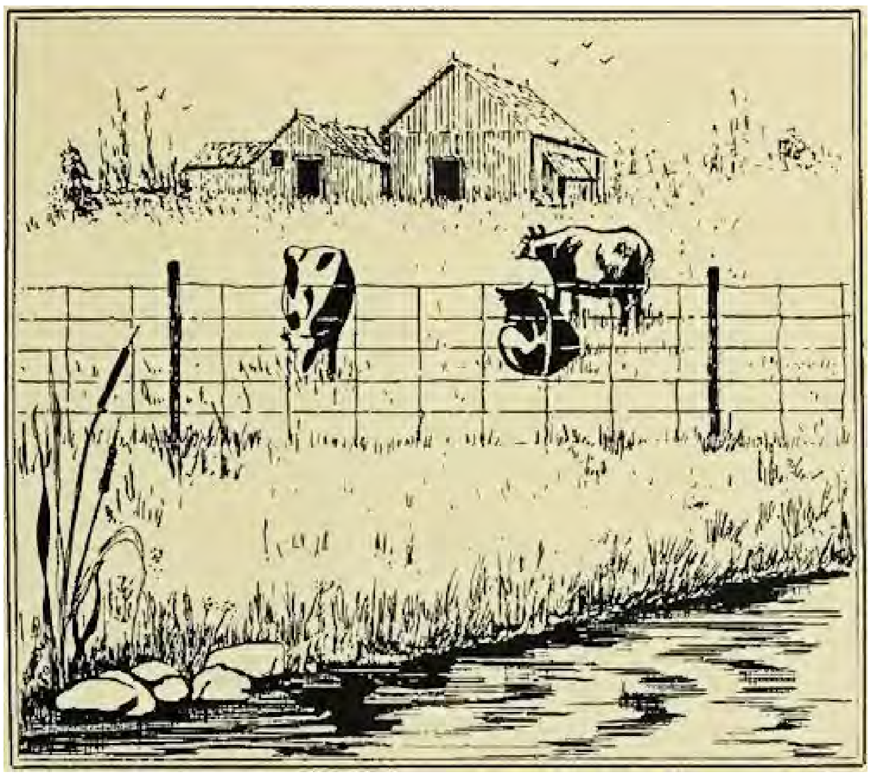
CLEAN UP RURAL BEACHES (CURB) PLAN

FOR LAKE HURON BEACHES IN THE MAITLAND VALLEY WATERSHED



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THE MAITLAND VALLEY
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FOR THE ONTARIO MINISTRY OF THE ENVIRONMENT

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DISCLAIMER

FOREWORD

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

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

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

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

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

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

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

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

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

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

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

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

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

Chairman
Provincial Rural Beaches Planning and Advisory Committee
c/o Environment Ontario
Water Resources Branch
135 St. Clair Ave. W.
Suite 100
Toronto, Ontario M4V 1P5

CLEAN UP RURAL BEACHES PLAN
(CURB)

FOR LAKE HURON BEACHES
IN THE
MAITLAND VALLEY CONSERVATION AUTHORITY
WATERSHED

MAITLAND VALLEY CONSERVATION AUTHORITY

RURAL BEACHES STUDY

Prepared by: Robert Fuller
Mary Ellen Foran

Prepared for: The Ontario Ministry of the Environment

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ACKNOWLEDGEMENTS

The Maitland Valley Conservation Authority Rural Beaches Study is made possible through funding provided by the Ontario Ministry of the Environment as a component of the Provincial Rural Beaches Strategy Program. The Maitland Rural Beaches Steering Committee comprised of representatives from the Ministries of the Environment, and Agriculture and Food, County Planning Departments and the Huron County Federation of Agriculture provide local direction to the study. Their guidance and support throughout the study is greatly appreciated.

We would also like to thank the Ministry of the Environment Southwest Region and MVCA staff members for their assistance to this project. Project staff wish to acknowledge the contribution of Derek Veenhof who participated in the data collection phase of the MVCA study. Dianne Dosman is gratefully acknowledged for her patience in typing this report.

Finally, staff wish to express their appreciation to the livestock operators of the MVCA watershed who participated in this study.

1.0 SUMMARY AND RECOMMENDATIONS

1.1 SUMMARY

The Maitland Valley Conservation Authority's (MVCA) Rural Beaches Study began in 1986 as a component of the Ministry of the Environments (MOE) Provincial Rural Beaches Program. The primary objectives of the study through the period April 1986 to December 1988 were to identify the sources of indicator bacteria which impaired water quality of Lake Huron beaches at Goderich and to assess the potential impacts of the agricultural sources identified. Information regarding agricultural practices associated with livestock production in the Maitland Watershed was gathered during this period through surveys. The MVCA CURB Plan was prepared in order to estimate the relative fecal coliform bacteria load delivered to Lake Huron beaches from the sources identified in the MVCA watershed and to propose means to reduce the impact of these sources on beach water quality.

The agricultural sources of indicator bacteria which were modelled include: milkhouse waste water disposal, livestock access, feedlot runoff, manure stack runoff, winter spreading, over application during spreading and spills. In addition, the contribution from faulty septic systems, urban non-point runoff and urban sewage plant discharges were estimated.

Algorithms were developed to estimate the annual fecal coliform (FC) load delivered to watershed streams from all sources in each sub-basin. An estimate was then made of the annual load delivered from watershed sub-basins to Lake Huron based on bacteria decay rates and stream travel times.

Annual loads delivered to Lake Huron were estimated to be 6.26E+14 FC/year from the Maitland River watershed and 3.13E+14 FC/year from the two lakeshore sub-basins. Three sources of indicator bacteria were determined to contribute the majority (945) of the total load delivered to Lake Huron. These sources were septic systems, winter spreading of manure and livestock access to watercourses. Thirty percent (2,772) of the households in the watershed were assumed to cause contamination through faulty septic systems. Approximately 8.32 million dollars would be required to repair this number of systems. Sixteen percent (495 farms) of livestock operations in the watershed were estimated to practice winter spreading of manure. It was assumed that no capital costs would be required on the farms to prevent this practice. Approximately 2.83 million dollars would be required to restrict cattle access at the 272 sites identified throughout the watershed.

The remedial measures considered to reduce loading from winter spread manure, septic systems and livestock access also were the most cost-effective in terms of the load reduced per dollar spent on physical improvements.

A 32 percent reduction in load delivered from the Maitland River watershed and two lakeshore sub-basins was established as a target goal. This represents a load reduction of 1.72E+14 FC/year and 1.00E+14 FC/year from the Maitland River and lakeshore sub-basins respectively. Septic system failure, winter spreading of manure and livestock access were identified as priority sources as the target load reduction could be achieved by reducing the load contributed from these sources.

The cooperation of government ministries, agencies and the private sector will be required in efforts to reduce bacterial loading to improve water quality within the MVCA watershed. Activities which could be undertaken by various sectors to reduce bacteria loading are proposed as an Implementation Plan. These activities are discussed for each source under four components: Information and Education, Policy and Planning, Data Collection and Monitoring and Extension. Over the five year period beginning in 1990 the MVCA would undertake activities as outlined in the Implementation Plan to reduce the bacteria load delivered to Lake Huron from activities within the Maitland watershed.

1.2 RECOMMENDATIONS

1. That the Maitland Valley Conservation Authority continue to participate in the Provincial Rural Beaches Program in cooperation with the Ontario Ministry of the Environment to improve water quality within the MVCA watershed.

2. That information and education activities be undertaken to inform watershed residents of the importance of proper private sewage and agricultural waste management practices on water quality.

3. That watershed residents be encouraged to repair inadequate private sewage systems and that further efforts be undertaken by the MOE, Health Units and MVCA to identify inadequate systems in the MVCA watershed.

4. That incentive programs and/or enforcement of existing environmental legislation be considered as mechanisms to improve private sewage disposal practices.

5. That a system be developed whereby records are kept on the construction and maintenance of private sewage disposal systems.

6. That livestock farmers be encouraged to adopt improved manure management practices.

7. That an environmental protection incentive program be continued after 1990, to assist farmers in implementing soil and water conservation practices and that the construction of milkhouse waste disposal systems, manure storages and stream fencing projects be eligible for assistance.

8. That all farmers in all watersheds be eligible for financial assistance through Provincial incentive programs.

9. That farmers be encouraged to adopt more cost effective conservation measures (ie. septic system improvements, restricting livestock access) before less cost effective measures are considered.

10. That future environmental incentive programs include low level and/or raised level stream crossings for livestock, as projects eligible for assistance.

11. That more detailed information be collected and records kept of projects receiving assistance through Provincial environmental incentive programs.

12. That Provincial planning guidelines be developed for use by municipalities preparing manure management regulations or by—laws.

13. That a Provincial fecal coliform standard be considered for effluent discharged from

municipal sewage lagoon systems.

14. That the MOE and MVCA should discuss the Authority's role with regard to the referral and follow—up of public reports of spills and complaints concerning water quality which are made to the MVCA.

2.0 INTRODUCTION

Water quality impairment within the Maitland Valley Conservation Authority watershed has been an issue of concern for a number of years. One indication of poor water quality has been the posting of public beaches at Goderich due to elevated bacterial concentrations. In response to the posting of numerous beaches along the Lake Huron shoreline during the summer of 1983, the Ontario Ministry of the Environment undertook a study to assess the microbiological quality of beaches at Goderich, Grand Bend and Ipperwash. They concluded that the majority of the fecal bacteria loading discharged to the Lake, originated in the agricultural areas of the contributing watersheds (MOE, 1984).

In 1986 the MVCA submitted a proposal to the MOE's Provincial Rural Beaches Program to undertake a Rural Beaches Study in the Maitland River watershed. Through this initiative, rural sources of surface water bacterial contamination were to be investigated and strategies proposed to mitigate their impact on downstream beaches. Over the period April 1986 to December 1988 efforts were focused on identifying the sources and extent of indicator bacteria concentrations. Information on livestock waste management practices, household waste disposal and attitudes of farm operators towards water quality was collected through surveys (MVCA, 1986 and 1987). Water quality also was monitored within the study areas over this period.

