winter spread was calculated as follows:

Parameter amount in winter spread manure = volume of manure/animal/day x conc.

of parameter in manure x number of animals x 365 days x % of manure winter spread.

a) The volume of manure produced per day (m^3/day) for each animal type are given in Appendix 3.

b) The concentrations of fecal coliform and phosphorus in manure are listed in Appendix 1.

c) The number of animals/livestock operation was gathered from the Livestock Operations Survey (Kelly, 1989).

d) It was assumed that 33% of the manure produced in a year was spread in the winter months.

2) A drain density of 1.09km/km^2 for Southwestern Ontario was used (Robinson and Draper, 1978).

3) A critical distance of 150 m to the watercourse was used (Fuller and Foran, 1989).

4) It was assumed that 10% of the manure that was spread in the winter months was delivered to the watercourse (Robinson and Draper, 1978).

5) A stack decay factor of 0.33 was used. It was calculated using a decay rate of 0.032 logs/day and an average manure storage time of 15 days, assuming manure was spread once a month during the winter months (Fuller and Foran,

1989) i.e. $10^{(-0.032)(15)} = 0.33$. The stack decay factor was not used in the algorithm estimating phosphorus loading.

6) A field decay factor of 0.35 was used. It was calculated using a bacteria decay rate of 0.066 logs/day (Thelin and Gifford, 1983) and an average of 7 days between spreading and a runoff event (Fuller and Foran, 1989) ie. $10^{(-0.066)(7)} = 0.35$. The field decay factor was not used in the algorithm estimating phosphorus loading.

2.1.2.7 Spring/Summer/Fall Manure Overspreading

This algorithm estimated fecal coliform and phosphorus delivered to watercourses as a result of overspreading manure during the spring, summer and fall periods.

Load = [(parameter amount produced annually - parameter amount in winter spread load) - parameter amount in stream access load] x stack decay x field decay x drain density x critical distance x delivery x % manure over applied + subsurface load.

A number of assumptions and calculations were made in order to calculate the spring/summer/fall overspreading load. They were as follows:

1) The parameter amount produced annually was calculated as follows:

Parameter amount produced annually = volume of manure/animal/day x parameter concentration x number of animals x 365 days.

a) Volume of manure produced/animal/day is listed in Appendix 3.

b) The fecal coliform and phosphorus concentrations are listed in Appendix 1.

c) The number of animals contributing fecal coliform and phosphorus to a watercourse were taken from the Livestock Operators Questionnaire (Kelly, 1989).

2) The parameter amount in winter spread manure was taken from section 2.1.2.6.

3) The parameter amount in stream access loadings was taken from section 2.1.2.2.

4) A stack decay factor of 0.5 was used. It was calculated using a decay rate of 0.01 logs/day (Thelin and Gifford, 1983) and a average manure storage time of 30 days (Fuller and Foran, 1989). A stack decay factor was not used in the phosphorus loading estimate.

5) A field decay factor of 0.35 was used. The method involved in this calculation is outlined in section 2.1.2.6, assumption #6. A field decay factor was not used in the phosphorus loading estimate.

6) A drain density of 1.09 km/km^2 for southwestern Ontario was used (Robinson and Draper, 1978).

7) A critical distance of 150 m was used.

8) It was assumed that 5 and 10% of the fecal coliform and phosphorus in manure respectively, spread within the critical distance would be transported to a watercourse (Fuller and Foran, 1989).

9) The percent manure over applied for each livestock operator was calculated by comparing the number of acres that were used to apply manure in the spring/summer and fall, as reported in the Livestock Operators Questionnaire (Kelly, 1989) to the recommended number of acres required to spread the same quantity of manure as outlined in the Agricultural Code of Practice (Ontario Ministry of Agriculture and Food *et al.*, 1976).

A subsurface fecal coliform and phosphorus load component was added to the above overspreading algorithm for liquid manure. The addition of this subsurface load was based on recent studies investigating the movement of bacteria to drainage tiles from liquid manure spread either in the spring or in the summer on land either fall plowed or recently cultivated (Foran and Dean, 1991).

The results showed rapid movement of a tracer bacteria *E. coli* (NAR) from the soil surface to drainage tiles in approximately one and two hours after spreading on fall plowed and recently cultivated land, respectively (Foran and Dean, 1991).

The subsurface load component for liquid spreading manure only, was calculated as follows.

Subsurface Load = parameter amount in spring/summer/fall overspreading x % manure over-applied x subsurface delivery.

10) The parameter amount in spring/summer/fall is calculated above, assumption #1.

11) The percent of manure overapplied is given in assumption 9.

12) The subsurface delivery to the watercourse from drainage tiles for fecal coliforms and phosphorus were 3.2 and 0.16 percent, respectively (Dean and Foran, 1991; Foran and Dean, 1991).

2.1.2.8 Waterfowl

Unique to the Big Creek watershed and in particular to Big Creek marsh is the large number of waterfowl that migrate through the area. Fecal coliform loadings from waterfowl during the spring migration were not considered in this algorithm due to fewer waterfowl migrating through the area and a shorter stopover period compared to the fall migration. Furthermore, fecal coliform contributions from waterfowl during the summer were not considered due to few waterfowl nesting in the area. As a result, an algorithm was developed to estimate fecal coliform loadings from waterfowl during the fall migration.

Load = fecal coliform concentration x number of waterfowl x stopover length.

A number of assumptions were made in order to calculate the waterfowl load. They were as follows

1) An average size waterfowl excretes approximately 5.0 x 10^9 FC/day (Hussong *et al.*, 1979; Palmer, 1982).

2) The number of waterfowl that migrate through the area was estimated from bird inventory information to be approximately 18,000. It was assumed that 50% of the waterfowl will defecate in the water.

3) The average stopover length in the fall was estimated to be two days.

2.1.2.9 Soil Erosion

Phosphorus loading from soil erosion within the Big Creek watershed was calculated using the following algorithm.

Load = area of row crops in watershed x annual phosphorus loss

A number of estimates were used to calculate this loading.

They were as follows:

1) Area of row crops in the watershed was estimated to be 2800 ha (Ministry of Agriculture and Food, 1985).

2) An estimated 2.63 kg phosphorus/ha/yr was loss from heavy clay soil in Essex County (Allsop *et al.*, 1987).

2.1.3 Fecal Coliform and Phosphorus Loadings to Holiday Beach

The phosphorus loading from individual sources within the watershed was calculated by summing all the estimated phosphorus loadings from these sources to a watercourse. The fecal coliform loading from specific sources were determined from the estimated fecal coliform loadings to a watercourse, adjusted for the effects of bacteria decay rate, bacteria travel time and source discharge type.

2.1.3.1 Bacteria Decay Rates

Decay rates for fecal coliform bacteria were estimated using *E. coli* nalidixic acid resistant (NAR) strain. Bacteria chambers filled with *E. coli* (NAR) were suspended in the water column of Big Creek to provide an estimate of fecal coliform mortality. The decay rate of fecal coliform in the water column was estimated to be 0.55 logs/day. This decay rate was used to model the mortality of fecal coliforms as they travelled in the water from various subbasins of Big Creek to the marsh.

A similar trial was conducted in Big Creek marsh, to estimate fecal coliform mortality in marsh sediment. The decay rate of *E. coli* (NAR) in marsh sediment during the fall/winter months was estimated to be 0.045 logs/day over 108 days (Loeffler, 1991). A second *E. coli* (NAR) decay experiment was conducted in the marsh sediment during the spring/summer months. The methodology of the spring/summer decay experiment was similar to the methodology used in the fall/winter decay experiment (Loeffler, 1991).

The decay rate of *E. coli* (NAR) in the marsh sediment during the spring/summer months was estimated to be 0.052 logs/day over 111 days. The actual *E. coli* (NAR) counts in the die-off chambers used to estimate the spring/summer decay rate are listed in Appendix 4. An average decay rate of 0.049 logs/day, calculated from the two estimated decay rates mentioned above, was used to model fecal coliform mortality as the bacteria travelled from the marsh to the outlet.

2.1.3.2 Bacteria Travel Times

The travel time of fecal coliforms in the Big Creek watershed was estimated using *E. coli* (NAR). It took 10 days for *E. coli* (NAR) bacteria released from station VII, to be detected at the Big Creek outlet, station XII, a distance of approximately 10 km (Figure 3; Loeffler, 1991). Another attempt to estimate the travel time of fecal coliforms in the Big Creek watershed was conducted in the spring/summer 1991 period. *E. coli* (NAR)

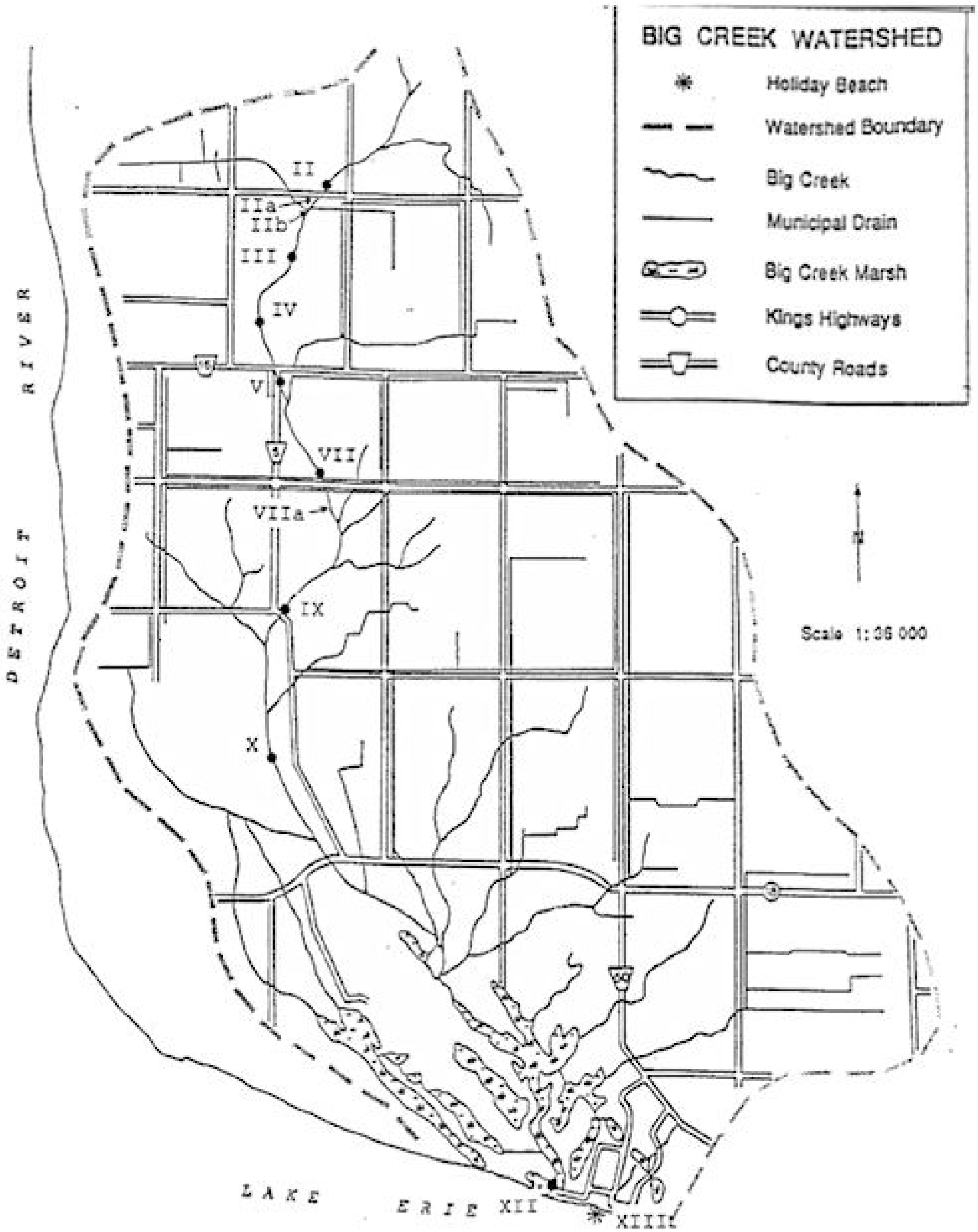

Figure 3. Location of grab water and swab sampling stations used to determine the travel time of *E. coli* (NAR) in the Big Creek watershed.

bacteria were released into the creek at station II on April 25th (Figure 3). Swabs were placed downstream from the point of tracer release at stations III, IV, V, VII, IX, X, XII and XIII (Figure 3). Grab water and swab samples were taken from the various stations and the results are listed in Appendices 5 and 6, respectively. The *E. coli* (NAR) bacteria took four days to be detected at the watershed outlet (Appendices 5 and 6). However, due to the very low number of *E. coli* (NAR) bacteria detected at the outlet, a second *E. coli* (NAR) bacteria pulse was released into Big Creek at station VIIa (Appendix 5).