2.1 Project Goal and Objectives

The goal of the Maitland Valley Conservation Authority Rural Beaches Study is to prevent the posting of public beaches at Goderich due to bacterial pollution originating within the Maitland River watershed. The objectives of the study through to December 1988 were:

- (i) to identify and rank livestock operations as to their potential to cause fecal bacteria contamination;
- (ii) to identify individual sources of bacterial pollution within the Maitland Watershed;
- (iii) to promote an awareness of the impacts of rural sources of bacterial contamination on surface water quality;
- (iv) to promote the adoption of alternative manure and waste management practices to reduce bacterial contamination;
- (v) to document water quality problems related to bacterial sources within the Maitland watershed.

The objective of this document is to estimate the relative fecal coliform bacteria contributions delivered to Lake Huron from the sources identified. In addition, strategies are proposed to reduce fecal coliform loads from specific sources in order to prevent future postings of public beaches within the MVCA jurisdiction.

2.2 Beaches of Concern

The public beaches of concern in the Maitland watershed are located on the Lake Huron shoreline at Goderich. Three beaches have been developed within the Town of Goderich south of the river mouth: Main Beach, St. Christopher's Beach and St. Christopher's Cove. Numerous other beaches occur along the entire shoreline within the MVCA's boundaries. In addition, small reservoirs are situated on the Maitland River in the municipalities of Brussels, Bluevale, Wingham, Wroxeter and Gorrie

3.0 LOADS DELIVERED TO WATERCOURSES FROM INDIVIDUAL SOURCES

3.1 Introduction

The number of fecal coliform bacteria (load) delivered to watercourses from specific sources was calculated for each sub-basin in the Maitland River watershed. Agricultural and urban sources considered were: milkhouse waste water, livestock access, feedlot/barnyard runoff, manure stack runoff, manure spreading, manure spills, household septic system failure, urban non—point runoff and sewage treatment plant discharges. The annual fecal coliform loads calculated from these sources are relative rather than absolute quantities. Industrial sources of bacterial pollution are minimal within the watershed and therefore loads were not estimated from this source. Since there are no significant wildlife populations at the Goderich beaches and natural areas account for less than 25 percent of the Watershed area bacteria loads from wildlife have also been excluded (Bos, 1988).

3.1.1 Farm Data Collection

Site specific farm data used to calculate source loads from agricultural practices were gathered during the Maitland Rural Beaches Study. Over the period of study, April 1986 to December 1988, site visits were completed at 431 high priority farms out of approximately 3,100 livestock farms identified in the Maitland River watershed. The 1986 and 1987 MVCA Annual Reports outline the method used to collect data on the high priority farms. The study areas included the majority of sub-basins in the Maitland River watershed with the exception of the North Maitland subwatershed (Figure 1). Farm visits also were completed in two sub-basins which have tributaries draining to the Lakeshore.

During farm visits a questionnaire was completed concerning manure and waste management practices, cropping and tillage practices, tile drainage, household waste disposal and to define general attitudes of farmers towards rural water quality. An attempt was made to rank the bacterial sources of pollution on these farms as either having a high or low potential to pollute a watercourse. The low potential sources were not included in the load calculations. Information on the actual livestock numbers and types as well as the management practices found on individual farms were used to calculate the fecal coliform loads from the high ranked sources. Four practices with the potential to pollute were routinely identified on these farms: runoff from barnyards and manure stacks, inadequate milkhouse waste water disposal, unrestricted cattle access to watercourses and winter spreading of manure.

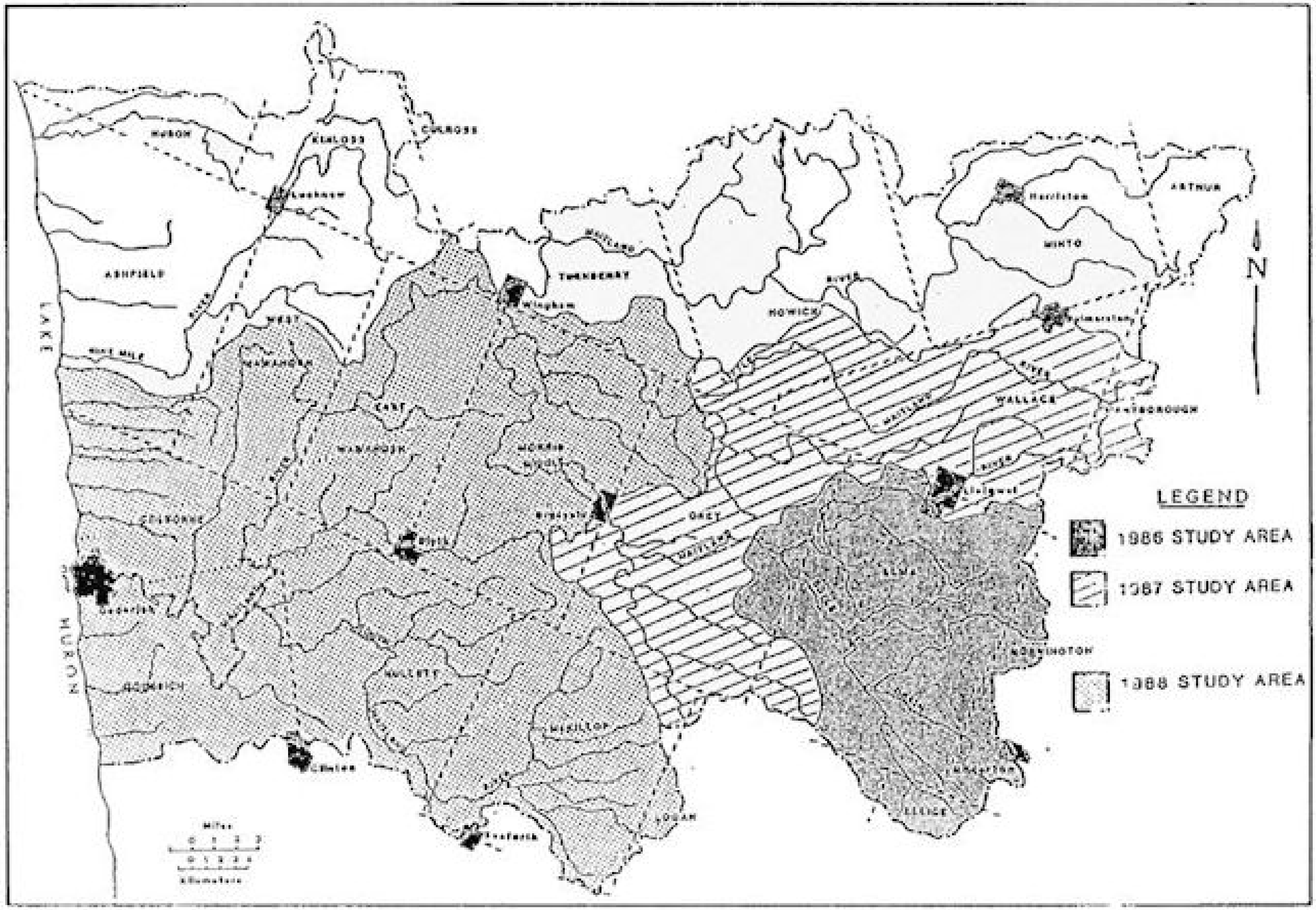

Figure 1: Watershed Study Areas

From the farm visits completed, it was found that 621 of the dairy operations surveyed had improper milkhouse waste water disposal and 16% of all operations surveyed practiced winter spreading of manure. These percentages were applied to the total number of dairy operations and to all livestock operations, respectively, when calculating the loads for these sources on a sub-basin basis.

A watershed inventory, based on visual assessment of all livestock operations was completed in 1987. Operation type, manure storage facilities, distance to a watercourse, livestock access and farm location were noted in the inventory (MVCA, 1987). The sources on these operations were assigned a pollution potential ranking. This information was then used to determine the sources of pollution in the North Maitland subwatershed. County averages for the number of livestock per farm and information from the questionnaires were used in the algorithms to calculate the fecal coliform loads from sources in this subwatershed.

3.1.2 Algorithm Development

Ecologistics Ltd., under contract to the Ontario Ministry of the Environment, developed a computer model called "Pollution from Livestock Operations Predictor" (PLOP) to estimate the impact of specific agricultural sources on water quality. These sources include: barnyards, solid manure stacks, milkhouse waste water and cattle access to watercourses.

Review of the PLOP model by participants in the Provincial Rural Beaches Strategy led to the refinement and development of additional formulas (Bos, 1988). These formulas were used as the basis for calculating the fecal coliform loads delivered to watercourses from a number of rural and urban sources. Individual factors or components of the algorithms were modified to represent local conditions or estimates of numbers.

3.2 Algorithms Used in Determining the Load Delivered from Sources to Receiving Streams

3.2.1 Milkhouse Waste Algorithm

The milkhouse waste algorithm estimated the total annual fecal coliform load delivered to nearby watercourses as a consequence of mismanagement of milkhouse waste water.

MHW LOAD = Concentration x Volume/Cow/Day x # Cows x 365 x Delivery

1. A concentration of 2000 fecal coliforms (FC) per litre was assumed in waste water entering a milkhouse drain.

2. A volume of 13L of waste water/cow/day was assumed.

3. A 365 day lactation period was assumed.

4. For dairy farms not visited in the watershed, it was assumed that the average number of milking cows per farm was 35 for Perth County, 31 for Huron County, and 33 for Wellington County (1986 Agricultural Statistics for Ontario, Publication 20, 1987).

5. For dairy farms not surveyed, it was assumed that the percentage of total dairy operations in the watershed with improper disposal was 62% (M.V.C.A., 1986 and 1987).

6. A delivery of 50,000% was assumed. This accounts for growth of bacteria in the tile system.

3.2.2 Livestock Access Algorithm

This algorithm estimated the fecal coliform load from livestock having access to a stream. A factor to account for differences in animal type (EAU), a location factor (LF), the probability of an animal defecating in the stream during an access event and an estimate of the average number of access events per day were included in the calculation.

ACCESS LOAD = Concentration/defecation x EAU x Prob. of defecation x
access events/day x LF x # animals x # days

1. A concentration of 8.9E+8 FC/defecation for a 454 kg (1,000 lb) steer was assumed.

2. Equivalent Animal Units (EAU) are given in Appendix A1.

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

4. It was assumed that the number of access events was 2.5 per animal per day (Demal, 1982).

5. A location factor of 1.0 was assumed 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 assumed 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).

3.2.3 Feedlot/Barnyard Runoff Algorithm

The feedlot/barnyard runoff algorithm was used to calculate the total annual fecal coliform load delivered to streams from feedlot/barnyard areas within 150m of a watercourse. The average manure accumulated (AMA) in kilograms on the feedlot was determined for each high priority farm identified in order to estimate an average manure pack (AMP). The volume of runoff was also calculated based on the yard size (ha) and the annual depth of precipitation (mm).

FEEDLOT LOAD = Concentration x AMP x Vol. of Runoff x Delivery

1. A concentration of 7.5E+9 FC/ha-mm for feedlot runoff was assumed (Hocking, per comm., 1988). This is equivalent to 75,000 FC/100ml.

2. The AMP was calculated as follows:

a) The AMA on the feedlot was first calculated:

$$\text{AMA} = \frac{\left(\#\text{Animals} \times \text{EAU} \times \dfrac{1.31\text{kg}}{\text{hr}} \times \dfrac{\text{Feedlot hr}}{\text{Day}} \times 8 \text{ days between scraping}\right)}{2}$$

   i) The EAU are given in Appendix A1.

   ii) An average excretion of 1.31 kg/hr for a 454 kg (1000 lb) steer was assumed (Ecologistics, 1988).

   iii) In a feedlot operation it was assumed that the cattle were out on the open lot for an average of 16 hours per day for half the year and only 3 hours per day for the other half of the year.

   iv) In a dairy operation with an open feed or exercise yard, it was assumed that the cows were on the lot for 1 hour per day year round.

b) The AMA was used to calculate the AMP:

$$\text{AMP} = \frac{(\text{AMA/yard area})}{67{,}180 \text{ kg/ha}}$$

   i) If the yard was scraped at least every 30 days, the maximum pack was 1.

   ii) One manure pack was assumed to be 67,180 kg/ha (Ecologistics, 1988).

3. The volume of runoff was determined as follows:

Area of yard (ha) x 914 mm annual precipitation x 0.60 x Proportion of year feedlot used.

i) It was assumed that the runoff from the yard area was 60% of the annual precipitation of 914mm (Coote and Hore, 1978).

4. A delivery of 80% was assumed if an operation was within 150m of a watercourse and runoff flowed toward the watercourse.

3.2.4 Manure Stack Runoff Algorithm

This algorithm estimated the total annual fecal coliform load originating from solid manure stacks with no runoff containment that were within 150m of a watercourse. For each high priority farm an average stack volume (ASV) in cubic metres was first determined based on survey data. This ASV was then used to determine the average size of yard area (ASA) covered by the manure stack in hectares.

STACK LOAD = Concentration x ASA x Runoff x Delivery

1. A concentration of 7.5E+9 FC/ha-mm for stack runoff was assumed (Hocking, per. comm., 1988). This is equivalent to 75,000 FC/100mL.

2. The ASA in hectares was calculated as follows:

a) The ASV was first calculated:

ASV = (1/1 + #of cleanouts) x [(#animals)(vol.)(#days/year) - (% of day on pasture)(# animals)(vol.)(# days pastured))

i) The volume of manure produced per day (m^3/day) for each animal type are given in Appendix A2.

ii) When dairy cows were pastured, it was assumed that they were on pasture for 75% of the day.

b) The ASA was determined using the ASV:

$$ASA = \frac{[((ASVm^3 - 14.3m^3)/7.36m^2) \text{ X } 5.36m + 18m^2]}{10{,}000m^2}$$

3. It was assumed that runoff from the stack area was 60% of the annual precipitation of 914mm (Coote and Hore, 1978).

4. A delivery of 80% was assumed if a stack was within 150m of a watercourse and runoff flowed toward the watercourse.

3.2.5 Winter Spread Manure Algorithm

This algorithm estimated the total fecal conform load delivered to watercourses from manure spread during the winter season. An estimate of the total number of bacteria which were winter spread was made for all livestock farms. Drain density (DD), critical distance (CD), and decay rate factors were also incorporated into this calculation.

WSM LOAD = # of bacteria winter spread x DD x CD x Delivery x Decay Rates

1. The number of fecal coliform bacteria winter spread was calculated as follows: Vol. of manure/animal/day x Concentration x # animals x # days x % of manure spread x % of operators winter spreading.

   i) The volume of manure produced per day (m^3/day) for each animal type are given in Appendix A2.

   ii) Concentrations in fecal coliforms per gram of fresh feces for the animal types were taken from Young et al., (1988). In the calculations (Appendix A3), these concentrations were changed to fecal coliforms per cubic metre by using a density factor of 1005 kg/m as given by Ecologistics (1988).

   iii) It was assumed that if an operation spreads manure in the winter season that 25% of the manure produced in the year was spread at this time.

   iv) It was assumed that 16% of all livestock operations not participating in a farm visit practised winter spreading of manure (MVCA, 1986 and 1987).

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

3. A critical distance of 150m was assumed.

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

5. It was assumed manure was spread once a month during the winter. Therefore, an average stack time of 15 days was used. A 1.5 order of magnitude die-off of bacteria may occur in the stack in this time.

6. It was assumed that a runoff event occurred once every fourteen days. Therefore the average time lapse between spreading and a runoff event was assumed to be 7 days.

7. A bacteria decay rate of 0.066 was assumed for manure spread in fields (Ecologistics, 1988). With the average time between spreading and a runoff event being 7 days, the field decay factor is 0.63. [i.e. $e^{-(7)(0.066)}$].

3.2.6 Spring, Summer, Fall Manure Spread Algorithm

This algorithm estimated the total fecal conform load delivered to watercourses as a result of over spreading during the spring, summer and fall periods.

Over Spreading Load =

[(# of bacteria produced - # of bacteria winter spread) - Access Load] x % of operators that over spread x Vol. of manure over spread x Delivery x Stack Die-off x Field Die-off.

1. Number of bacteria produced was calculated as follows:

   Volume of manure/animal/day x Concentration x 6 animals x 365

   i) Volume of manure - see 3.2.5. - 1 (i)
   ii) Concentration - see 3.2.5 - 1 (ii)

2. The number of bacteria estimated to be spread during the winter period was subtracted.

3. The number of bacteria delivered to watercourses from cattle access was subtracted.

4. It was assumed that five percent of the operators over spread manure (Hayman, per. comm., 1988).

5. It was assumed that twenty five percent of the manure produced on these farms was over-applied (Hayman, per. comm., 1988).

6. Delivery was calculated as follows:

   i) Drain density x critical distance x % of delivery = (0.0082)

   ii) Drain density - see section 3.2.5 - 2

   iii) Critical distance - see section 3.2.5 - 3

   iv) It was assumed that five percent of the manure spread within the critical area would be transported to a watercourse.

7. An average storage time of 30 days was assumed. A two order of magnitude die-off of bacteria was assumed to occur during this time period (Thelin and Gifford, 1983).

8. Field decay rate - see section 3.2.5 - 7

3.2.7 Septic System Failure Algorithm

The septic system algorithm estimated the total annual fecal coliform load to watercourses as a consequence of faulty household septic systems. In order to calculate this load per sub-basin, the sub-basin populations had to be determined. Township populations and number of households were obtained from the municipal clerks offices. This population and number of households also included the police villages without a sewage treatment plant. It was assumed that the rural population was spread homogeneously throughout the township. The sub-basin populations were then calculated by multiplying the township's rural population by the sub-basin's area in the township over the township's total area. For sub-basins including a police village, the police villages populations were added to the appropriate sub-basin population.

SSF LOAD = Concentration x Volume x Sub-basin Pop. x Failure Rate x Delivery

1. A concentration of 1.0E+7 FC per litre of effluent at the tile outlet was assumed (Hocking, per. comm., 1988).

2. A volume of 275L/day/person was assumed (Paquette, per. comm., 1989).

3. A 30% failure rate of all septic systems was assumed (Bos, 1988).

4. A delivery rate to a watercourse of 50% was assumed.

3.2.8 Urban Non-Point Algorithm

The urban non-point algorithm estimated the total annual fecal coliform load to watercourses from urban runoff and storm sewers. In order to calculate this load per sub-basin, the population densities for the towns and villages had to be determined. The population and areas were obtained from the respective municipal offices. The population densities were all found to be low (<50 people/hectare). Therefore, a value of 3.1E+10 FC/ha was used (Marsalek *et al*, 1985 and Marsalek, 1978). The urban non-point loads were then included in the appropriate sub-basins.

UNP LOAD = Load/ha x Urban Area (ha)

3.2.9 Sewage Treatment Plant Discharges

Information on the operation of sewage treatment facilities for municipalities located in the Maitland River watershed was obtained from the Ministry of the Environment or the municipal plant operators.

The municipalities of Goderich, Brussels, Blyth, and Palmerston had sewage treatment plants (STP's) which discharge effluent continuously throughout the year. Wingham, Listowel, Milverton and Harriston had STP's with lagoons from which effluent is released during various seasonal periods.

For all systems, the volume and time of waste discharge to a watercourse was obtained from operational records. The average concentration of fecal coliform bacteria in the effluent during discharge was also obtained from historical data. No data on the fecal coliform concentration in the effluent released from the Milverton STP was available, therefore, it was assumed to be equal to the concentration in effluent released from the Wingham lagoon.

Annual loads delivered to the receiving watercourse were calculated by multiplying the annual volume discharge by the average concentration.

3.2.10 Manure Spills

The manure spill algorithm estimated the total annual fecal conform load due to manure spills from storage facilities and from improper spreading practices.

Information was obtained from the MOE District Office, Abatement Staff regarding known occurrences in the watershed. Five spills were known to have occurred in the portion of the watershed covered by the Owen Sound District Office (Huron and Bruce Counties) during 1988 (Struthers, per. comm., 1988). The volume of one spill was estimated to have been 2,500 gallons. Three of the five were found to be tile drain contamination, therefore, no volumes were given.

Four spills occurred in the Perth County section of the watershed during 1988 (Walker, per. comm., 1988). Again the volume of waste delivered to the stream was generally not known.