Again, the number of bacteria detected at the outlet from this second bacteria pulse was low, thus the initial travel time estimate of 10 days was used to model fecal coliform movement from the upper reaches of the watershed to the outlet. This 10 day travel time estimate was altered to represent flow in the creek and the marsh It was assumed for all subbasins, that four of the 10 days were required for the bacteria to travel through the marsh to the outlet. The various subbasin areas are outlined in Figure 2. The remaining six of the 10 days were used to estimate the creek travel time for the various subbasins.

It was estimated that the bacteria took four days to travel from various watercourse in subbasins E, F, G and H to the marsh. A six day creek travel time was used to estimate the movement of fecal coliform bacteria from subbasins A, A_1, B, C and D to the marsh (Figure 2). A two day creek travel time was used to estimate the movement of fecal coliform bacteria from subbasins J, K, L, M, N, O, P and Q to the marsh (Figure 2). The travel time of the bacteria from the watershed outlet to Holiday Beach was assumed to be negligible.

2.1.3.3 Discharge Type

The fecal coliform loads calculated for each source type in each subbasin of Big Creek were separated into two categories: continuous and pulse discharge loads. Continuous discharge refers to sources which regularly discharge fecal contaminated effluent into a watercourse. In this report the continuous sources discussed are faulty septic systems, livestock stream access, and milkhouse waste.

Pulse discharge refers to precipitation events which induce runoff laden with fecal coliforms. Pulse sources discussed in this report were barnyard/feedlot runoff, manure stack runoff, winter spreading manure and spring/summer/fall manure overspreading.

To estimate the number of fecal coliforms delivered to Holiday Beach from the various subbasins watercourse loadings, the following equation based on fecal coliform decay rates and stream travel times was used.

$N = \text{antilog} (\log N_o - (Kt))$

Where

N = number of fecal coliforms delivered to Holiday Beach

N_O = the initial number of fecal coliforms delivered to watercourses in each subbasin by source.

K = log decay rate per day

t = time of travel (days) from the subbasin to Holiday Beach

The initial number of fecal coliforms (N_o) delivered to watercourses was modified for pulse discharge sources. The pulse discharge sources had N_o multiplied by the percent frequency of precipitation events for the year. The frequency of seasonal precipitation events was determined by examining precipitation records from 1941-1970 collected by a precipitation network in Essex County (Sanderson, 1980). From the records, the frequency of precipitation events during the year was 0.27 (Sanderson, 1980).

2.2 RESULTS and DISCUSSION

2.2.1 Fecal Coliforms

The estimated fecal coliform loading to watercourses, relative contributions and rankings of the various sources calculated using the appropriate CURB algorithms are listed in Appendix 7. The total estimated fecal coliform loading to watercourses was 9.60×10^{14} FC (fecal coliform)/year. The ranking for the various sources indicated the greatest contribution to a watercourse was spring/summer/fall overspreading (Appendix 7).

The estimated fecal coliform loading to Holiday Beach, relative contributions and rankings of the various sources, are listed in Table 1. These results take into account the discharge nature of fecal coliforms from the source (continuous or pulse discharge), travel time of the fecal coliforms from source to Holiday Beach and mortality of fecal coliforms during this travel time. The total estimated contribution of fecal coliforms to Holiday Beach from the Big Creek watershed was 1.42×10^{13} FC/year. Faulty septic systems within the Big Creek watershed had the greatest fecal coliform loading of 1.04×10^{13} FC/year (Table 1) .

This result was confirmed from sediment samples collected at the Big Creek outlet which showed high fecal coliform counts of a human origin. The source of the fecal contamination can be determined by comparing the fecal streptococcus count to the fecal coliform count. When both fecal coliforms and *E. coli* counts are greater than 100 organisms/100 g and relatively similar in magnitude, then fecal streptococcus counts four times less than or 0.7 times greater than the fecal coliform count indicate contamination from human or animal sources, respectively. At the Big Creek outlet, the fecal streptococcus value of 160 organisms/100 g was approximately four times less than the fecal coliform count of 440 organisms/100g, indicating a human origin to the fecal coliform contamination. An estimated 347 homes in the Big Creek watershed contributed to the faulty septic system loading.

Table 1. Fecal coliform loadings to Holiday Beach from the Big Creek watershed estimated by C.U.R.B. algorithms, relative fecal coliform contributions (%) and rankings of various sources.

SOURCES	FECAL COLIFORMS (FC/year)	RELATIVE CONTRIBUTION (%)	RANKING
Faulty Septic Systems	1.04×10^{13}	73.0	1
Winter Spread Manure	1.74×10^{12}	12.2	2
Spring/summer/fall Manure Overspreading	1.52×10^{12}	10.7	3
Livestock Stream Access	5.65×10^{11}	4.0	4
Milkhouse Waste	1.16×10^{10}	0.08	5
Manure Stack Runoff	6.83×10^{9}	0.05	6
Barnyard / Feedlot Runoff	3.09×10^{9}	0.02	7
TOTAL	1.42×10^{13}		

The second and third highest relative contributions were winter spread manure and spring/summer/fall manure overspreading, respectively (Table 1). The combined relative contributions of the top three sources of fecal coliforms was 95.9% of the total fecal coliform loading (Table 1). The fecal coliform loading from the other sources listed in Table 1 were comparatively insignificant.

The winter spread manure and spring/summer/fall manure overspreading sources had comparable fecal coliforms loadings of 1.74×10^{12} and 1.52×10^{12} FC/year, respectively (Table 1). These sources had a combined relative fecal coliform contribution of approximately ⅓ of the total loading (Table 1). Thus, a significant fecal coliform loading to Holiday Beach can be attributed to improper manure management practices.

The estimated loading of fecal coliforms from waterfowl over a two day period during the fall migration was 2.4×10^{12} FC. This fecal coliform source is natural in origin and difficult to eliminate due to the large number of waterfowl that are dependent upon Big Creek marsh as a stopover area during their migration periods. Furthermore, the interest in waterfowl in the area by naturalist and hunting groups make it difficult to eliminate this source. As a result, contributions from this source may be tolerated as baseline fecal coliform loadings.

Unusually dry summer conditions in 1991 provided an opportunity to investigate bacteria survival under extreme drought conditions. During this drought period, pronounced cracks developed in the heavy clay stream bed. After precipitation induced stream flow this fall (1991) *E. coli* (NAR) bacteria were detected in the water column. The *E. coli* (NAR) bacteria were released into the watershed as part of a tracer study in April 1991. These bacteria were detected in an area of Big Creek that had been dry for approximately 40 days.

The presence of this bacteria in a section of stream that was dry for an extended period of time was probably due to their survival in upstream pools and movement downstream during a precipitation event. Thus, under the driest stream conditions in Big Creek the *E. coli* (NAR) bacteria were capable of surviving in small pools of water in an otherwise dry stream with no flow. These results demonstrate the extraordinary survival capabilities of *E. coli* (NAR) bacteria. It is documented that other enteric bacteria which are pathogenic such as, *Shigella* sp., *Salmonella* sp., *Campylobacter* sp. and *Yersinia* sp. have similar survival characteristics.

Phosphorus

The estimated phosphorus loading to Holiday Beach from the Big Creek watershed, relative contributions and rankings of the various sources are listed in Table 2. The total estimated loading of phosphorus to Holiday Beach was 8860.5 kg/year. The highest ranked source of phosphorus was soil erosion at 7358.4 kg/year, or 83.0 % of the total phosphorus load.

Table 2. Phosphorus loadings to Holiday Beach from the Big Creek watershed estimated by C.U.R.B. algorithms, relative phosphorus contributions (%) and rankings of various sources.

SOURCES	PHOSPHORUS (kg/year)	RELATIVE CONTRIBUTIONS (%)	RANKING
Soil Erosion	7358.4	83.0	1
Faulty Septic Systems	1171.0	13.2	2
Spring/summer/fall Manure Overspreading	142.7	1.6	3
Manure Stack Runoff	70.4	0.8	4
Milkhouse Waste	47.8	0.5	5
Winter Spread Manure	35.2	0.4	6
Livestock Stream	30.2	0.3	7
Barnyard\feedlot Runoff	4.8	0.05	8
TOTAL	8860.5		

This value could be reduced substantially by implementing soil conservation measures in order to reduce soil erosion from cultivated fields. The second and third highest ranked sources of phosphorus loading were faulty septic systems and spring/summer/fall manure overspreading, respectively (Table 2). Faulty septic systems had an estimated phosphorus loading of 1171.0 kg/year from approximately 347 homes with improperly operating septic systems in the Big Creek watershed (Table 2). Overall, the top two sources of phosphorus loadings to Holiday Beach, soil erosion and faulty septic systems, accounted for 97.8% of the total phosphorus loading to Holiday Beach (Table 2).

CHAPTER THREE

THE IMPACT OF THE DETROIT RIVER, WESTSIDE HOMES AND BIG CREEK WATERSHED ON WATER QUALITY AT HOLIDAY BEACH

3.1 METHODOLOGY

The potential impact of fecal coliform and nutrient contamination at Holiday Beach from the Detroit River, Westside homes and Big Creek watershed were investigated. Weekly water samples were collected beginning April 16th to October 16th, 1991 from Bar Point, mouth of the Detroit River, along the Lake Erie shoreline to Holiday Beach (Figure 4). Sediment samples were taken on July 25th, 1991 using a shipek, from locations at the mouth of the Detroit River, Lake Erie and Big Creek outlet. The Detroit River sediment samples were taken on a transect across the mouth of the river, close to Bar Point (Figure 4). The Lake Erie sediment samples were taken off-shore in approximately three metres of water and near-shore (Figure 4).

The off and near-shore sampling locations corresponded with the shoreline water sampling stations (Figure 4). Since the movement of lake water is predominantly east from the Detroit River, near and off-shore lake samples were not taken east of Holiday Beach. The impact of fecal coliform contributions from lakeside homes located east of subwatershed 0 were considered to have minimal impact on water quality at Holiday Beach. Although net littoral drift has been shown to move coarse sediment (sand) westward in this lakeshore area, the movement of fecal coliform and nutrients would not follow this movement due to their association with fine sediments (silt, clay).

The faulty septic system algorithm previously outlined in section 2.1.2.1 was used to estimate the fecal coliform and phosphorus loadings from the Westside homes to Lake Erie. A negligible fecal coliform mortality rate and travel time were assumed for bacteria migrating downstream east to Holiday beach from faulty septic systems of Westside homes.

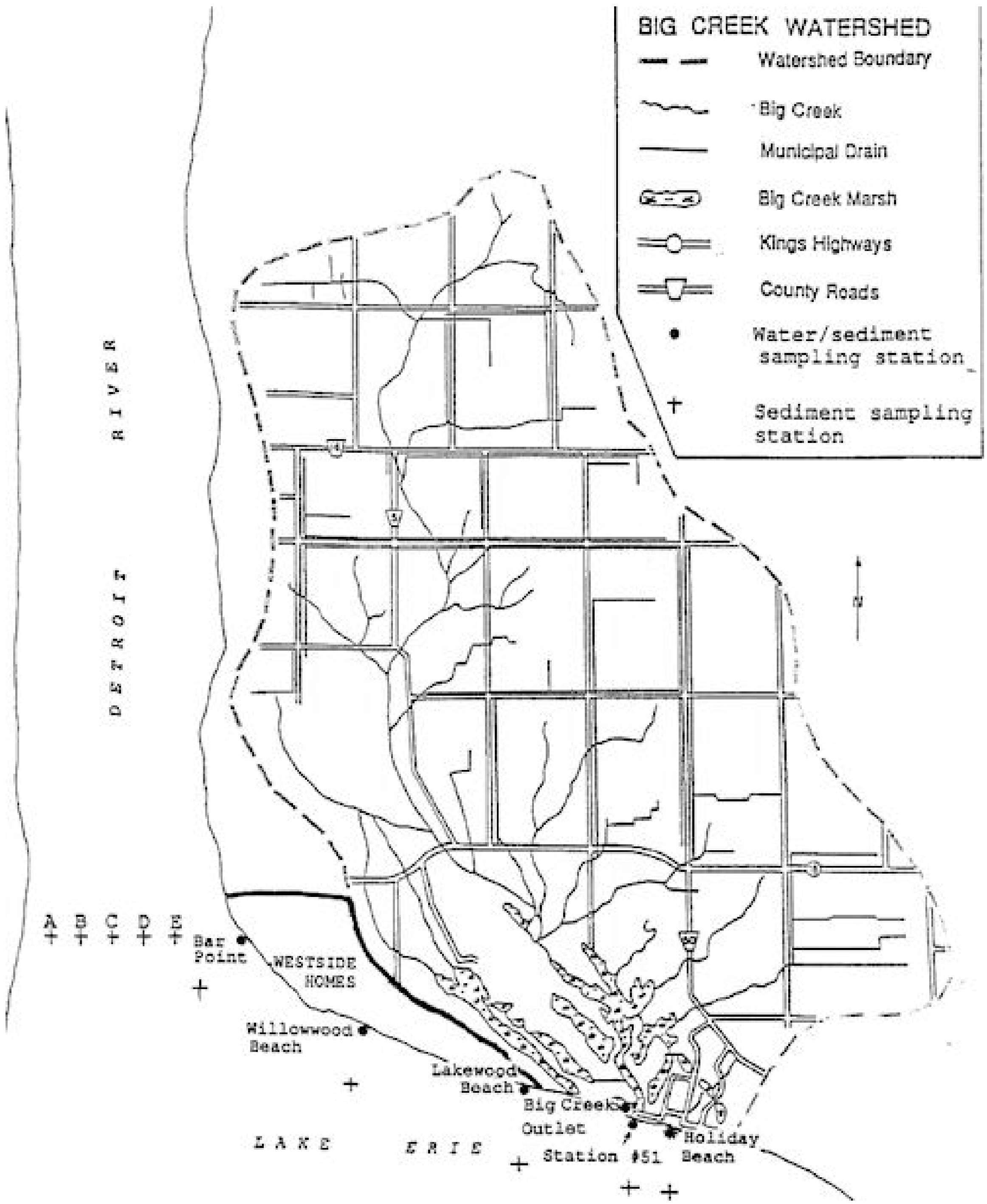

Figure 4. Location of water and sediment sampling stations selected to compare the impact of the Detroit River, Westside homes and the Big Creek watershed on water quality at Holiday Beach.

3.2 RESULTS and DISCUSSION

3.2.1 Fecal Coliforms

3.2.1.1 Water Component

The estimated fecal coliform loading from 405 Westside homes with potentially faulty septic systems using the CURB algorithm from section 2.1.2.1 was 4.44×10^{14} FC/year. This estimated fecal coliform loading from the Westside homes was greater than the estimated 1.04×10^{13} FC/year loading from 347 homes within the Big Creek watershed (Table 1). This was due to a greater number of homes in Westside area compared to the number of homes within the Big Creek watershed. As well, the greater estimated fecal coliform loading from the Westside homes can be attributed to an assumed negligible mortality rate and travel time of the bacteria released from improperly operating septic systems.

Examination of water and sediment data along the shoreline bordering the Westside home area, from Willowwood to Lakewood Beach, indicated geometric mean fecal coliform counts were below the allowable levels of 100 organisms/100 ml (Appendix 8). Occasionally, fecal coliform counts in this area were higher than allowable levels, indicating the potential for fecal contamination does exist (Appendix 8). Hence, the estimated fecal coliform loading from this area can be considered a pulse rather than a continuous discharge source. As a result, precipitation events will influence fecal coliform loadings from this area.

An analysis of the 1991 water column data showed a decreasing trend in geometric mean fecal coliform and *E. coli* numbers (# of organisms/100ml) in samples collected from Bar Point, the mouth of the Detroit River, along the Lake Erie shoreline to Holiday Beach (Table 3; Figure 4). The decline in fecal coliform and *E. coli* counts along the Lake Erie shoreline was probably due to dilution and mortality of the bacteria entering the Lake from the Detroit River and occasionally the Westside homes.

The mean fecal coliform and *E. coli* values measured along the lake shoreline did not exceed the acceptable level, except at Bar Point. The data indicated that this high fecal coliform count at Bar Point can be attributed to human waste, since the geometric fecal streptococcus value was approximately four times less than the fecal coliform value (Table 3).

There was an increase in bacteria counts of various parameters measured at the Big Creek outlet compared to Lakewood Beach. However, the mean fecal coliform count at the Big Creek outlet was below the allowable level (Table 3). This result suggests that on average, the Big Creek watershed has fecal coliform discharges within allowable limits. However, on some occasions, fecal coliform counts measured at the Big Creek outlet and at the other sampling locations listed in Table 3 were higher than acceptable (Appendix 8). These elevated fecal coliform counts may be due to certain

Table 3. Geometric mean bacteria* numbers/100 ml in water samples collected between April 16th to September 16th, 1991 at various locations from the mouth of the Detroit River along the Lake Erie shoreline to Holiday Beach.

SAMPLE LOCATION	Fecal Coliform	Escherichia Coliform	Pseudomonas Aeruginosa	Fecal Streptococcus
	organisms/100ml			
Bar Point	169.8	101.8	11.7	64.6
Willowwood Beach	78.9	54.0	11.1	58.2
Lakewood Beach	47.5	29.7	10.1	31.2
Big Creek Outlet	69.9	49.2	11.6	107.8
Station #51	39.8	25.1	7.3	25.1
Holiday Beach	41.3	25.9	7.7	31.4

* Geometric mean bacteria values calculated from 24 samples

weather conditions such as a storm event or prevailing wind direction. Within the Big Creek watershed, a storm event will increase the volume and velocity of water discharged to Lake Erie. The increase in velocity will lower the travel time of fecal coliforms to the outlet. As a result, fecal coliform mortality rate will be lowered due to insufficient residence time within the watershed, causing elevated fecal coliform counts at the outlet and possibly at Holiday Beach.

Wind direction can be an important factor effecting fecal coliform counts at Holiday Beach. A strong south-west wind could direct fecal coliform contaminated water inland from point discharge areas like the Detroit River, or Big Creek outlet, causing an increase in fecal coliform counts at Holiday Beach. Other environmental factors such as lake mixing, lake set-up and dredging may contribute to elevated fecal coliform counts at Holiday Beach.

Overall, fecal coliform and *E. coli* levels in grab water samples provide an indication of fecal contamination to an area at the time of sampling. Fecal coliform and *E. coli* levels in sediment samples provide an indication of fecal contamination to an area over a period of time.

3.2.1.2 Sediment Component

Sediment samples taken along a transect at the mouth of the Detroit River showed fecal coliform and *E. coli* values higher than acceptable levels, with the highest values recorded on the U.S. side of the river, transect location A (Table 4). Furthermore, a decreasing trend in bacteria counts was observed from Bar Point towards Lakewood Beach for both the off and near-shore lake samples (Table 4). This trend in fecal coliform counts appeared to follow the flow direction and dispersal pattern of the Detroit River.

The fecal coliform and *E. coli* values in off-shore lake sediments were greater than corresponding near-shore values and in most cases the off-shore bacteria values exceeded acceptable levels (Table 4). A comparison of the fecal coliform and fecal streptococcus values indicated that the elevated bacteria levels in the off-shore lake sediments were of a human origin. The probable source of the fecal coliform contaminated lake sediment was the Detroit River plume. The sharp contrast of fecal coliform and *E. coli* counts in the sediment compared to the water column (Table 3) suggest increased survival of the bacteria in sediment compared to the water column.

The near-shore lake sediment samples had higher than acceptable levels of fecal coliform and *E. coli* counts of 440 and 440 organisms/100 g respectively, measured at the Big Creek outlet (Table 4). The Big Creek watershed was contributing fecal coliform and *E. coli* bacteria to Lake Erie. An analysis of the fecal coliform and fecal streptococcus results from the outlet indicated a human origin to the high fecal coliform counts. This confirms the high ranking of faulty septic systems, predicted from the CURB algorithms as a significant source of fecal coliforms.

Table 4. Indicator bacteria numbers/100 g in sediment collected July 25th, 1991 from the Detroit River and off and near° shore lake sampling locations.

SAMPLE LOCATION	Fecal Coliform	*Escherichia Coliform*	*Fecal Streptococcus*
	organisms/100g		
Detroit River			
Transect A	3400	3400	160
Transect B	140	140	40
Transect C	220	220	<40
Transect D	460	460	<40
Transect E	280	280	<40
Lake Erie (Off-shore)			
Bar Point	440	340	160
Willowwood Beach	260	260	40
Lakewood Beach	80	80	<40
Station #51	40	40	<40
Lake Erie (Near-shore)			
Bar Point	160	160	40
Willowwood Beach	80	80	140
Lakewood Beach	80	80	<40
Big Creek Outlet	440	440	160
Station #51	2600	2600	280
Holiday Beach	180	180	40

The fecal coliform and E. coli bacteria counts increased significantly at station #51, located downstream, east of the outlet. Higher than acceptable levels of fecal coliform and *E. coli* bacteria, 2600 and 2600 organisms/100 g, respectively, were measured at station #51 (Table 4). These counts were significantly higher than fecal coliform and *E. coli* counts at both near and offshore Lakewood Beach sample stations located immediately west of the Big Creek outlet (Table 4). The increase in fecal coliform and *E. coli* counts at station #51 indicated an accumulation of fecal contaminated sediment in this area from the Big Creek watershed.

The near-shore sediment sampled at Holiday Beach had bacteria counts lower than station #51, 180 and 2600 organisms/100 g, respectively, indicating significant bacteria mortality during movement towards the beach. However, the Holiday Beach fecal coliform values were still higher than acceptable levels (Table 4) . In fact, the bacteria counts at Holiday Beach were higher than at Lakewood Beach, 180 and 80 organisms/100 g, respectively, indicating the significant impact of the Big Creek watershed discharge to water quality at Holiday Beach (Table 4).

An analysis of the fecal coliform and fecal streptococcus results at Holiday Beach indicated a human origin to the high fecal coliform counts. The proximity of the Big Creek outlet to Holiday Beach was not sufficient to allow significant dilution or mortality of the fecal coliforms discharged from the watershed. Better dilution of the discharge from the watershed did occur further out into the lake as evident from station #51 off and near-shore lake sediment fecal coliform readings of 40 and 2600 organisms/100g, respectively (Table 4). Overall, the Big Creek watershed had a significant fecal coliform loading to Lake Erie.

3.2.2 Phosphorus

The estimated phosphorus loading to Holiday Beach from faulty septic systems of the Westside homes using the appropriate CURB algorithm was 1366.9 kg/year based on 405 homes. This value was greater than the estimated phosphorus loading of 1171.0 kg/year from the homes within the Big Creek watershed (Table 2). The primary reason for the greater estimated phosphorus loading from the Westside homes was a larger number of homes with improperly functioning septic systems.

There was an estimated 405 homes in the Westside area compared to 347 homes in the Big Creek watershed, with improperly functioning septic systems. An estimated combined phosphorus loading of 2537.9 kg/year was contributed from both the Big Creek watershed and the Westside homes to Holiday Beach.

The mean total and dissolved phosphorus concentrations measured at Bar Point along the shoreline to Lakewood Beach were relatively similar (Table 5). The mean dissolved phosphorus concentrations discharged from the Big Creek watershed were 0.024 and 0.041 mg L^{-1} for 1991 and 1990, respectively (Table 5). These concentrations were higher than Lakewood Beach, indicating significant dissolved

Table 5. Mean total and dissolved phosphorus and suspended solids in water samples taken from April 16th to September 16th, 1991 at various locations from Bar Point along Lake Erie shoreline to Holiday Beach.

SAMPLE LOCATION	TOTAL PHOSPHORUS ($mg\ L^{-1}$)	DISSOLVED PHOSPHORUS ($mg\ L^{-1}$)	SUSPENDED SOLIDS ($mg\ L^{-1}$)
Bar Point	0.16	0.015	73.32
Willowwood Beach	0.086	0.01	56.61
Lakewood Beach	0.10	0.011	68.16
Big Creek			
1991	0.32	0.024	122.49
1990	0.42	0.041	
Station #51	0.14	0.013	74.39
Holiday Beach			
1991	0.11	0.011	67.40
1990	0.13	0.013	

phosphorus contributions from the Big Creek watershed to Lake Erie. The mean concentration of dissolved phosphorus discharged from the Big Creek watershed was lowered at Holiday Beach where mean dissolved phosphorus concentrations were 0.011 and 0.013 mg L^{-1} for 1991 and 1990, respectively (Table 5). The primary reason for the lower dissolved phosphorus concentration at Holiday Beach was lake dilution of the watershed discharge.

The mean total phosphorus concentration of 0.16 mg L^{-1} measured at Bar Point, at the mouth of the Detroit River, was significantly lower than the mean total phosphorus discharge of 0.32 mg L^{-1} measured at the Big Creek outlet (Table 5). The higher mean total phosphorus concentration at the outlet compared to Bar Point, can be attributed to greater soil erosion within the Big Creek watershed. Furthermore, a high suspended solids concentration of 122.49 mg L^{-1} at the outlet provided additional evidence of elevated soil erosion processes occurring in the Big Creek watershed (Table 5). Phosphorus and suspended solids data at the various sampling stations are listed in Appendix 9.

Since phosphorus is tightly bound to the soil, minimizing soil erosion within the Big Creek watershed by practising soil conservation measures will reduce phosphorus loadings to a watercourse and subsequently Lake Erie. The elevated levels of both total phosphorus and suspended solids discharged from the watershed were substantially reduced in the lake due to dilution. The total phosphorus and suspended solids concentrations measured at Holiday Beach were 0.11 and 67.40 mg L^{-1}, respectively (Table 5).

The nitrogen concentrations of various compounds at sampling stations located along the Lake Erie shoreline and at the Big Creek outlet are listed in Table 6. Relatively little change in total kjeldahl nitrogen, nitrite and nitrate concentrations were observed in water samples taken from Bar Point, the mouth of the Detroit River, to Lakewood Beach (Table 6). Significantly higher concentrations in total Kjeldahl nitrogen, nitrite and nitrate were measured at the Big Creek outlet compared to Lakewood Beach.