Since the volume of spills was not known, it was assumed that an average spill would deliver 20,000 gallons (90,920 L) to the stream. A concentration of 1.80E+7 fecal conforms per litre representing the fecal coliform concentration of swine manure stored in a liquid manure storage tank was multiplied by the volume to estimate the load from one spill (Hayman, per. comm., 1988).

To calculate the annual load delivered to watershed streams, the spills were centered in two sub-basins. The four which occurred in Perth County were placed in sub-basin 11, while the five in Huron County were assumed to occur in sub-basin 20. A total load was then estimated by multiplying the number of spills by the load from one spill.

4.0 FECAL COLIFORM LOAD DELIVERED TO A STREAM FROM A FICTITIOUS DAIRY FARM

The following example demonstrates the use of the algorithms for calculating fecal coliform loads for a sample dairy farm.

The dairy herd consists of 35 milking cows and 20 heifers/dry cows. Both the cows and heifers/dry cows are pastured for 6 months of the year. The field in which the heifers/dry cows are pastured is diagonally cut by a stream. This stream is their only source of water.

The cows have an exercise yard which is 372 m^2 (4000 ft^2). The yard is scraped weekly. Manure is stacked on a concrete pad and it is usually spread three times per year which includes a winter time spreading.

The milkhouse drain is connected to the field tile. Four people live in the farm house and the septic system is faulty. The farmstead is located about 100m from a watercourse.

The bacteria loading by this farm is calculated below:

1. Milkhouse Waste Load

$$\text{LOAD} = \frac{200\text{ FC}}{100\text{ ml}} \times \frac{1000\text{ ml}}{1\text{L}} \times 13\text{L/cow/day} \times 35\text{ cows} \times \frac{365\text{ days}}{\text{year}} \times \frac{50{,}000}{100}$$

$$= 1.66\text{E+11 FC/year}$$

2. Access Load

$$\text{LOAD} = 8.9\text{E+8} \frac{\text{FC}}{\text{def}} \times 0.71 \times 0.18\text{ def} \times \frac{2.5}{\text{day}} \times 1.6 \times 20\text{ heifers} \times 183\text{ days}$$

$$= 1.66\text{E+12 FC/year}$$

3. Feedlot and Barnyard Runoff Load

$$\text{AMA} = [35\text{ cows} \times 1.62 \text{ X } 1.31\text{kg/hr} \times 1\text{ hr/day} \times 7\text{ days}] / 2$$

$$= 259.97\text{kg}$$

$$\text{AMP} = \frac{(\text{AMA/yard area})}{67{,}180\text{ kg/ha}} = \frac{(259.97\text{kg/.0372ha})}{67{,}180\text{ kg/ha}}$$

$$= 0.104$$

$$\text{Runoff} = 0.0372\text{ ha} \times 914\text{mm} \times 0.60 \times 365\text{ days/365 days} = 20.40\text{ ha-mm}$$

LOAD = $7.5E+9 \frac{FC}{ha\text{-}mm} \times 0.104 \times 20.40\ ha\text{-}mm \times 0.8$

= 1.27E+10 FC/year

4. Stack Runoff Load

For cows

ASV = $(1/1 + 3)\ ((35\ cows \times \frac{0.058132^3}{day/cow} \times 365\ days) - (35\ cows \times$

$\frac{0.0581m^3}{day/cow} \times 0.75 \times 183\ days)]$

= $115.78m^3$

ASA = $\frac{[((115.78m^3 - 14.3m^3)\ /7.36m^2) \times 5.36m + 18m^2]}{10{,}000m^2}$

= 0.00919 ha

LOAD = $7.5E+9 \frac{FC}{ha\text{-}mm} \times 0.00919\ ha \times \frac{914mm}{year} \times 0.60 \times 0.8$

= 3.02E+10 FC/year

For heifers/dry cows

ASV = $(1/1 + 2)\ [(20\ hei. \times \frac{0.0227m^3}{day/\ hei.} \times 365\ days)-(20\ hei. \times \frac{0.0227m^3}{day/hei.} \times$
$1 \times 183\ days))$

= $27.54m^3$

ASA = $\frac{[((27.54m^3 - 14.3m^3)/7.36m^2) \times 5.36m + 18m^2]}{10{,}000m^2}$

= 0.0027 ha

LOAD = $7.5E+9 \frac{FC}{ha\text{-}mm} \times 0.0027ha \times \frac{914mm}{year} \times 0.60 \times 0.8$

= 9.096E+9 FC/year

Total LOAD from Stacks = (3.024E+10) + (9.096E+9)
= 3.93E+10 FC/year

5. Winter Spreading Load

For cows

$$\text{LOAD} = 5.0E{+}11\ \frac{FC}{m^3} \times \frac{0.0581m^3}{\text{day/cow}} \times 35 \text{ cows} \times 365\ \frac{\text{days}}{\text{year}} \times 0.25 \times \frac{1.09\ km}{km^2} \times 0.15km \times 0.1 \times 0.63 \times 0.05$$

$$= 4.78E{+}10 \text{ FC/year}$$

For heifers/dry cows

$$\text{LOAD} = 5.0E{+}11\ \frac{FC}{m^3} \times \frac{0.0227m^3}{\text{day/hei.}} \times 20 \text{ hei.} \times 365\ \frac{\text{days}}{\text{year}} \times 0.25 \times \frac{1.09m}{km^2} \times 0.15km \times 0.1 \times 0.63 \times 0.05$$

$$= 1.07E{+}10 \text{ FC/year}$$

Total LOAD from Winter Spreading = (4.78E+10) + (1.07E+10)
= 5.85E+10 PC/year

6. Spring, Summer, Fall Manure Spreading Load

For cows

$$\# FC = (35 \text{ cows} \times 5.0E{+}11\ \frac{FC}{m^3} \times 0.0581\frac{m^3}{\text{day}} \times 365 \text{ days}) - (4.78E{+}10)$$

$$= 3.755E{+}14 \text{ FC}$$

$$\text{LOAD} = 3.755E{+}14 \text{ FC} \times 0.25 \times 1.09\frac{km}{km^2} \times 0.15km \times 0.05 \times 0.01 \times 0.63$$

$$= 4.835E{+}9 \text{ FC/year}$$

For heifers

$$\# FC = (20 \text{ heifers} \times 5.0E{+}11\ \frac{FC}{m^3} \times 0.0227\frac{m^3}{\text{day}} \times 365 \text{ days})$$

$$= (1.07E{+}10) - (1.66E{+}12) = 8.118E{+}13 \text{ FC}$$

$$\text{LOAD} = 8.118E{+}13 \text{ FC} \times 0.25 \times 1.09\ \frac{km}{km^2} \times 0.15km \times 0.05 \times 0.01 \times 0.63$$

$$= 1.045E{+}9 \text{ FC/year}$$

Total LOAD = 4.835E+9 + 1.045E+9 = 5.88E+9 FC/year

7. Septic System Load

$$\text{LOAD} = 1.0E{+}7\ \frac{FC}{L} \times \frac{275\ L}{\text{person/day}} \times \frac{365\ \text{days}}{\text{year}} \times 4\ \text{persons} \times 0.5$$

$$= 2.01E{+}12\ \text{FC/year}$$

Total Annual Bacteria Loading to Watercourse (Figure 2)

1.66E+11	Milkhouse Waste (MHW)
1.66E+12	Livestock Access (Access)
1.27E+10	Yard Runoff (Yard)
3.93E+10	Manure Stack Runoff (Stacks)
5.85E+10	Winter Spreading (W.SM.)
5.88E+9	Spring-Fall Spreading (S-F.SM)
2.01E+12	Septic System (Septic)
----------	---------------------------
3.45E+12	FC/year

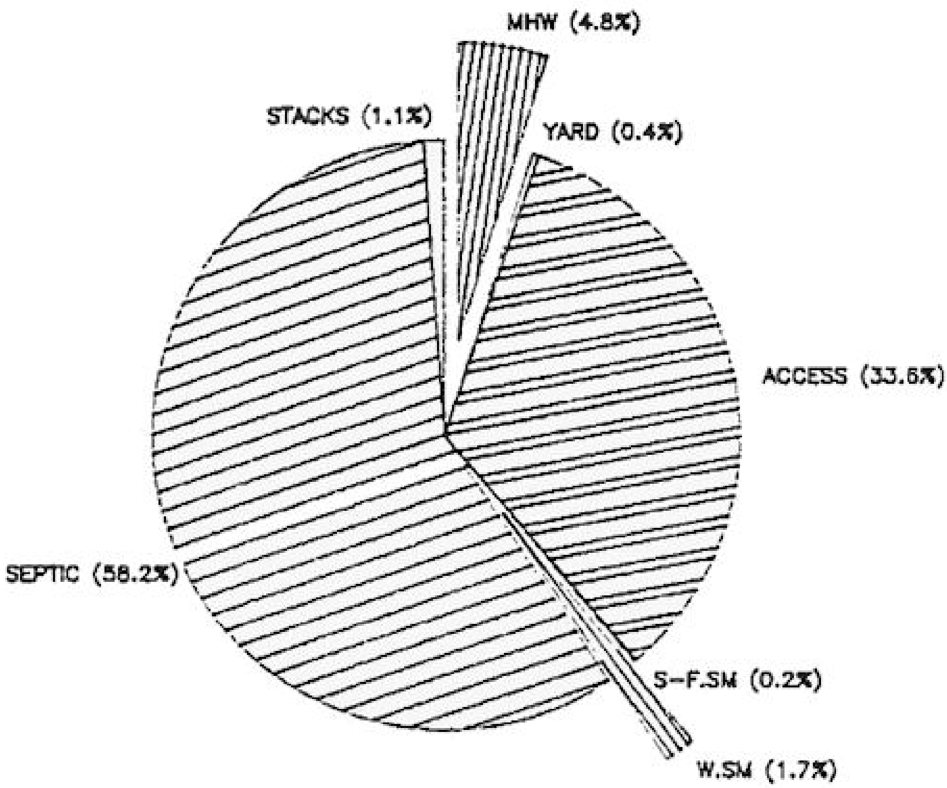

Figure 2: Fecal Coliform Loads Delivered to a Stream from a Sample Dairy Farm

5.0 LOADS DELIVERED FROM WATERSHED SUB-BASINS TO LAKE HURON

5.1 Introduction

The fecal coliform loads calculated for each source type in each sub-basin of the watershed were separated into two categories: continuous discharge loads and event or pulse discharge loads.