Nitrogen concentrations measured at the various sampling stations are listed in Appendix 9. The use of nitrogen fertilizers and manure in agricultural production within the watershed, elevated the concentrations of nitrogen parameters measured downstream. Once the nitrogen contaminated water reached Holiday Beach, it was diluted by the lake to concentrations observed at Lakewood Beach (Table 6). The delivery of nutrients, phosphorus and nitrogen, and suspended solids from the Big Creek watershed, provides conditions conducive for fecal coliform survival.

3.3 CONCLUSIONS

3.3.1 Fecal Coliforms

Faulty septic systems of homes within the Big Creek watershed had the greatest fecal coliform loading of all sources in the watershed as estimated from the CURB algorithms. This was confirmed by high fecal coliform levels of 440 organisms/100 g

Table 6. Mean nitrogen concentrations of various compounds in water samples taken from April 16th to September 16th, 1991 at various locations from Bar Point along Lake Erie shoreline to Holiday Beach.

SAMPLE LOCATION	Total Kjeldahl Nitrogen ($mg\ L^{-1}$)	Nitrite Nitrogen ($mg\ L^{-1}$)	Nitrate Nitrogen ($mg\ L^{-1}$)
Bar Point	0.72	0.015	0.38
Willowwood Beach	0.92	0.013	0.31
Lakewood Beach	0.72	0.017	0.36
Big Creek Outlet	2.50	0.037	0.42
Station #51	1.09	0.026	0.30
Holiday Beach	0.82	0.018	0.35

measured in sediment sampled at the outlet of Big Creek watershed. Even higher fecal coliform levels were found in lake sediment sampled downstream from the outlet at station #51. An analysis of the sediment samples at both stations indicated a human origin to the fecal coliform contamination. The data shows that the Big Creek watershed was a dominate source of fecal contamination to Holiday Beach. However, certain weather conditions such as wind direction and water levels, may increase the influence of the Detroit River fecal contaminated plume on water quality at Holiday Beach.

Agricultural activity which contributed the greatest fecal coliform contamination to Holiday Beach was manure spreading as estimated by the CURB algorithms (Table 1). Significant contamination from this activity indicates improper manure spreading practices, with regard to timing and application rates, exist in the watershed.

3.3.2 Phosphorus

Soil erosion within the Big Creek watershed had the greatest phosphorus loading as estimated from the CURB algorithms (Table 2). This estimate was supported by a relatively higher total phosphorus concentration measured at the Big Creek outlet compared to the other sampling stations (Table 5). Additional information confirming the CURB algorithm estimate was the relatively high suspended solids concentration measured at the outlet (Table 5).

Faulty septic systems within the watershed had the second highest phosphorus loading as estimated from the CURB algorithms. This estimate was supported by a relatively higher dissolved phosphorus concentration measured at the Big Creek outlet compared to the other sampling stations (Table 5).

The impact of manure spreading on phosphorus loadings was minimal with the spring/summer/fall manure overspreading providing the greatest load (Table 5). Overall, any agricultural activity which promotes soil erosion will have the greatest impact on phosphorus loadings. Significant phosphorus loadings to Holiday Beach from the Big Creek watershed will lower water quality by providing an essential nutrient required for fecal coliform bacteria to survive. Similarly, a constant supply of nitrogen from the Big Creek watershed will provide another essential nutrient required for fecal coliform survival.

3.4 REMEDIAL ACTIONS

3.4.1 Cost Effectiveness

Faulty septic systems operating within the Big Creek watershed had the greatest loading of fecal coliforms. An estimated 347 homes within the watershed or 70 percent of all homes in the watershed have improperly functioning septic systems. The estimated cost of installing a new septic system in the Essex region ranged from $5,000-$6,000. Thus, the estimated total cost of upgrading septic systems in the Big

Creek watershed ranges from $1.7 to 2.1 million. Instead of installing new septic systems, old systems may be improved for an estimated cost of $3,000/system. Such improvements would include upgrading the septic bed, removing septic overflow features and pumping out the septic tank. The total cost of implementing these improvements depends upon the number of septic systems that would function properly with improvements.

Another source of fecal coliform loadings was the Westside homes, located between Bar Point and Lakewood Beach. An estimated 405 homes in this area have improperly operating septic systems. The homes in this area have traditionally been summer cottages, however an increasing number of homes have become permanent. The septic systems in this area are in most cases the original systems and few improvements in septic operation have occurred with the change in residential use.

In addition, due to lot size restrictions and the density of homes in the area, limitations in septic system location make it difficult for these lots to be serviced by septic systems. Because of these conditions a sanitary sewer system would solve the septic waste disposal problem in this area. A centralized sanitary waste disposal system rather than individual septic systems will provide a long term solution to the fecal coliform loadings from this area. It is believed that similar changes in residential use and septic system failure exist in the lakeside area located east of subwatershed O, or east of Lake Erie Country Club. Since this area lies outside the watershed boundary, fecal coliform loadings from faulty septic systems in this area were not considered to impact water quality at Holiday Beach. It was believed that loadings from this source were directed to the lake where bacteria mortality and lake flow direction minimized the impact of this source on water quality at Holiday Beach.

Manure spreading practices combining winter manure spreading and spring/summer/fall manure overspreading, were determined to be the greatest contributor of fecal coliform contamination to Holiday Beach of the various agricultural sources (Table 1). Increases in manure storage can alleviate the need to winter manure spread and to overspread manure in the spring/summer/fall months. The estimated cost of liquid manure storage for a dairy operation ranges from $15,000-$45,000, and for a swine operation ranges from $20,000-$25,000.

The estimated cost of a solid manure system ranges from $20,000-$30,000. Based on these ranges, the average cost of constructing manure storage facilities was $39,000. As a result, the estimated total cost of improving the manure storage facilities of all 17 livestock operations was $663,000. Individual livestock operators interested in improving their manure storage capacity will have storage facilities designed to meet their specific needs.

The next greatest fecal coliform loading from agricultural activity was livestock stream access to watercourses. In the Big Creek watershed, an estimated 29 km of creek was considered vulnerable to livestock access. In most cases, pasture was located on both sides of the watercourse. As a result, to restrict livestock access to the watercourse both sides would require a barrier. This will increase the watercourse perimeter vulnerable to livestock access to 58 km. Various types of fencing are available to be used as a barrier to restrict livestock stream access. Page wire fencing with steel posts was estimated to cost $640/1000 m.

The total cost of using page wire fencing to restrict livestock access to Big Creek was approximately $37,120. Electric fencing with steel posts was estimated to cost $430/1000 m. Solar panels can be used to charge the fence for approximately $120. The estimated total cost of using electric fencing to restrict livestock stream access was approximately $24,940. Barb wire fencing with steel post was estimated to cost $370/1000 m. The total cost of using barb wire fencing to act as a barrier along the creek was approximately $21,460. Associated with restricting livestock stream access is the cost of providing an alternative source of water. Water from the watercourse can be pumped to a nearby watering trough.

A solar pump estimated to cost $700 can be used to deliver the water to a watering trough. Another possible source of water for livestock could be secured by digging a well at an estimated cost of $3,700-$4,000 depending on location. This estimate does not include the purchase of a pump required to deliver the water from the well.

The fecal coliform contributions from other agricultural sources namely, milkhouse waste, manure stack runoff and barnyard runoff were significantly lower than the other agricultural sources. Lowering the fecal coliform contributions from these sources will provide a minimal reduction to the overall fecal coliform loading to Holiday Beach. As a result, time and money should be spent on reducing the fecal coliform loadings from the major contributors mentioned above.

A comparison of the capital cost associated with lowering fecal coliform loadings from faulty septic systems, manure spreading practices and livestock stream access was performed to determine a cost-effectiveness ratio. An average cost of $1.9 million was used to improve the estimated 347 homes in the watershed with improperly operating septic systems. An average cost of $663,000 was used to establish appropriate manure storage facilities to improve manure spreading practices.

An average cost of $30,000 was used to restrict livestock access from a watercourse and to provide an alternative source of drinking water. The respective fecal coliform loadings from these sources are listed in Table 1. A cost-effectiveness ratio (capital cost/fecal coliform loading) for faulty septic systems, manure spreading practices and livestock stream access was calculated to be 1.82, 2.03 and 0.52, respectively. Based on these results, restricting livestock access to the watercourse proved to be the most cost-effective measure to reduce fecal coliform loadings.

Furthermore, restricting livestock access to the watercourse will reduce soil erosion, which was determined to be the premier source of phosphorus loadings (Table 2). The second and third most cost-effective measures were septic system improvement and manure storage facilities, respectively. Septic system improvement will not only lower fecal coliform loadings, but also reduce phosphorus loadings from this source, which was determined to have the second highest phosphorus loading (Table 2).

3.5 IMPLEMENTATION PROGRAM

Workshops will be used to present the results of the CURB study on the Big Creek watershed and to promote the CURB Implementation Program locally. The public will be informed of Provincial grants available through the Implementation Program to individuals who voluntarily submit a proposal to improve or modify their activity to improve water quality. Demonstration projects will be undertaken to encourage activities that will lower both fecal coliform and phosphorus loadings to a watercourse and subsequently downstream to a public beach. Site visits will provide an opportunity to develop a liaison with landowners and to assist individuals submitting a water quality improvement plan.

3.5.1 Fecal Coliforms

Significant fecal coliform loading reduction can be achieved by improving septic systems operating in the Big Creek watershed. Information will be available regarding the detrimental health effects of improperly functioning septic systems on water quality. Septic system maintenance such as pumping out septic tanks and protecting weeping beds, will be emphasized to insure effective operation of existing or newly installed systems.

In addition, water conservation measures will be promoted to optimize the operation of the septic system. Priority for financial assistance from the Provincial government will be given to proposals which will result in the most cost-effective reduction in fecal coliform loadings. A study being conducted by Malden Township into the feasibility of a centralized sanitary treatment system, will be referenced to determine the suitability of providing Provincial grants to individuals wishing to install a new septic system in this proposed area.

Fecal coliform loadings from agricultural sources can be significantly reduced by eliminating winter manure spreading and avoiding spring/summer/fall manure overspreading. The determination of nutrient concentrations of manure and of soil to which the manure is to be applied, will be encouraged to set appropriate application rates, thus reducing the manure overspreading load. The timing of manure application will be reviewed, due to the information gathered on fecal coliform survival in marsh sediment. An establishment of a manure transfer program will be considered in order to alleviate pressure on livestock operators who winter spread manure or spring/summer/fall manure overspread because of manure storage limitations. The transfer of manure from livestock operations to other operations such as cash crop farms, nurseries or landscape companies will assist the livestock operator in manure management.

The conservation authority will provide technical assistance to individuals who are eligible for Provincial grants through the CURB Implementation Program, to increase their manure storage capacities to insure a minimum of 240 days storage. Priority for financial assistance of manure storage expansion will be given to proposals that will have the most cost-effective impact on lowering fecal coliform loadings.

Fecal coliform contributions from livestock stream access can be eliminated by restricting livestock access. Technical and financial support will be provided to operators wanting to eliminate livestock stream access. The establishment of a barrier along the watercourse will insure livestock restriction. Various types of fencing are available, as well as certain tree species which can be used as live fences to restrict livestock access. As a consequence to livestock restriction to a watercourse, technical and financial assistance will be provided to secure an alternative source of water. Priority for financial assistance will be given to watercourse restriction proposals that will have the most cost-effective impact on lowering fecal coliform loadings. In addition to lowering fecal coliform contributions from livestock, eliminating livestock access to watercourses will reduce erosion of the streambank and subsequent phosphorus loadings.

3.5.2 Phosphorus

Significant reductions in phosphorus loadings can be achieved by reducing soil erosion. Phosphorus present in the soil is tightly bound to clay particles. As a result, significant phosphorus loadings to the aquatic environment occurs with soil erosion. The Land Stewardship and the National Soil Conservation Programs have encouraged implementation of soil conservation practices. Conservation practices will continue to be promoted, especially in targeted watersheds. Technical assistance will be provided to establish erosion control features such as vegetated buffer strips along watercourses and rock chutes at drainage tile outlets.

In Essex county, the maintenance of drainage ditches by digging out and redefining the ditch is costly and exposes the ditch banks and bottom to erosive forces which increase the loading of soil bound phosphorus. Technical assistance will be provided to establish residue cover of cultivated fields to reduce soil loadings from cultivated fields to drainage ditches. As well, cultivation practices such as no-till and conservation tillage will be promoted to minimize soil erosion. The establishment of vegetation within ditches will act as a filter, stopping eroding soil from moving downstream. As well, ditch vegetation will sequester some of the phosphorus in the eroded soil, reducing phosphorus loadings. The Conservation Authority along with drainage engineers, can provide technical assistance in the selection and management of appropriate vegetation to be established in ditches.

Agricultural runoff from surface and subsurface sources to adjoining watercourses dramatically increases watercourse flow rate. Mediating the flow of water from agricultural sources within the watershed, especially during peak discharges, will reduce the rapid flux of nutrients and sediment to a watercourse and subsequent loadings to Holiday Beach. The establishment of retention ponds within the watershed will allow sedimentation to occur and mediate the flow of agricultural runoff. The possible use of such features in the Big Creek watershed should be examined in consultation with a drainage engineer.

Septic systems operating within the Big Creek watershed were determined to contribute significant phosphorus loadings. Detergents are the primary source of phosphorus from septic systems. The Conservation Authority will promote the use of phosphate-free detergents and will provide water conservation information to reduce grey water loadings to septic systems. Priority for septic system improvement will be given to proposals which have the most cost-effective reduction in phosphorus loadings.

The loading of phosphorus from milkhouse waste water can have a significant impact on downstream water quality. Technical assistance will be provided to dairy operators wanting to reduce phosphorus loadings to a watercourse from their operation. Financial assistance available from the Provincial government to improve milkhouse waste water disposal will be given to proposals that have the most cost-effective reduction in phosphorus loadings.

3.5.3 Big Creek Marsh

The Big Creek marsh will be studied to determine the causes) for the lack of vegetation within the marsh. The history of the marsh will be examined using aerial photographs and vegetation surveys to document the decline of vegetation. Preliminary results from water samples taken from the marsh indicated relatively high atrazine and metolachlor concentrations (Appendix 10). Vegetation common to the marsh such as arrowheads, cattails and bulrushes are sensitive to concentrations of these herbicides greater than 0.1 mg L^{-1}. Results showed the highest atrazine and metolachlor concentrations were measured during the summer period, which corresponded to agricultural use of these herbicides (Appendix 10).

An effort will be made to inform farmers of the importance of proper herbicide storage, handling and application to reduce environmental contamination from their use.

Big Creek marsh will be assessed for suitable sites to establish experimental compartments to assist in the explanation of germination failure of wetland vegetation. Compartments would be made from synthetic curtains, open to an upstream source selected to represent an array of discharges from different land uses, including agricultural, residential and natural sources. If feasible, these small experimental compartments will be established and vegetated with selected species and the success of germination will be compared among compartments. Water and sediment samples will be taken within the compartments to determine background concentrations of various nutrients, herbicides and other pertinent parameters. Results will be used to develop an overall plan to re-vegetate Big Creek marsh.

The longevity of tracer bacteria in the sediment of Big Creek marsh suggests an environment capable of supporting fecal coliforms. The relatively low flow rate of water through the marsh may reduce bacteria dispersal in the water column and allow bacteria to settle to the marsh bottom (G. Palmateer, per. comm., 1990). The large surface area:volume ratio of Big Creek marsh and lack of vegetation allows prevailing winds to disturb the marsh sediment, resuspending bacteria within the water column. Once the bacteria are resuspended, they could be flushed out of the marsh into Lake Erie, posing a threat to water quality at Holiday Beach. The re-vegetation of the marsh with hydrophytes such as arrowheads and cattails would reduce the mixing of the marsh bottom by impeding wind action. In addition, the vegetation in the marsh would compete with the bacteria for nutrients, inducing bacteria mortality. In general, the re-vegetation of the marsh would improve the ecological balance of the area.

The movement of fecal coliforms out of the marsh to Lake Erie, has created a build up of fecal coliforms in the sediment at the marsh outlet. Wind action can resuspend fecal coliforms into the water column resulting in possible contamination at Holiday Beach. Dredging and removing of this sediment from the marsh outlet would eliminate any immediate potential loading of fecal coliforms from this source. Numerous sediment cores should be taken at the marsh outlet to determine the depth of sediment to be removed.

If dredging is found to be feasible, it should be conducted in the fall period in order to minimize water quality impairment at Holiday Beach as a result of resuspending the fecal coliform contaminated lake sediment. The removal of this fecal contaminated sediment will provide only temporary water quality improvements and a long term commitment should be made to reduce fecal contaminated sediment loadings from the Big Creek watershed.

3.5.4 Other Watersheds

Watersheds in Essex region, namely Belle, Ruscom, Puce and Little (upper reaches) Rivers and Pike and Little Creeks watersheds draining into Lake St® Clair; and Cedar, Wigle, Hillman and Sturgeon Creeks watersheds draining into Lake Erie, all meet the eligibility guidelines for the Provincial Clean Up Rural Beaches (CURB) program (Figure 5). Watersheds eligible for the CURB program must be rural in nature, having fecal coliform pollution sources such as faulty septic systems, livestock stream access, milkhouse wastewater and inappropriate manure management practices impacting on water quality at downstream beaches. Water quality at beaches monitored by the Windsor-Essex County Health Unit are listed in Table 7. The geometric mean fecal coliform counts for the 1991 swimming season at Sandpoint, Belle River, Cedar Creek, Seacliffe and Point Pelee NW beaches were 1000.8, 1111.7, 85, 212.5 and 129.2 organisms/100 ml, respectively (Table 7).

These mean and weekly measured fecal coliform counts indicate water quality at these beaches can be improved to meet the provincial standard of 100 organisms/100 ml. It is believed that water quality is similarly impaired by upstream rural activity at public beaches not monitored by the health unit, such as Ruscom, Hillman and Point Pelee Beaches (Figure 5). To improve water quality at these beaches, an understanding of the soil type, topography, land use and management in the watersheds is required.

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Table 7. Geometric mean fecal coliform counts measured at Sandpoint, Belle River, Cedar Creek, Seacliff and Point Pelee NW beaches during the summer of 1991.

DATE	FECAL COLIFORMS (# organisms/100 ml)				
	Sandpoint Beach	Belle River Beach	Cedar Creek Beach	Seacliffe Beach	Point Pelee NW
June 10	45	110	330	480	175
June 17	2300	680	15	25	10
June 24	265	225	105	140	30
July 2	95	145	10	35	10
July 8	560	1550	25	60	270
July 15	25	110	10	130	10
July 22	145	2400	20	265	220
July 29	4050	700	45	100	445
Aug. 6	95	840	25	50	20
Aug. 12	3100	620	20	105	60
Aug.19	1111	5800	370	880	35
Aug. 27	220	160	45	280	265
MEAN	1000.8	1111.7	85	212.5	129.2

The Belle and Ruscom Rivers both drain into Lake St. Clair (Figure 5). The watersheds of these rivers were combined into a single watershed, incorporating Moison and Duck Creeks watersheds, to consider the cumulative effect of these watersheds on water quality at Belle River and Ruscom and possibly Sandpoint Beaches (Figure 5).The predominant soil type of this unified watershed is Brookston clay with Wauseon sandy loam soil located at its mouth. Dispersed throughout the upper reaches of the watershed are sandy to and gravel deposits. The area of the watershed is 263 km^2 with a slope of approximately 0.07%.

The Puce River and Pike Creek watersheds drain into Lake St. Clair and may be effecting water quality at Belle River and Sandpoint Beaches. For the purpose of the CURB program, the 4th concession drain was included in the Puce River watershed. The predominant soil type of both watersheds is clay. The watershed area of the Puce River and Pike Creek are 68.4 and 87.3 km^2, respectively. The topography of the watersheds is relatively flat with a slope of 0.1% and 0.09% for the Puce River and Pike Creek watersheds, respectively.

The Little River watershed drains into Lake St. Clair near Sandpoint Beach. The dominate soil types in the watershed are Brookston clay and Brookston clay loam. The watershed area was estimated to be approximately 58 km^2, of which approximately 30 km^2, the upper reaches, is being considered for remedial measures. The slope of the watershed is 0.09%.

The Cedar Creek watershed, located east of Big Creek, has a marsh at its outlet which drains into Lake Erie, close to Cedar Beach (Figure 5). The predominant soil type in the watershed is Brookston clay. The area of the watershed is 115.7 km^2 with approximately a 0.06% slope.

Wigle Creek watershed, located east of Cedar Creek drains into Lake Erie near Cedar Beach (Figure 5). The watershed area was estimated to be 39.8 km^2 with a slope of approximately 0.15%. The dominant soil type in the watershed is clay.

The Sturgeon Creek watershed also drains into Lake Erie and may effect water quality at Seacliffe and Point Pelee NW beaches. The soil type in the watershed is predominantly clay with sand and sandy to deposits located near the lake. The area of the watershed is 20.7 km^2 with a slope of approximately 0.3%.

Hillman watershed has a marsh at its outlet which drains into Lake Erie. It is believed that this watershed affects water quality at Hillman Beach and Point Pelee beaches. The watershed area was estimated to be 79 km^2 with a 0.2% slope.

These watersheds are similar to Big Creek watershed in numerous ways. The predominant clay soil and an negligible stream gradient are common to all watersheds. These conditions require extensive drainage systems to be used to assist natural drainage to enable various land use activities. The Cedar and Hillman Creeks watersheds have a marsh at their mouth, similar to Big Creek watershed. The land use in these watersheds is largely agricultural with rural homes dispersed throughout the watershed. The number of rural homes within the watersheds with potentially faulty septic systems was estimated to range from 65-75%, which corresponded with the estimated 70% of homes with potentially faulty septic systems in the Big Creek watershed.

Information concerning the size, type and location of various livestock operations within these watersheds were gathered from the Ministry of Agriculture and Food and various producer groups. This information indicated relatively similar numbers and types of livestock operations in these watersheds compared to the Big Creek watershed.

Due to the many similarities of these other watersheds to the Big Creek study watershed, in terms of soil type, topography, land use and management, it is recommended these watersheds be included into the CURB Implementation Program outlined for Big Creek. Landowners in these watersheds will be encouraged to submit a water quality improvement plan and be considered for appropriate funding allowances from the CURB Implementation Program.

3.5.5 BELLE RIVER BEACH IMPROVEMENT

The Town of Belle River is concerned about water quality at Belle River Beach. The accumulation of activated carbon sludge along Belle River Beach, discharged from a nearby water treatment plant, has impaired water quality. The Ministry of the Environment has suggested to the Town that this problem be addressed through the Essex Region CURB plan. An assessment of the situation has determined that the sludge material would have to be removed in order to improve water quality.

A preliminary estimated cost for removing the contaminated sludge ranged from $50,000 to $60,000, but may be higher if a local disposal site can not be secured. Further information on the Belle River Beach clean-up is described in correspondence to Dale Henry in Appendix 11. Upstream remedial measures to improve water quality at Belle River Beach will have minimal impact if the contaminated sludge at the beach is not removed. As a result, the removal of the contaminated sludge at Belle River Beach is an integral component of the CURB strategy for Belle River watershed.

3.6 RELATED IMPROVEMENTS or BENEFITS

The improvement of water quality at Holiday Beach will maintain the popularity of the Conservation Area as a place to spend a relaxing day or vacation. Improvements in water quality noted by reduced health risks will gain the confidence of the public and their continued use of the area. Attendances figures at Holiday Beach have increased from 48,504 in 1990 to 52,064 in 1991. It is anticipated that continued increases in park attendance will occur, as the public becomes informed of the remedial measures occurring in the watershed to improve water quality at Holiday Beach. Increases in park attendance will not only provide revenues to the authority, but also stimulate the local economy.

Dairy operators within the Big Creek watershed have noticed an increase in milk production as a result of not allowing livestock to drink from a watercourse. The increase in milk production can be related to an improvement in herd health as a result of providing an alternative clean source of drinking water. Similar improvements in herd health may be recognized with other livestock operators who prevent livestock from entering watercourses and drinking the water.

The reduction in nutrient loadings to Lake Erie from the Big Creek watershed will assist in lowering the trophic status of the lake, especially in the vicinity of Holiday Beach. Less available nutrients, particularly nitrogen and phosphorus, will limit algae growth. When excessive nutrients are available, algal blooms occur, primarily in the summer season when the water is warm. Algal blooms are aesthetically unpleasing and deter individuals from entering the water. Wave action may direct clumps of algae inland, depositing them along the beach. Rotting algae on the beach attracts flies and insects, which are undesirable pests to beach-goers. Consistent algae problems may reduce beach attendance, giving the beach a bad reputation and lowering revenues collected.

The presence of algae in Big Creek marsh is detrimental to the capacity of the marsh to function as an estuary for spawning fish. When algae begins to die-off in the water column, decomposition of the material by bacteria requires a considerable amount of dissolved oxygen. The sequestering of dissolved oxygen by decomposing microbes reduces the oxygen available to fish.

When fish experience oxygen stress, growth becomes retarded, susceptibility to diseases is increased and under severe conditions of oxygen deprivation, fish kills occur. Lake Erie supports a large commercial perch and pickerel fishing operation employing a large number of people. Reductions in fish populations will lower quotas, resulting in reduced revenues for the fishing company and possible employee lay-offs.

3.7 RECOMMENDATIONS

1) The Essex Region Conservation Authority (ERCA) implement the Clean Up Rural Beaches (CURB) Plan and enter into an agreement with the Ministry of the Environment to administer grants and provide technical assistance for the improvement of water quality in targeted watersheds in Essex County under the CURB Implementation Program.