Continuous discharge types included the following sources: milkhouse waste water, livestock access, septic systems or household wastes, and effluent discharged from urban sewage treatment plants. Urban sewage treatment systems which discharged effluent from lagoons seasonally during high stream flow conditions also were considered as a continuous source. Event discharge types contributed fecal coliform bacteria during rainfall runoff events. These sources included manure stacks, feedlots and barnyards, manure spread in fields, manure spills, and urban stormwater.

The following decay formula was used to estimate the number of fecal coliform bacteria delivered to Lake Huron at Goderich based on the number of bacteria delivered to watercourses in each sub-basin, bacteria decay rates and stream travel times.

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

Where N = number of bacteria delivered to the area of concern
N_O = initial number of bacteria delivered to watercourses in the sub-basin by source type
k = log decay rate per day
t = time of travel from the sub-basin to the area of concern

5.2 Travel Times

The time for streamflow to travel (travel times) from each sub-basin in the Maitland watershed to the river mouth at Lake Huron was determined in days under different streamflow conditions (Appendix A4).

Event Flows

Event flow travel times for each sub-basin were based on the MVCA stream flow forecasting system. Under this system, the hydrological characteristics of the individual sub-basins were determined and time of travel under runoff event conditions established.

Baseflow Conditions

Water survey data gathered at the Authority streamflow monitoring stations was used to estimate mean streamflow velocities for the various seasons of the year. Travel times were determined based on the velocity and the length of reach for each sub-basin.

For the purposes of the model, travel times for the fall, winter and spring seasons during low flow conditions were found to be equal. A separate travel time was estimated for the summer period to account for the differences which can occur due to weedy and/or extremely low flow conditions.

5.3 Decay Rates

Decay rates for fecal coliform bacteria suspended in the water column were estimated for conditions found in the Maitland River for the four seasons of the year. Decay rates varied with stream conditions including nutrient levels, temperature, turbidity and pH.

Decay rates were chosen by comparing MVCA water quality data to stream conditions under which experiments were completed by the MTRCA, LSRCA, UTRCA, ABCA and MOE in other watersheds. Based on this data, the decay rates used in this model were as follows: winter, 0.20 logs/day; spring and fall, 0.26 logs/day; summer, 0.35 logs/day (Young, per. comm., 1988).

Decay Calculations for Sources which Contributed during Events

The total fecal coliform load for a source which contributed during an event was multiplied by the percent frequency of events by season. The frequency of events was determined by examining hydrographic records for three MVCA gauging stations for the years 1986 through 1988. Increases in stream discharge were assumed to be associated with runoff/rain events (MacPherson, per. comm., 1989). The number of discharge peaks occurring by season were counted and a frequency of events calculated by averaging the number of events which occurred by season for the three stations over the three year period. The frequency of events used for the four seasons were: winter (0.22), spring (0.22), summer (0.21) and fall (0.35). The corresponding decay rate for the season was then used in the equation along with the event based travel time for the appropriate sub-basin. A total fecal coliform load delivered to the beach by source for each sub-basin was then determined by summing the loads delivered by season.

Example: In sub-basin 17 the manure stack runoff load delivered to the stream was 6.49E+10 FC/year and the event travel time was 2.9 days. Therefore using the log decay formula the loads delivered to Lake Huron by season were:

Winter: N = antilog(log 1.43E+10 - 0.20 (2.9)) N = 3.75E+09

Spring: N = antilog(log 1.43E+10 - 0.26 (2.9)) N = 2.51E+09

Summer: N = antilog(log 1.36E+10 - 0.35 (2.9)) N = 1.32E+09

Fall: N = antilog(log 2.27E+10 - 0.26 (2.9)) N = 4.00E+09

The annual load delivered to Lake Huron of 1.16E+10 FC/year equals the sum of the loads delivered by the seasons.

All loads delivered to the beach for sources which discharged during event conditions were calculated in this method with the exception of winter spreading of manure. The fecal coliform load delivered to the beach for winter spread manure was assumed to occur over the winter season only.

Decay Calculations for Sources which Discharged Continuously

Loads delivered to the beach for sources which discharged continuously throughout the year were divided by four to represent the load by season. Livestock access was assumed to contribute during one half of the year -mid spring through mid fall.

The decay rate for the season was used in the equation along with the base flow travel time for that season.

Example: In sub-basin 17 the milkhouse waste load delivered to the stream was 7.35E+11 FC/year. The seasonal load equalled 1.84E+11 (ie: 7.35E+11/4). Therefore using the log decay formula the loads delivered to Lake Huron by season were:

Winter: N = antilog(log 1.84E+11 - 0.20 (4.41))
N = 2.41E+10

Spring: N = antilog(log 1.84E+11 - 0.26 (4.41))
N = 1.31E+10

Summer: N = antilog(log 1.84E+11 - 0.35 (7.11))
N = 5.97E+08

Fall: N = antilog(log 1.84E+11 - 0.35 (4.41))
N = 1.31E+10

The annual load delivered to the Lake Huron of 5.09E+10 FC/year equalled the sum of the loads delivered by the seasons.

6.0 COSTS OF ALTERNATIVE MEASURES

Costs of alternative remedial measures were estimated for the agricultural sources as well as for septic system improvements. Standard unit costs for the construction of remedial measures were developed for each source by farm type. All the high rated sources of fecal coliform bacteria on each farm in each sub-basin were assigned a standard cost.

The total cost of improvements was then estimated by source for each sub-basin. This allowed for relative comparisons of various scenarios.

6.1 Manure Storage

In order to estimate the costs for manure storage improvements a standard number of animals was assigned to each farm type (Table 1). Average farm sizes were determined from 1986 Agricultural Statistics for Ontario, Publication 20, and from the MVCA Beaches Study survey data.

Table 1: Average Farm Sizes Used in Calculating Manure Storage Costs

Farm Type	Average Farm Size
Dairy	34 cows
	20 heifers
Beef-cow calf	20 cows
	7 heifers
Beef-feeders	90
Beef-slaughter	90
Swine-farrowing	50 sows + gilts
	150 weaners to 12 weeks of age
Swine-finishing	300
Poultry-broilers	50,000 birds per crop
Poultry-layers	8,000 hens

Manure storage size requirements for these average farms were based on the Manure Storage Proposal Field Sheet (Appendix A5). All solid manure storage sizes were based on storage of 200 days manure production, while the liquid containment facilities were sized for 240 days. The majority of townships in the watershed have adopted bylaws which require liquid manure systems to contain a minimum of 240 days production.

The sizes and costs of solid manure storages with stack runoff containment were estimated for all farm types with the exception of a laying hen operation. Costs of storage construction for these operations were estimated for a total liquid manure system. For each farm type a storage size and cost was calculated for a system combining solid manure storage with three options for runoff containment:

1. open concrete tank
2. covered concrete tank
3. earthen storage

The following assumptions were made in calculating the size of runoff containment systems:

1. no runoff enters the storage from roofed areas
2. no additional areas contribute runoff to the storage, i.e. barnyards, exercise areas, feedlots, etc.
3. no milkhouse waste water is added to the storage for dairy operations.

Figures used in estimating costs of construction of the storages were selected from a presentation given by R. Fleming, 1988 and are shown Table 2.

Table 2: Values Used to Determine Manure Storage Costs

Liquid systems		
Open concrete tank	$21.89/m^3	$ 0.62/ft^3
Covered concrete tank	$55.09/m^3	$1.56/ft^3
Earthen storage	$2.12/m^3	$ 0.06/ft^3
Chain link safety fence for open concrete tanks	$42.65/m	$13.00/ft
Hog panelling for safety fence around earthen storages	$26.25/m	$ 8.00/ft
Solid systems		
Concrete pad	$21.53/m^2	$2.00/ft^2
4' high concrete wall	$82.02/m	$25.00/ft

Solid manure storages were sized for a 1.82 metre (6 ft) stack having a 1.22 metre (4 ft) concrete wall on 3 sides of the stack area. A 2.43 metre (8 ft) depth was used to determine the size and cost of the liquid containment systems.

The cost of these systems does not include items which may be required such as: permits, permeability testing, manure transfer piping or pumping systems and work required to divert clean surface water from the storage, i.e. diversion berms, eavestroughing, etc.

Costs of the various remedial options by farm type are shown in Table 3.

All farms rated as high contributors from a manure stack during an on-farm site visit were assigned a cost for manure storage improvement. In the North Maitland River basin (sub-basins 1-5), those farm operations identified as having a high runoff pollution potential from a manure stack during the roadside survey were given a cost for storage improvements.

Table 3: Costs for Manure Storage Systems for Livestock Operations (dollars)

SYSTEM	OPEN CONCRETE TANK			COVERED CONCRETE TANK			EARTHEN LAGOON		
Operation	Solids	Liquids	Total	Solids	Liquids	Total	Solids	Liquids	Total
Dairy	11,700.	6,520.	17,420.	11,700.	9,270.	20,170.	11,700.	3,160.	14,060.
Beef Cow	4,490.	2,570.	7,060.	4,490.	3,540.	8,030.	4,490.	2,400.	6,890.
Beef Feeder	7,000.	3,690.	10,690.	7,000.	5,180.	12,180.	7,000.	2,670.	9,670.
Beef Slaughter	8,800.	4,730.	13,530.	8,800.	6,620.	15,420.	8,800.	2,850.	11,650.
Swine-Farrowing	5,680.	3,000.	8,680.	5,680.	3,930.	9,610.	5,680.	2,500.	8,180.
Swine-Finishing	8,750.	5,000.	13,750.	8,750.	7,140.	15,890.	8,750.	2,900.	11,650.
Poultry-Laying Hen	0.	16,980.	16,980.	0.	27,520.	27,520.	0.	4,730.	4,730.
Poultry-Broilers	11,020.	6,520.	17,540.	11,020.	9,415.	20,440.	11,020.	3,156.	14,180.

6.2 Feedlot and Barnyard Runoff

A standard area of 372 m^2 (4000 ft^2) was assumed to calculate the cost of constructing a storage to contain feedlot runoff. This area would generate a runoff volume of 204 m^3 (7200 ft^3) over a 240 day period. This standard size was applied to both beef and dairy operations identified as high contributors.