2) ERCA provide information of provincial grants available from the CURB Implementation Program to repair old or install new septic systems, to expand manure storage facilities, to restrict livestock access to a watercourse and to

establish a milkhouse washwater disposal system through voluntary submission of a water quality improvement plan by interested individuals.

3) ERCA make site visits to individuals interested in the CURB Program, to provide technical assistance in the completion of the water quality improvement application forms.

4) ERCA conduct workshops and establish demonstration projects to promote the CURB Implementation Program and to emphasize the importance of proper septic system operation and agricultural practices and their benefits to water quality.

5) ERCA, in co-operation with the Ministry of the Environment, will monitor changes in water quality associated with landowner water quality improvement projects approved for provincial grants.

6) ERCA continue to promote soil conservation measures such as no-till and conservation tillage and drain management measures such as permanent vegetative cover and rock chutes to reduce soil and phosphorus loadings to a watercourse.

7) ERCA evaluate the feasibility of a manure-transfer program, to provide high nutrient material to operations such as nurseries, cash-crop operations and

mushroom farms, as an option to manage manure and help prevent manure overspreading and winter manure spreading.

8) The use of retention ponds within a drainage network should be examined in consultation with drainage engineers to allow sedimentation *of* eroding soil to occur, to reduce bacterial contamination of receiving watercourse and to moderate watercourse flow at peak discharges.

9) Research combining the expertise of the Ministries of Agriculture, Environment and Health be conducted to establish manure application rates and spreading practices to reflect the potential for fecal coliform contamination *of* a watercourse in Essex County.

10) The feasibility of revegetating the Big Creek marsh should be assessed in order to improve water quality at Holiday Beach.

11) ERCA provide technical assistance in the removal of activated carbon sludge from the Belle River Beach as part of the CURB plan for the Belle River watershed.

12) ERCA, in co-operation with relevant agencies, develop an algorithm to estimate fecal coliform and phosphorus loadings from waterfowl.

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APPENDICES

Appendix 1. Fecal coliforms and phosphorus concentrations of various sources used in the E.R.C.A. CURB algorithms

SOURCE	FECAL COLIFORMS+	PHOSPHORUS*
Milkhouse Waste	2000 FC/L	1.7×10^{-4} kg/L
Livestock Stream Access	8.9×10^{8} FC/defecation	1.2×10^{-3} kg/defecation
Barnyard/manure Stack Runoff	7.5×10^{9} FC/ha-mm	8.5×10^{-5} kg/L
Septic System	1.0×10^{7} FC/L	3.1×10^{-5} kg/L
Manure Spreading		
- Cattle	5.0×10^{11} FC/m^3	5.8×10^{-1} kg/m^3 #
- Swine	1.0×10^{13} FC/m^3	
- Chickens	9.9×10^{13} FC/m^3	
- Sheep	1.6×10^{13} FC/m^3	
- Horses	8.7×10^{13} FC/m^3	

* (Ecologistics Ltd., 1988)
\# (Hocking and Dean, 1989)
\+ (Fuller and Foran, 1989)

Appendix 2. Equivalent animal units of various livestock used in E.R.C.A. CURB algorithms.*

LIVESTOCK	WEIGHT	PHOSPHORUS	FECAL COLIFORMS
	kg	animal units	
Beef Cow		1.04	1.04
Slaughter Steer	455	1.04	1.00
Yearling Beef	365	0.78	1.00
Beef Calf	190	0.53	0.48
Dairy Cow		1.50	1.62
Dairy Heifer	318	1.50	1.62
Dairy Calf	136	0.46	0.36
Sow/boar		0.60	
Feeder Pig	22-90	0.40	
Sheep	45	0.17	0.02
Turkey	4.5	0.03	
Chicken	1.8	0.02	
Horse	455	1.20	0.0013

* (Ecologistics Ltd., 1988)

Appendix 3. Volume of manure produced/day for different livestock

LIVESTOCK TYPE			MANURE PRODUCED * m^3 day^{-1}
	6-15 months		0.0170
	15-24 months		0.0227
Cattle	Beef Cows		0.0581
	Dairy Cows	- free stall	0.0581
		- tie stall	0.0616
	Weaners		0.0023
Swine	Feeders		0.0071
	Sows and Litters		0.1700
Chicken Broilers			0.0001
Turkey Broilers			0.0003
Turkey Breeders And Toms			0.0007
Sheep			0.0042
Horses			0.0566

* (Fuller and Foran, 1989)

Appendix 4. Estimated die-off of *E. coli* (NAR) bacteria in chambers placed in Big Creek marsh sediment from May 5, to Sept. 16, 1991.

DATE mm/dd/yr	Day	Water Temp. (°C)	Sediment Temp. (°C)	*E. coli* (NAR)/100 g sediment Chamber One	Chamber Two	Mean	Logarithm Mean
05/28/91	0	32		1.8E+08	60000000	1.2E+08	8.079181
05/30/91	2	25		6000000	6000000	6000000	6.778151
06/04/91	7	20		1800000	600000	1200000	6.079181
06/10/91	13	27		440000	1000000	720000	5.857332
06/24/91	27	21		1000000	26000	513000	5.710117
07/08/91	41	30	28	100000	16000	58000	4.763428
07/22/91	55	28	27	32000	40	16020	4.204663
08/06/91	70	27	24	4800	40	2420	3.383815
09/03/91	98	25	24	40	40	40	1.60206
09/16/91	111	23	23	40	40	40	1.60206

DAY	Logarithm Mean	Regression Output	
0	8.08		
2	6.78	Constant	7.007382
7	6.08	Std Err of Y Est	0.495591
13	5.86	R Squared	0.95215
27	5.71	No. of Observations	10
41	4.76	Degrees of Freedom	8
55	4.20		
70	3.38	X Coefficient(s) -0.05192	
98	1.60	Std Err of Coef. 0.004115	
111	1.60		

Appendix 5. Grab water samples used to detect *E. coli* (NAR) bacteria in order to estimate travel time of fecal coliforms in Big Creek in 1991.*

		SAMPLING STATIONS (# of organisms/100 ml)									
DATE	TIME	II	IIa	IIb	III	VII	VIIa	IX	X	XII	XIII
April 25	13:29		<100								
	13:33		<100								
	13:37		8850000								
	13:42		3450000								
	13:47		387000								
	15:51				<100						
	16:45			92000							
	18:30				<100						
April 26		<100		250	500	<4		<4			
				100	650	4		4			
April 29		<4			<4	<4		<4	<4	<4	
April 30		<4			<4	<4		8	4	<4	<4
May 6						<4		<4	<4	<4	<4
May 7	11:50					<4					
	12:12						400				
	12:15						>20800000				
	12:18						>12900000				
	12:40							58	<4	<4	<4
	14:55							<4	<4		
	18:30								<4		
	18:45							<4	<4		
May 8								12	<4		
May 9						12		160	<4	<4	<4
May 10						<4		<4	<4	<4	<4
May 15						<4		<4	<4	<4	<4
May 21						<10			<10	<10	<4
May 27						4			4	<4	<4
June 3						60			4	<4	<2
June 10						<2			<4	<4	<4
June 17						<10			<10	<10	<2
June 25						<4			<4	<10	<2
July 2						<4				<4	<4
July 8						200				10	<10
July 15										<4	<4
July 22										<4	<4
July 29										<4	<4
Aug. 6										<4	<4
Aug. 12										4	4
Aug. 19										4	4
Aug. 27										4	4
Sept. 3										4	4
Sept. 9										10	4
Sept. 16										<7	<7
Sept. 23										<10	<10
Sept. 30										<100	<10
Oct. 7										<50	<4
Oct. 21										<10	<4
Oct. 28										<10	<4

* initial average number of *E. coli* (NAR) bacteria released April 25, 1991 into Big Creek was 1.8×10^9.

Appendix 6. Swab samples used to detect *E. coli* (NAR) bacteria in order to estimate travel time of fecal coliform in Big Creek in 1991.

DATE	SAMPLING STATIONS						
	III	IV	V	VII	IX	X	XII
April 25	-						
April 26	+	-	-		-		
April 29	-	-	-	-	-	-	+
April 30	-	-	-	-	-	-	+
May 2		-	-	+	-	+	+
May 6				+		-	+
May 7				+	-	-	+
May 8				+	-	-	-
May 9				-	-	-	+
May 10				+	-	-	+
May 13				+	-	-	-
May 15				-	-	+	
May 21				+		-	-
May 27				+		+	
June 3				+		+	+
June 4				+		+	
June 17				-		-	+
June 25				+		+	+
July 2				+			+
July 8				+			+
July 15				+			+
July 22							-
July 29							+
Aug. 6							-
Aug.12							-
Aug.19							+
Aug.27							+
Sept.3							+
Sept.9							-
Sept.16							-
Sept.23							+
Sept.30							-
Oct.7							+
Oct.15							-
Oct.21							-
Oct.28				+			-
Nov.4				+			-
Nov.11				+			-
Nov.18				+			-
Nov. 25				+			-

\+ means bacteria were present
\- means bacteria were absent.

Appendix 7. Fecal coliform loadings to a watercourse in the Big Creek watershed estimated by CURB algorithms, relative fecal coliform contributions (%) and rankings of various sources.

SOURCES	Fecal Coliforms (fc/year)	Relative Contributions (%)	RANKING
Spring/summer/fall Manure Overspreading	4.08×10^{14}	42.5	1
Faulty Septic Systems	3.80×10^{14}	39.6	2
Winter Spread Manure	1.58×10^{14}	16.4	3
Livestock Stream Access	1.35×10^{13}	1.4	4
Barnyard Runoff	3.72×10^{11}	0.04	5
Manure Stack Runoff	1.49×10^{11}	0.02	6
Milkhouse Waste	9.23×10^{10}	0.01	7

Appendix 8. Fecal coliforms, Fecal streptococcus, *Pseudomonas aeruginosa* and *Escherichia coli* counts at various stations during 1991.

Station: Holiday Beach

Date mm/dd/yr	Fecal coliforms	Fecal streptococcus	*Pseudomonas aeruginosa*	*Escherichia coli*
	- - - - - - - - - -	number of organisms/100ml	- - - - - - - - - -	
04/16/91	400	200	<10	200
04/22/91	300	<100	<10	100
05/06/91	100	110	<4	90
05/13/91	4	4	<4	<4
05/21/91	4	<4	<4	<4
05/27/91	80	140	4	40
06/03/91	4	4	<4	<4
06/10/91	260	150	8	150
06/17/91	10	20	<4	10
06/24/91	40	30	8	40
06/26/91	136	160	60	116
07/02/91	28	24	4	<4
07/08/91	70	50	<10	20
07/15/91	10	10	<10	10
07/22/91	60	70	<4	20
07/25/91	348	136	40	164
08/06/91	10	<10	<4	10
08/12/91	70	4	4	10
08/19/91	400	84	8	400
08/27/91	60	40	8	60
09/03/91	8	4	60	8
09/09/91	10	10	4	10
09/16/91	<30	150	<10	<20
09/23/91	<50	<80	<10	<50
09/30/91	<30	<70	<4	<30
10/21/91	<10	<10	<4	<10
10/28/91	990	>1500	>600	860
11/04/91	1000	120	<20	<500
Geometric mean				
(04/16-09/16)	41.26	31.36	7.7	25.91

Appendix 8. Continued

Station: Station #51

Date mm/dd/yr	Fecal coliforms	Fecal streptococcus	*Pseudomonas aeruqinosa*	*Escherichia coli*
	- - - - - - - - - - - number of organisms/100ml - - - - - - - - - - -			
04/16/91	300	<100	10	300
04/22/91	<1000	200	<10	<1000
05/06/91	100	390	4	90
05/13/91	<10	10	<4	<10
05/21/91	8	<4	<4	8
05/27/91	60	20	<4	60
06/03/91	20	8	<4	4
06/10/91	80	60	<4	40
06/17/91	<4	20	4	<4
06/24/91	20	<10	<10	<10
06/26/91	32	56	12	32
07/02/91	60	10	16	60
07/08/91	40	<10	<10	10
07/15/91	10	<10	<4	<10
07/22/91	40	20	<4	20
07/25/91	60	168	4	52
07/29/91	170	70	48	70
08/06/91	20	10	<4	10
08/12/91	4	4	4	4
08/19/91	28	52	4	12
08/27/91	40	10	4	30
09/03/91	140	10	516	20
09/09/91	140	40	10	60
09/16/91	24	<60	<10	20
09/23/91	<40	120	<10	<20
09/30/91	<20	<40	4	<10
10/21/91	<10	<10	<4	<10
10/28/91	900	760	>600	900
11/04/91	1500	130	<10	1500
Geometric mean (04/16-09/16)	39.76	25.11	7.29	25.13

Appendix 8. Continued

Station: Big Creek Outlet

Date mm/dd/yr	Fecal coliforms	Fecal streptococcus	*Pseudomonas aeruginosa*	*Escherichia coli*
	- - - - - - - - - - -	number of organisms/100ml	- - - - - - - - - - -	
04/16/91	200	<100	<10	200
04/22/91	200	400	<10	200
05/06/91	30	10	16	30
05/13/91	20	20	<4	10
05/21/91	40	30	10	40
05/27/91	36	120	<10	24
06/03/91	100	420	<4	70
06/10/91	12	30	<4	40
06/17/91	<100	<100	10	<100
06/24/91	52	60	112	8
06/26/91	12	68	<4	12
07/02/91	280	700	32	110
07/08/91	na	200	<10	na
07/15/91	36	116	4	28
07/22/91	104	170	4	104
07/25/91	220	440	40	130
07/29/91	220	320	36	110
08/06/91	20	<10	<4	10
08/12/91	80	40	4	30
08/19/91	80	80	4	30
08/27/91	50	20	12	50
09/03/91	130	560	600	130
09/09/91	240	180	20	100
09/16/91	100	>3000	<10	100
09/23/91	120	280	<10	120
09/30/91	<100	<100	<10	<100
10/21/91	<100	<100	<20	<100
10/28/91	<70	220	<10	<70
11/04/91	120	300	<10	<60
Geometric mean (04/16-09/16)	69.87	107.75	11.61	49.22

Appendix 8. Continued

Station: Lakewood Beach

Date mm/dd/yr	Fecal coliforms	Fecal streptococcus	*Pseudomonas aeruginosa*	*Escherichia coli*
	- - - - - - - - - - - number of organisms/100ml - - - - - - - - - - -			
04/16/91	500	200	30	400
04/22/91	<100	200	<10	<100
05/06/91	360	90	12	340
05/13/91	4	<4	<4	4
05/21/91	20	<4	<4	20
05/27/91	290	210	12	270
06/03/91	276	140	12	84
06/10/91	80	70	<4	50
06/17/91	24	10	<4	<4
06/24/91	16	16	16	8
06/26/91	96	196	72	72
07/02/91	60	50	52	40
07/08/91	56	16	4	36
07/15/91	<4	<4	4	<4
07/22/91	140	60	8	84
07/25/91	110	124	20	90
07/29/91	44	44	16	12
08/06/91	16	<4	12	16
08/12/91	12	24	4	12
08/19/91	20	10	4	10
08/27/91	30	20	20	20
09/03/91	40	20	4	40
09/09/91	40	10	12	10
09/16/91	<30	<50	20	<10
09/23/91	<80	100	<10	<80
09/30/91	<10	<40	4	<10
10/21/91	<10	<10	<4	<10
10/28/91	24	80	36	8
11/04/91	1400	<70	28	<700
Geometric mean (04/16-09/16)	47.47	31.24	10.08	29.73

Appendix 8. Continued

Station: Willowwood Beach

Date mm/dd/yr	Fecal coliforms	Fecal streptococcus	*Pseudomonas aeruginosa*	*Escherichia coli*
	- - - - - - - - - -	number of organisms/100ml	- - - - - - - - - -	
04/16/91	700	100	20	700
04/22/91	300	1300	<10	200
05/06/91	580	60	16	400
05/13/91	<4	12	<4	<4
05/21/91	540	16	<4	350
05/27/91	12000	>1500	88	4000
06/03/91	540	550	24	320
06/10/91	372	290	28	76
06/17/91	510	20	24	140
06/24/91	50	90	28	50
06/26/91	150	530	80	60
07/02/91	40	10	4	20
07/08/91	110	30	8	40
07/15/91	8	<4	<4	4
07/22/91	84	>600	4	24
07/25/91	120	150	8	50
07/29/91	70	80	8	
07/06/91	10	<10	<10	10
08/12/91	36	44	4	36
08/19/91	56	20	4	52
08/27/91	40	10	12	10
09/03/91	50	60	32	30
09/09/91	10	10	8	10
09/16/91	<10	<20	36	<10
09/23/91	<50	<40	<10	<10
09/30/91	<20	<30	<4	<10
10/21/91	<10	<10	<4	<10
10/28/91	980	1500	>12	770
11/04/91	1100	120	<10	1100
Geometric mean (04/16-09/16)	78.98	49.12	11.08	53.97

Appendix 8. Continued

Station: Bar Point

Date mm/dd/yr	Fecal coliforms	Fecal streptococcus	*Pseudomonas aeruginosa*	*Escherichia coli*
	- - - - - - - - - - - number of organisms/100ml	- - - - - - - - - -		
04/16/91	800	800	<10	800
04/22/91	1200	300	140	500
05/06/91	420	30	<4	290
05/13/91	320	36	8	308
05/21/91	>400	8	28	376
05/27/91	>1000	390	36	720
06/03/91	1500	770	40	700
06/10/91	280	60	16	60
06/17/91	220	<10	20	30
06/24/91	170	420	24	170
06/26/91	90	120	24	30
07/02/91	420	230	20	200
07/08/91	144	80	28	128
07/15/91	110	60	4	40
07/22/91	330	90	<4	120
07/25/91	50	44	<4	20
07/29/91	50	50	<4	50
08/06/91	10	20	<4	<10
08/12/91	120	50	8	120
08/19/91	120	32	8	60
08/27/91	140	210	4	80
09/03/91	100	10	4	70
09/09/91	90	10	20	50
09/16/91	<10	<10	12	<10
09/23/91	200	150	<10	200
09/30/91	<10	<10	<4	<10
10/21/91	140	<20	<4	<10
10/28/91	>1000	600	24	>1000
11/04/91	1600	110	<10	1400
Geometric mean (04/16-09/16)	169.81	64.58	11.74	101.81

Appendix 9. Concentrations of nitrogen and phosphorus compounds and suspended solids at various stations during 1991.

STATION: HOLIDAY BEACH

Date mm/dd/yr	NITROGEN (mg/L) Free Ammonia	Total Kjeldahl	Nitrite	Nitrate	PHOSPHORUS (mg/L) Total	Dissolved	Suspended Solids (mg/L)
04/16/91	0.01	1.31	0.03	0.6	0.26	0.022	226
04/22/91	0.144	2.2	0.08	2.4	0.31	0.043	213
05/06/91	0.033	0.68	0.03	0.8	0.16	0.015	154
05/13/91	0.134	0.43	0.01	0.3	0.077	0.008	0.4
05/27/91	0.374	2.2	0.06	0.4	0.265	0.042	86.7
06/03/91	0.061	0.32	0.01	0.5	0.023	0.003	5.9
06/10/91	0.015	2.77	0.02	0.1	0.3	0.034	166
06/17/91	0.045	0.33	0.02	0.4	0.019	<0.001	<5.0
06/24/91	0.019	0.36	0.01	0.4	0.035	0.004	22.2
06/26/91	0.004	0.58	0.01	0.3	0.076	<0.001	80.3
07/02/91	<0.1	0.25	0.01	0.3	<0.01	<0.01	9.6
07/08/91	<0.1	1.51	0.02	0.1	0.22	<0.01	110
07/15/91	0.1	0.25	0.01	0.2	<0.01	<0.01	4.4
07/22/91	<0.1	0.95	<0.01	0.2	0.16	<0.01	110
07/22/91	<0.1	0.78	0.01	0.1	0.13	<0.01	58.3
07/25/91	<0.1	0.37	0.01	0.2	0.03	<0.01	36.9
07/29/91	0.1	0.45	0.01	0.1	0.03	0.01	12.7
08/06/91	0.1	0.52	0.01	0.1	0.02	0.01	16.4
08/12/91	0.1	0.5	0.01	0.1	0.04	0.01	13.7
08/19/91	0.1	0.33	0.01	0.2	0.04	0.03	13.5
09/03/91	<0.1	0.43	<0.01	<0.1	0.04	0.03	32.7
09/09/91	<0.1	0.38	<0.01	0.1	0.03	<0.01	16.6
09/16/91	<0.1	1.01	<0.01	0.1	0.24	<0.01	161
09/23/91	<0.1	1.14	0.03	<0.1	0.42	0.05	381
09/30/91	<0.1	0.35	0.01	<0.1	0.05	<0.01	48.8
10/07/91	<0.1	0.69	<0.01	0.1	0.2	<0.01	119
10/21/91	0.0233	0.4	0.02	0.3	0.064	0.011	90.1
10/28/91	<0.1	1.26	0.02	0.8	0.16	0.01	82.4
11/04/91	<0.1	0.61	0.03	0.3	0.15	0.02	116
mean (04/16 to 09/16)	0.093	0.82	0.018	0.35	0.11	0.011	67.4

Appendix 9. Continued

STATION: STATION #51

Date mm/dd/yr	NITROGEN (mg/L) Free Ammonia	Total Kjeldahl	Nitrite	Nitrate	PHOSPHORUS (mg/L) Total	Dissolved	Suspended Solids (mg/L)
04/16/91	0.012	1.52	0.04	0.6	0.27	0.024	205
04/22/91	0.228	3.9	0.12	1.6	0.53	0.049	402
05/06/91	0.031	0.74	0.02	0.7	0.13	0.013	136
05/13/91	0.027	1.14	0.06	0.5	0.15	0.011	33
05/21/91	0.024	0.28	0.01	0.4	0.019	<0.001	6.4
05/27/91	0.21	1.48	0.03	0.3	0.166	0.027	56
06/03/91	0.078	0.37	0.01	0.5	0.029	0.005	10
06/10/91	0.019	3.32	0.02	<0.1	0.33	0.023	102
06/24/91	0.083	1.58	0.03	0.3	0.17	0.021	75.5
06/26/91	0.122	2	0.11	0.1	0.22	0.005	90.3
07/02/91	<0.1	0.31	0.01	0.3	<0.01	<0.01	10.9
07/08/91	<0.1	1.63	0.02	0.1	0.23	<0.01	109
07/15/91	<0.1	0.32	0.01	0.2	0.01	<0.01	4.9
07/22/91	<0.1	0.61	<0.01	0.1	0.09	<0.01	52.1
07/25/91	<0.1	0.4	0.01	0.2	0.02	<0.01	47.2
07/29/91	0.1	0.55	0.01	0.1	0.05	0.01	28.9
08/06/91	0.1	0.56	0.01	0.1	0.04	0.01	26.6
08/12/91	0.1	0.48	0.01	0.1	0.05	0.01	12.4
08/19/91	0.1	0.36	0.01	0.1	0.07	0.04	22.7
08/27/91	0.1	1.29	0.01	0.1	0.19	0.01	63.9
09/03/91	<0.1	0.51	<0.01	0.1	0.05	0.02	59.2
09/09/91	<0.1	0.51	<0.01	0.1	0.06	<0.01	29.8
09/16/91	<0.1	1.22	<0.01	0.2	0.26	<0.01	138
09/23/91	<0.1	1.8	0.03	0.1	0.42	0.08	432
09/30/91	<0.1	0.55	0.01	<0.1	0.09	<0.01	92.8
10/07/91	<0.1	0.57	<0.01	0.1	0.2	<0.01	144
10/21/91	0.066	0.44	0.02	0.3	0.068	0.025	52.9
10/28/91	<0.1	0.61	0.01	0.7	0.06	0.02	38
11/04/91	<0.1	0.61	0.02	0.3	0.14	0.02	105
mean (04/16 to 09/16)	0.093	1.09	0.026	0.3	0.14	0.013	74.39

Appendix 9. Continued

STATION: BIG CREEK OUTLET

Date dd/mm/yr	NITROGEN (mg/L) Free Ammonia	Total Kjeldahl	Nitrite	Nitrate	PHOSPHORUS (mg/L) Total	Dissolved	Suspended Solids (mg/L)
04/16/91	0.013	1.75	0.04	0.7	0.28	0.039	213
04/22/91	0.293	2.75	0.08	1.9	0.355	0.046	212
05/06/91	0.094	2.4	0.07	1.1	0.285	0.018	182
05/13/91	0.013	2.66	0.04	0.1	0.31	0.014	154
05/21/91	0.012	2.6	0.01	<0.1	0.3	0.023	135
05/27/91	0.006	3.25	0.11	1.5	0.385	0.101	84.4
06/03/91	0.137	3.36	0.14	2.2	0.38	0.023	131
06/10/91	0.241	3.91	0.01	<0.1	0.35	0.024	164
06/17/91	0.133	2.6	0.04	<0.1	0.33	0.011	132
06/24/91	0.018	0.29	0.01	0.4	0.021	0.007	14.7
06/26/91	0.115	2.8	0.11	0.2	0.3	0.01	121
07/02/91	0.1	1.11	0.04	0.3	0.1	0.01	72.7
07/08/91	<0.1	3.5	0.04	0.1	0.48	0.01	322
07/15/91	<0.1	0.43	0.01	0.2	0.02	<0.01	30.8
07/22/91	0.1	1.48	0.01	0.1	0.2	<0.01	64.2
07/25/91	<0.1	2.1	0.01	0.1	0.28	<0.01	109
07/29/91	0.2	1.12	0.02	0.1	0.21	0.01	82.7
08/06/91	0.1	0.89	0.01	0.1	0.09	0.01	52.1
08/12/91	0.1	3.05	0.01	0.1	0.38	0.01	115
08/19/91	0.1	1.82	0.01	0.1	0.4	0.06	84.3
08/27/91	0.1	3.16	0.01	0.1	0.44	0.02	104
09/03/91	<0.1	3.38	0.02	<0.1	0.48	0.12	169
09/09/91	<0.1	5.2	0.02	<0.1	0.6	<0.01	167
09/16/91	<0.1	4.46	<0.01	<0.1	0.6	<0.01	23.8
09/23/91	<0.1	6.55	0.04	0.1	0.83	<0.01	316
09/30/91	<0.1	3.9	0.02	<0.1	0.46	0.01	152
10/07/91	<0.1	9.98	<0.01	<0.1	1.46	0.05	761
10/21/91	0.923	6.8	0.11	<0.1	0.88	0.057	421
10/28/91	0.3	4.15	0.05	0.1	0.42	0.12	95.1
11/04/91	0.6	3.63	0.1	0.5	0.34	0.09	91.8
mean (04/16 to 09/16)	0.1	2.5	0.037	0.42	0.32	0.024	122.49