Average costs of storage construction used were:

1.	open concrete tank	$ 7510.00
2.	covered concrete tank	$11330.00
3.	earthen storage	$ 3354.00

Note: If both manure stack runoff and feedlot runoff were combined in a single system, the cost of construction could be less, since the cast of fencing would be reduced due to economies of scale.

6.3 Milkhouse Waste Water Disposal

The costs of four types of milkhouse waste water disposal systems were considered. These included a sediment tank treatment trench system, storage in a open concrete tank, covered concrete tank or earthen lagoon. In addition, it was assumed that a further 62% of the remaining dairies in each sub-basin also would contribute milkhouse wastes to the river system and, therefore, would require an alternative disposal system.

Sediment Tank Treatment Trench System

A standard unit cost of $3000 per system was applied to all farms identified as having inadequate milkhouse waste water disposal.

Storage of Milkhouse Waste Water

To determine the average volume of waste water requiring storage, a standard herd size of 34 cows producing 13 L of waste water per cow per day was used. Over a 240 day period a total volume of 106 m (3740 ft^3) would require storage.

The costs used in the model for milkhouse waste storage were:

1.	open concrete tank	$4200.00
2.	covered concrete tank	$6120.00
3.	earthen storage	$2730.00

The costs used were for the construction of the storage system only and do not include the costs of any transfer or pumping systems which may be required.

6.4 Livestock Access

For each livestock access site in the portion of the watershed where farm surveys were completed, the length of streambank requiring fencing was multiplied by a value of $6.50 per metre ($2.00/ft).

A value of $5,000 per site was added to those farms where a stream crossing was required. For all sites a value of $1,000 was used to estimate the cost of providing an alternate watering system.

In the North Maitland River basin, the length of streambank requiring fencing per site was assumed to be 762 metres. It was assumed that all access sites in this basin would require a stream crossing and an alternate watering system.

6.5 Winter Manure Spreading

There are a number of reasons why winter manure spreading may be practiced. These include convenience, timing, a concern for soil compaction or insufficient storage space. A capital cost of zero could be assumed if farmers were encouraged to utilize existing storage areas more efficiently and not winter spread. A greater capital cost would be incurred if a certain percentage of operations required construction of additional storage.

6.6 Septic Systems

The number of households requiring septic system improvements in each sub-basin was multiplied by a standard unit cost of $3,000 per system.

6.7 Annual Operating Coats

A comparison of the alternatives considered for manure storage, feedlot runoff containment and milkhouse waste disposal by total capital cost, annual amortized cost, annual operating cost and total annual cost is given in Table 4.

An average lifespan of five years was assumed for milkhouse waste treatment trench systems. All manure storage alternatives were assumed to have a lifespan of 20 years. The lifespan of a stream bank fencing project was assumed to be five years. To calculate the annual amortized cost of construction for each option, the total capital cost was divided by the economic lifespan.

Annual operating costs for the milkhouse waste treatment trench system are approximately equal to the cost of emptying the sediment tank twice annually. The annual operating cost for all manure stack, feedlot and milkhouse waste storage systems was based on the cost of emptying and spreading the liquid portion by a custom operator. A value of $0.21 per m^3 ($0.06 /ft) was used to calculate the cost of spreading the total annual volume of liquids (R. Fleming, 1988).

No costs were calculated for spreading the solid manure as the volume was assumed to be equal for each farm type. The total annual cost represents the sum of the amortized cost per year (for construction) and the annual operating cost.

Table 4: Annual Costs for Alternative Remedial Measures by Farm Type

Remedial Measure	Econ. Life Span	Capital Cost	Capital Cost per Head	Amort. Cost ($/year)	Annual [1] Operating Cost	Total Annual Cost
Manure Storage [2]						
		- - - - - - - - - - - - - dollars - - - - - - - - - - - - -				
Dairy						
open concrete tank	20	17,420	512	871	708	1,579
covered concrete tank	20	20,170	593	1,009	541	1,550
earthen storage	20	14,060	414	703	906	1,609
Cow-calf						
open concrete tank	20	7,060	353	353	252	605
covered concrete tank	20	8,030	402	402	197	599
earthen storage	20	6,890	345	345	384	729
Beef-feeder						
open concrete tank	20	10,690	119	535	383	918
covered concrete tank	20	12,180	135	609	295	904
earthen storage	20	9,670	107	484	555	1,039
Beef-slaughter						
open concrete tank	20	13,530	150	677	510	1,187
covered concrete tank	20	15,420	171	771	394	1,165
earthen storage	20	11,650	129	583	678	1,261
Swine-farrowing						
open concrete tank	20	8,680	174	434	298	732
covered concrete tank	20	9,610	192	481	230	711
earthen storage	20	8,180	164	409	448	857
Swine-finishing						
open concrete tank	20	13,750	46	688	534	1,222
covered concrete tank	20	15,890	53	795	410	1,205
earthen storage	20	11,650	39	583	720	1,303

Remedial Measure	Econ. Life Span	Capital Cost	Capital Cost per Head	Amort. Cost ($/year)	Annual Operating Cost	Total Annual Cost
Poultry-laying hens		- - - - - - - - - - - -	- dollars -	- - - - - - - - - - - -		
open concrete tank	20	16980	2.12	849	2055	2904
covered concrete tank	20	27520	3.44	1376	1576	2952
earthen storage	20	4730	0.60	237	2270	2507
Poultry-broilers						
open concrete tank	20	17540	0.35	877	714	1591
covered concrete tank	20	20440	0.40	1022	547	1569
earthen storage	20	14180	0.28	709	906	1615
Feedlot Runoff Containment (all farm types)						
open concrete tank	20	7510	---	376	853	1229
covered concrete tank	20	11330	---	567	657	1224
earthen storage	20	3350	---	168	1061	1229
Milkhouse Waste Disposal						
treatment trench	5	3000	88	600	150 (3)	750
open concrete tank	20	4200	124	210	442	652
covered concrete tank	20	6120	180	306	341	647
earthen storage	20	2730	80	137	594	731

(1) Annual Operating Cost - based on annual cost of spreading liquids only.

(2) For all farm types with the exception of laying hen operations, comparisons are based on the costs of a solid manure storage with one of three stack runoff containment options. Costs for laying hen operations are based on a total liquid manure system.

(3) Based on estimated cost of emptying twice annually.

7.0 MODEL PREDICTIONS

7.1 Annual Fecal Coliform Loads Delivered to Streams

The annual fecal coliform loads delivered to receiving watercourses from each high ranked source were summed to determine an annual load delivered to watercourses in each sub-basin (Appendix 81).

Septic system failure, livestock access and winter spread manure accounted for 96 percent of the total fecal coliform load delivered to watercourses in the Maitland River watershed and 94 percent in the lakeshore sub-basins (Figure 3).

In total, septic systems (68%) and agricultural sources (30%) accounted for 98 percent of the total load. Urban sources only contributed approximately two percent of the annual load delivered to watercourses. Eighty-eight percent of the total annual load delivered to streams can be attributed to continuous discharge sources. Contamination of watercourses by runoff from winter manure spread fields comprised the majority of the total annual event source load.

7.2 Annual Fecal Coliform Loads Delivered to Lake Huron

The annual fecal coliform loads delivered to Lake Huron are given by sub-basin and source in Appendix 82.

Septic system failure (62%), winter spread manure (26%) and livestock access (6%) accounted for the majority of the fecal coliform load delivered from the Maitland River watershed to Lake Huron (Figure 4). These same sources contributed 94% of the load delivered to Lake Huron from the lakeshore sub-basins. Urban non-point source discharges (6%) from the Town of Goderich also appeared to be a significant factor in the lakeshore sub-basins.

For the entire study area, septic systems failure (65%) and agricultural sources (31%) resulted in the majority of the fecal coliform load delivered to Lake Huron. Urban sources contributed the remaining three percent.

Approximately seventy-five percent of the total load delivered to Lake Huron can be attributed to continuous discharge sources. This was less than the 88 percent of the total annual load delivered to watershed streams from the same sources. This difference was due to the decay formula used to calculate bacteria delivery to Lake Huron. Travel times were greater during baseflow conditions under which continuous discharge sources contributed bacteria, therefore, a larger number of bacteria perished. The decay rate also affected the rate of bacteria die-off. Winter spreading of manure used the lowest decay rate as all loading occurred during the winter season. Inversely, the decay rates used for livestock access were the greatest as delivery was calculated for the spring through fall period.

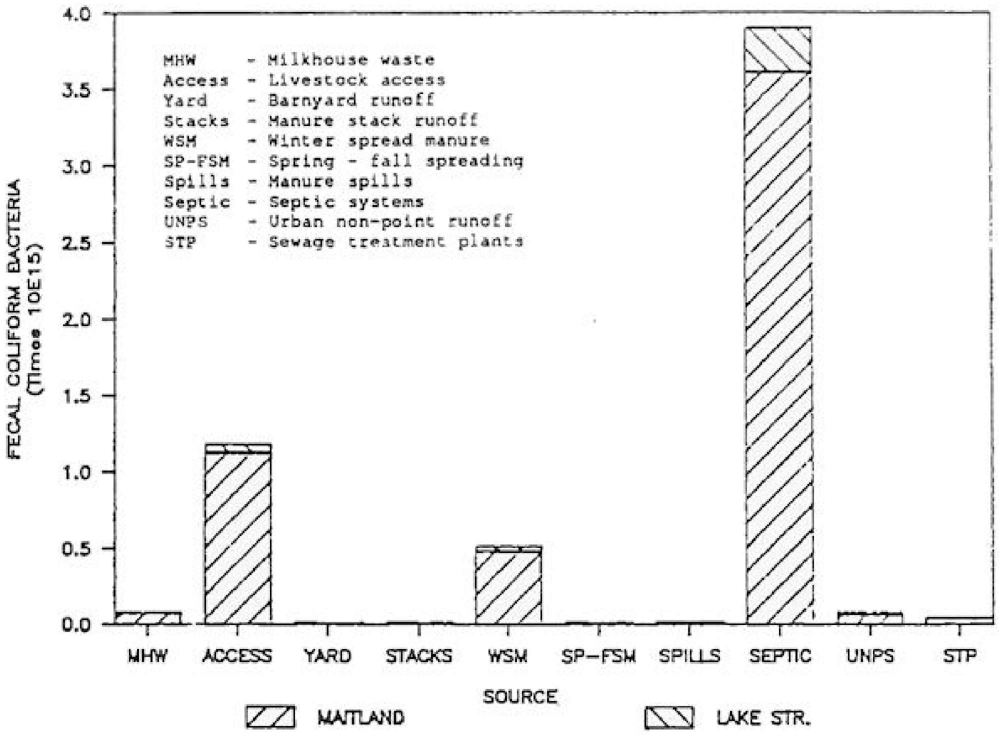

Figure 3: Annual Loads Delivered to Watershed Streams from the Maitland River Watershed and Lakeshore Sub-basins

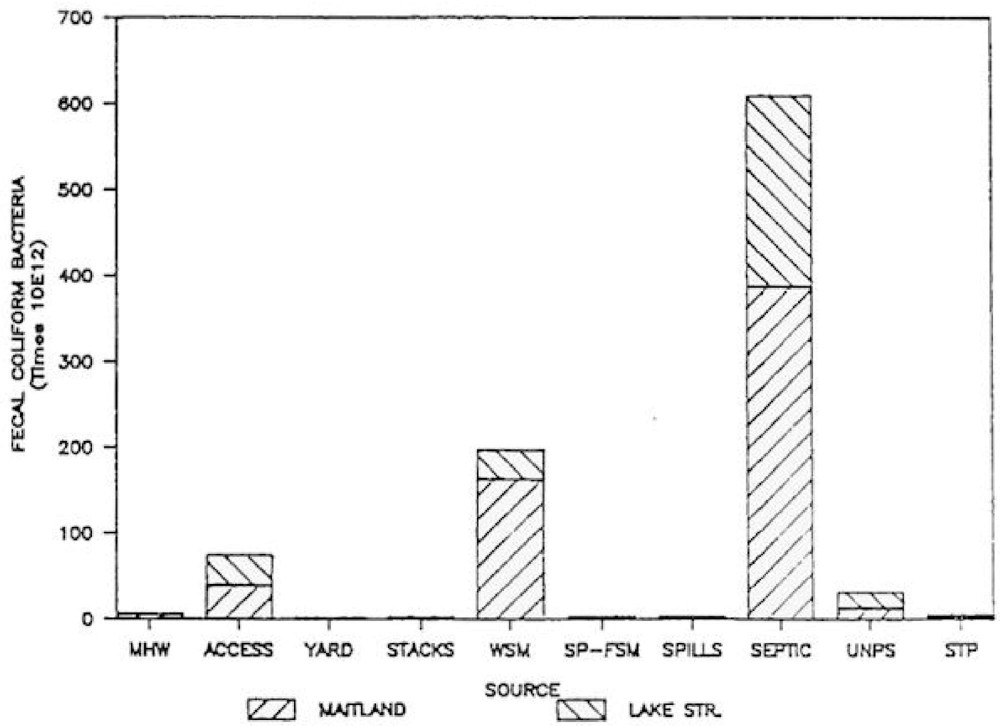

Figure 4: Annual Loads Delivered to Lake Huron from the Maitland River Watershed and Lakeshore Sub-basins

7.3 Annual Fecal Conform Loads Delivered to Lake Huron by Major Basin

In order to facilitate the interpretation of model predictions and the preparation of strategies, the thirty-one sub-basins of the Maitland River watershed were grouped into major basins (Figure 5). The annual load delivered by source from the five major basins of the Maitland River and the two lakeshore stream sub-basins are summarized in Appendix B3.

The total annual load delivered to Lake Huron from each of the major basins varied by nearly an order of magnitude. Loads ranged from a value of 4.23E+13 to 3.43E+14 fecal coliforms per year. The Main Maitland River basin contributed the greatest total annual load (36.6%) to the Lake (Figure 6). This basin ranked number one in load delivered from milkhouse waste, manure stack runoff, winter spread manure, spring/summer/fall spreading, septic system failure, and sewage treatment plants and it ranked second for livestock access, feedlot runoff and urban non-point contamination. The Lakeshore sub-basins (33.3%) contributed the next largest annual fecal coliform load.

The Main Maitland River basin and the two lakeshore sub-basins contributed approximately 70 percent of the estimated annual load while accounting for 29 percent of the land area. This was due to the fact that travel times to the Lake for these two basins were less, consequently the die-off of bacteria was less. Although the Middle Maitland River basin comprises approximately 25 percent of the land area it contributed only 6.5% of the total load.

This data would indicate that targeting remedial strategies towards those sub-basins in close proximity to Lake Huron would reduce fecal coliform loads most effectively.

7.4 Summary of Remedial Costs

7.4.1 Capital Costs of Construction

An estimate of the capital costs for construction of the proposed remedial measure for the agricultural sources and septic system improvements are summarized by sub-basin and major basin in Appendices B4 and B5.

For the entire watershed, the construction costs of the four remedial measures considered for milkhouse waste water disposal ranged from 1.37 million dollars for storage in an earthen system to 3.07 million dollars for a covered concrete storage (Table 5). Three alternatives were considered for runoff containment from feedlots: earthen storages, open concrete tanks and covered concrete tanks. Costs of these systems ranged from 0.18 to 0.611 million dollars for earthen and covered concrete storages respectively. Construction of solid manure storages with similar runoff containment facilities to feedlots would cost between 2.51 and 3.46 million dollars.