Appendix 9. Continued

STATION: LAKEWOOD BEACH

Date mm/dd/yr	NITROGEN (mg/L) Free Ammonia	Total Kjeldahl	Nitrite	Nitrate	PHOSPHORUS (mg/L) Total	Dissolved	Suspended Solids (mg/L)
04/16/91	0.009	0.99	0.01	0.6	0.24	0.017	240
04/22/91	0.049	1.06	0.04	1	0.19	0.015	174
05/06/91	0.021	0.5	0.02	0.6	0.11	0.012	130
05/13/91	0.095	0.41	0.01	0.5	0.029	<0.001	<5.0
05/21/91	0.037	0.56	0.01	0.4	0.039	<0.001	15.4
05/27/91	0.1	0.82	0.02	0.3	0.104	0.023	71
06/03/91	0.273	1.7	0.09	1.7	0.22	0.02	50.2
06/10/91	0.076	1.32	0.02	0.4	0.172	0.004	114
06/17/91	0.042	0.36	0.02	0.5	0.026	<0.001	<5.0
06/24/91	0.031	0.3	0.01	0.3	0.024	<0.001	17
06/26/91	0.091	1.75	0.02	0.2	0.185	0.003	113
07/02/91	<0.1	0.34	0.01	0.3	<0.01	<0.01	13.3
07/08/91	<0.1	0.48	0.01	0.2	0.07	<0.01	56.2
07/15/91	<0.1	0.28	0.01	0.2	0.01	<0.01	10.4
07/22/91	0.1	0.52	<0.01	0.2	0.04	<0.01	38.3
07/25/91	<0.1	0.56	0.01	0.2	0.14	<0.01	83.8
07/29/91	0.1	0.39	0.01	0.1	0.01	0.01	17.8
08/06/91	0.1	0.39	0.01	0.1	0.01	0.01	11.9
08/12/91	0.1	0.4	0.01	0.2	0.03	0.01	15.4
08/19/91	0.1	0.45	0.01	0.2	0.13	0.04	42.6
08/27/91	0.1	1.08	0.01	0.1	0.19	0.01	89.8
09/03/91	<0.1	0.56	<0.01	0.1	0.09	<0.01	59.8
09/09/91	<0.1	1.15	0.01	0.1	0.2	<0.01	116
09/16/91	<0.1	0.94	<0.01	0.2	0.22	<0.01	146
09/23/91	<0.1	1.67	0.03	0.2	0.47	<0.01	447
09/30/91	<0.1	0.38	0.01	<0.1	0.06	0.01	57.5
10/07/91	<0.1	0.63	<0.01	0.1	0.18	<0.01	115
10/21/91	0.027	0.6	0.01	0.2	0.086	0.023	96.7
10/28/91	<0.1	0.42	<0.01	0.4	0.04	<0.01	28.5
11/04/91	<0.1	0.56	0.02	0.3	0.17	0.02	113
mean (04/16 to 09/16)	0.089	0.72	0.017	0.36	0.1	0.011	68.16

Appendix 9. Continued

STATION: WILLOWWOOD BEACH

Date mm/dd/yr	NITROGEN (mg/L) Free Ammonia	Total Kjeldahl	Nitrite	Nitrate	PHOSPHORUS (mg/L) Total	Dissolved	Suspended Solids (mg/L)
04/16/91	0.009	1.09	0.01	0.6	0.28	0.016	256
04/22/91	0.024	0.7	0.04	1.1	0.19	0.019	86.6
05/06/91	0.023	0.54	0.02	0.6	0.11	0.007	109
05/13/91	0.021	0.23	0.01	0.6	0.016	<0.001	<5.0
05/21/91	0.078	0.7	0.01	0.3	0.068	0.009	37
05/27/91	0.073	0.96	<0.01	0.2	0.096	0.008	31.1
06/03/91	0.065	0.43	0.02	0.4	0.031	0.002	12.7
06/10/91	0.051	1.08	0.01	0.5	0.146	0.001	123
06/17/91	0.028	0.31	0.02	0.4	0.022	<0.001	<5.0
06/24/91	0.026	0.29	<0.01	0.3	0.024	<0.001	15.9
06/26/91	0.005	0.72	0.02	0.3	0.098	<0.001	79.5
07/02/91	<0.1	8.42	0.01	0.3	<0.01	<0.01	20.3
07/08/91	<0.1	0.47	0.01	0.2	0.06	0.02	50.3
07/15/91	<0.1	0.29	0.01	0.2	0.02	<0.01	7.9
07/22/91	<0.1	0.48	0.01	0.2	0.02	<0.01	29.6
07/25/91	<0.1	0.98	0.01	0.2	0.21	<0.01	117
07/29/91	0.1	0.37	0.01	0.1	0.02	0.01	19.5
08/06/91	0.1	0.45	0.01	0.1	0.02	0.01	28.6
08/12/91	0.1	0.43	0.01	0.1	0.06	0.01	21.4
08/19/91	0.1	0.37	0.01	0.2	0.14	0.05	33.8
08/27/91	0.1	0.79	0.01	0.13	0.01	0.01	
09/03/91	<0.1	0.96	<0.01	0.1	0.22	<0.01	177
09/09/91	<0.1	0.52	<0.01	0.1	0.07	<0.01	33.9
09/16/91	<0.1	0.47	<0.01	0.2	0.12	<0.01	58.5
09/23/91	<0.1	0.98	0.02	0.3	0.32	<0.01	302
09/30/91	<0.1	0.66	0.01	<0.1	0.08	0.02	69.4
10/07/91	<0.1	0.5	<0.01	0.1	0.15	<0.01	80
10/21/91	0.018	0.32	<0.01	0.2	0.041	0.015	39.8
10/28/91	<0.1	1.31	0.01	0.5	0.17	0.01	68.8
11/04/91	<0.1	0.57	0.02	0.3	0.17	0.02	108
mean (04/16 to 09/16)	0.071	0.92	0.013	0.31	0.086	0.01	56.61

Appendix 9. Continued

STATION: BAR POINT

Date mm/dd/yr	NITROGEN (mg/L) Free Ammonia	Total Kjeldahl	Nitrite	Nitrate	PHOSPHORUS (mg/L) Total	Dissolved	Suspended Solids (mg/L)
04/16/91	0.008	0.58	0.01	0.6	0.12	0.013	103
04/22/91	0.045	0.8	0.04	1.4	0.37	0.037	79.7
05/06/91	0.018	0.62	0.02	0.6	0.126	0.007	120
05/13/91	0.036	0.27	0.02	0.6	0.014	<0.001	<5.0
05/21/91	0.095	0.5	0.01	0.8	0.024	0.008	13.9
05/27/91	0.074	0.53	<0.01	0.4	0.068	0.011	49.1
06/03/91	0.122	0.66	0.05	0.9	0.074	0.022	38.2
06/10/91	0.057	0.82	0.02	0.7	1.1	0.001	99.3
06/17/91	0.015	0.34	0.02	0.4	0.022	<0.001	<5.0
06/24/91	0.037	0.44	0.01	0.4	0.052	0.005	41.5
06/26/91	0.003	0.94	<0.01	0.1	0.096	0.004	85.1
07/02/91	<0.1	0.49	0.01	0.3	0.06	0.05	35.7
07/08/91	<0.1	0.36	0.02	0.2	0.06	<0.01	40.9
07/15/91	<0.1	0.85	0.02	0.2	0.09	<0.01	253
07/22/91	<0.1	0.84	0.01	0.2	0.11	<0.01	65.7
07/25/91	<0.1	0.32	0.01	0.2	0.13	0.01	40.9
07/29/91	0.1	1.09	0.01	0.2	0.32	0.01	132
08/06/91	0.1	0.49	0.01	0.1	0.02	0.01	26.5
08/12/91	0.1	3.14	0.01	0.2	0.48	0.01	245
08/19/91	0.1	0.46	0.01	0.2	0.15	0.08	25.1
08/19/91	0.1	0.79	0.01	0.13	0.01	0.01	
09/03/91	<0.1	0.46	0.01	0.1	0.08	0.01	37.4
09/09/91	<0.1	0.79	<0.01	0.1	0.13	<0.01	79.5
09/16/91	<0.1	0.7	<0.01	0.1	0.16	<0.01	87.8
09/23/91	<0.1	0.71	0.01	0.2	0.2	<0.01	132
09/30/91	<0.1	0.35	0.01	<0.1	0.05	0.02	54.6
10/07/91	<0.1	0.5	<0.01	0.1	0.14	<0.01	65.8
10/21/91	0.022	0.37	<0.01	0.2	0.04	0.01	42.8
10/28/91	<0.1	0.5	<0.01	0.4	0.07	0.02	52.1
11/04/91	<0.1	0.57	0.02	0.3	0.15	0.01	90.5
mean (04/16 to 09/16)	0.075	0.72	0.015	0.38	0.16	0.015	74.32

Appendix 10. Concentrations of total atrazine and metolachlor herbicides in water samples taken from various locations in Big Creek marsh in June and December 1990.

LOCATION	DATE	Total Atrazine	Metolachlor
		$\mu g\ L^{-1}$	
HOLIDAY BEACH A	June 90	ND	ND
	Dec. 90	0.15	ND
HOLIDAY BEACH B	June 90	NA	NA
	Dec. 90	0.15	ND
HWY #18	June 90	1.74	ND
	Dec. 90	0.47	0.62
KNAPP'S ISLAND	June 90	1.64	ND
	Dec. 90	0.38	ND
BRENNAN'S LANE	June 90	2.79	ND
	Dec. 90	0.38	0.60
CREEK ROAD	June 90	2.79	ND
	Dec. 90	0.33	ND

ND - Herbicide can not be confirmed to be present in trace amounts.
NA - Sample not available.

360 fairview avenue west
essex, Ontario
N8M 1YS
519-776-5209

Appendix 11. Correspondence to Dale Henry

file no.
3204-11

Mr. Dale Henry
Head, Stormwater and
Combined Sewer Overflow Unit
Ministry of the Environment
1 St. Clair Avenue West
Toronto, Ontario
M4V 1PV

Dear Sir:

Re: Funding Assistance for Cleanup of Belle River Beach
Clean-up Rural Beaches Program and/or Urban Beaches Program

Further to our recent discussions, please find enclosed the following background information pertaining to the above:

1) Letter from the Town of Belle River to Mr. Pat Hayes, M.P.P., August 28, 1991.

2) Letter from the Town of Belle River to The Honourable Ruth Grier, Minister of the Environment dated October 04, 1991.

3) Letter from The Honourable Ruth Grier, to the Town of Belle River dated October 15, 1991.

4) Letter from the Town of Belle River to the Essex Region Conservation Authority dated December 06, 1991.

As noted in the attachments, the Town concerned with the pollution of their large municipal beach, caused by the activated carbon sludge from the adjacent water treatment plant, which remains trapped on the beach at this time.

The letter from the Honourable Ruth Grier to the Town, suggests that this problem be addressed through our C Plan which is currently being finalized for various watersheds including the Belle River.

The preliminary estimated cost of removal of this material is $50,000 to $60,000, and may be higher depending on whether a disposal site can be found nearby.

......./2

In recent telephone discussions we have been advised by Keith Wilson, of the MOE Rural Beaches Program, that this particular problem, not being from a rural watershed source, might be better addressed through the “URBAN” Beaches Program. We understand that you are responsible for this particular program.

We would appreciate your consideration of funding through either the Urban or Rural Clean-up Program. We are certainly prepared to identify this $50,000 to $60,000 clean-up operation as part of our CURB Plan, or to follow up with whatever other formal application process you may require.

Yours truly

K . J. Schmidt
General Manager

SRT/as
Encl.

c.c. Mr. Keith Wilson - Clean-up Rural Beaches Program
Mr. Jim Drummond, Windsor Office MOE
Town of Belle River
Mr. Richard Tighe, ERCA Member, Town of Belle River