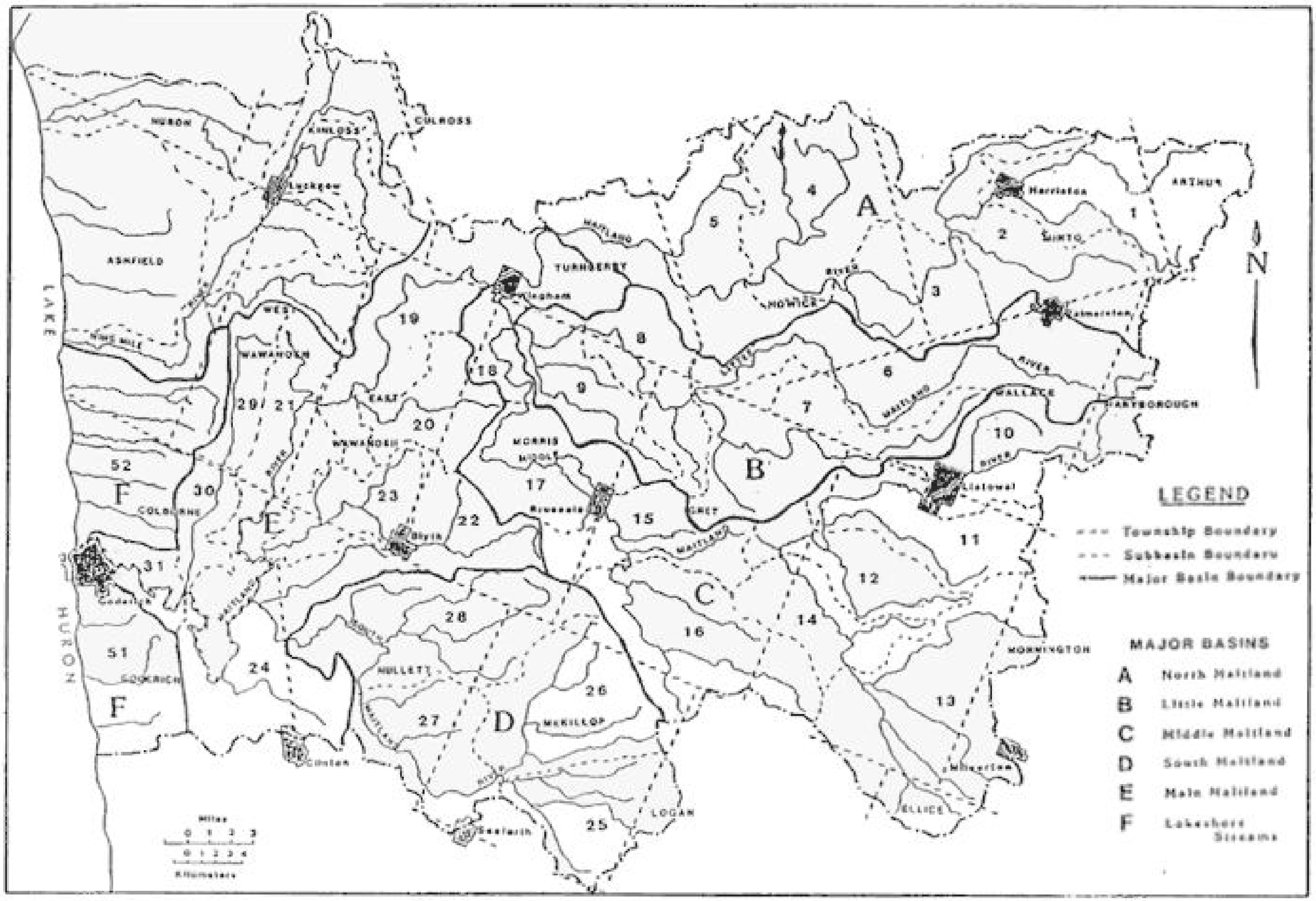

Figure 5: Major Watershed Basins

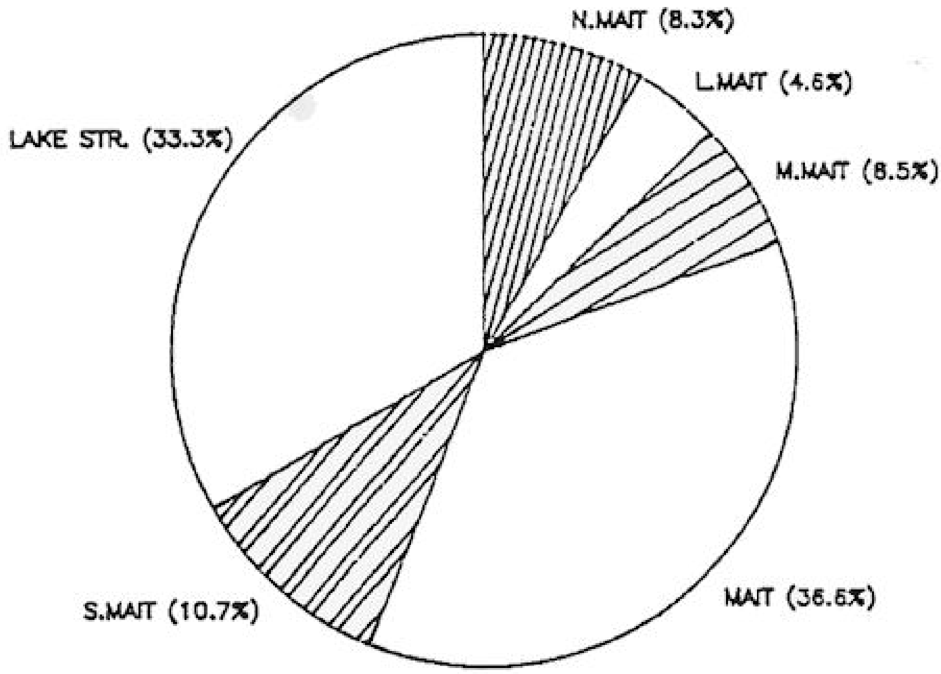

Figure 6: Percent Load Delivered to Lake Huron from Major Watershed Basins

Table 5: Summary of Remedial Costs

Source	No. Sites Contributing	Capital Costs
Milkhouse Waste Water	501 Farms	$1,368,000.- $3,069,000.
Livestock Access	272 Sites	$2,834,000.
Feedlots	84 Farms	$180,000. - $611,000.
Manure Stacks	443 Farms	$2,510,000.-$3,460,000.
Winter Spreading	495 Farms	*
Spring, Summer, Fall Spreading	155 Farms	*
Septic Systems	2,772 Households	$8,316,000.
Urban Non-Point Sources	10 Towns	*
Urban Sewage Treatment Plants	8 Towns	*

* No capital cost calculated.

Approximately 2.83 million dollars would be required to restrict livestock from watercourses at the 272 sites identified throughout the study area. Replacement of the 2,772 septic systems deemed to be faulty would cost 8.32 million dollars.

From the farm surveys the lack of manure storage space did not appear to be the dominant reason for winter spreading as two-thirds of those farmers indicated that they had a minimum of four months of manure storage (MVCA, 1986 and 1987). Therefore, no capital costs would be required to address winter spreading of manure if a change in management occurred such that farmers would no longer winter spread. In this case, farmers would utilize existing storage area. Winter spreading has been estimated to occur on approximately 495 farms.

No capital costs were associated with manure spills as it was assumed that in all cases accidents or improper handling resulted in the incident. Capital costs for improvements to urban sewage treatment facilities or to address urban non-point source contamination were not provided as they were beyond the scope of this study.

7.4.2 Annual Operating Costs

The construction of solid manure systems with earthen runoff containment storages proved to be the most inexpensive alternative for all farm types when the capital costs of construction were considered alone. Systems with covered concrete tanks were the most expensive. This order also held for the capital costs of feedlot runoff containment storages.

The order was reversed, however, when an estimated annual operating cost was added to the annual amortized cost to provide a total annual cost of the system to the farmer. Covered concrete tanks became the least expensive to operate for all farm types, with the exception of laying hen operations, when the total annual costs are considered over a twenty year period.

Of the four alternatives proposed for milkhouse waste disposal, earthen storages were also the most inexpensive followed closely by the sediment tank treatment trench systems. Covered concrete tanks were the most expensive alternative. Treatment trench systems (based on a five year life span) became the most expensive systems and covered concrete tanks the least expensive when the total annual costs were calculated.

As selection of an alternative for use by a farm operator may vary depending on the initial capital cost or the total annual cost, no single alternative can be chosen as superior.

7.5 Cost Effectiveness

A cost effectiveness ratio was calculated in order to evaluate the relationship between the capital costs of implementing various alternatives and the associated fecal coliform load reductions to Lake Huron. This ratio was prepared by dividing the number of fecal conform bacteria delivered to Lake Huron from each source by the cost of the proposed remedial measure. Comparisons of cost-effectiveness are given by the number of fecal coliform bacteria reduced at the Lake for each dollar spent (Appendix B6).

In all major basins earthen storages were shown to he the most cost effective alternative for milkhouse waste water disposal, while covered concrete tanks were the least (Figure 7). In the cases of runoff containment from feedlots and improvements to manure storages, earthen storages, open concrete tanks and covered concrete tanks were ranked as greatest to least cost effective, respectively.

Using the assumption that no capital costs are required to reduce winter spreading of manure, this option would be the most cost effective in terms of bacteria load reduced per dollar spent on structural improvements. Improvements to septic systems and restricting livestock access are shown to be the most cost effective alternatives in the major basins and for the entire study area. In terms of capital costs for improvements to septic systems a load reduction of 7.33E+7 fecal coliforms per year would be achieved per dollar spent. This results in an average reduction of 2.20E+11 fecal coliforms per new system. An average reduction of 2.65E+7 bacteria was determined per dollar spent on controlling livestock access to watercourses.

Remedial alternatives were most cost-effective when implemented in sub-watersheds in close proximity to Lake Huron. The lakeshore and Main Maitland River basins had the greatest ratios of bacteria reduced per dollar spent for all remedial measures.

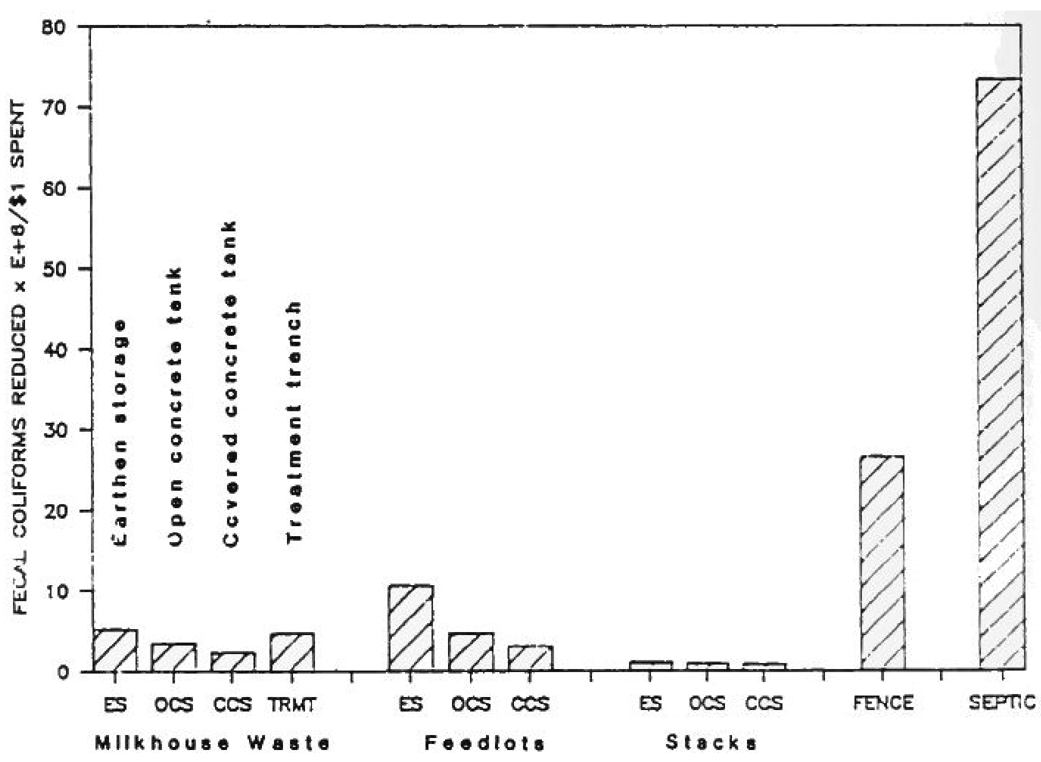

Figure 7: Cost Effectiveness of Remedial Measures for Selected Sources

8.0 IMPLEMENTATION PLAN

8.1 Introduction

8.1.1 Target Load Reduction at Lake Huron

During the MOE's 1984 investigation of factors affecting bacterial pollution along the Lake Huron shoreline, three sample stations were established at Goderich beaches. Water samples were collected daily between June 13 and August 14 and analyzed for various bacterial parameters. The geometric mean concentration in the 71 samples collected at station #G01 (Main Beach) was 110 fecal coliforms per 100 mL. Densities ranged between a minimum of 4 and a maximum of 61,500 per 100 mL. No beach sample data was available for the summer of 1983 during which the beaches were posted for an extended period of time. Densities of 600 and 6,500 fecal coliforms per 100 mL were recorded at the Main and South Beaches, respectively when they were posted for a short period during August 1987 (Harrison, per. comm., 1987).

A mean density of 75 fecal coliforms per 100 mL was selected as target concentration at the Goderich beach. This represents a reduction of approximately 32 percent (35 FC/100 mL) at station #G01 based on 1984 data.

To calculate a target load reduction it was assumed that a 32 percent reduction in the concentration at the beach would require a corresponding 32 percent reduction in load delivered from contributing watersheds. Based on the model predictions 6.26E+14 fecal coliforms per year are delivered to Lake Huron from the Maitland River watershed and 3.13E+14 from the two lakeshore sub-basins. A 32 percent load reduction would be equivalent to a decrease of 1.72E+14 and 1.00E+14 fecal coliforms per year delivered from the Maitland River watershed and lakeshore sub-basins respectively.

8.1.2 Target Sources

Septic system failure (3.88E+14), winter spreading of manure (1.64E+14), and livestock access to streams (4.01E+13) were estimated to contribute the majority (94%) of the fecal coliform load delivered to Lake Huron from the Maitland River watershed. These same sources showed the greatest load reduction per dollar spent on capital improvements or corrective measures. Therefore, faulty septic systems, winter spreading of manure, and livestock access should be recognized as priority sources.

In order to achieve the target load reduction of 1.72E+14 FC/year from the Maitland watershed and 1.00E+14 FC/year from the lakeshore sub-basins a number of implementation options could be considered. For the Maitland River watershed the target load reduction could be achieved by correcting approximately 44%. of the faulty septic systems across the entire watershed or by improving 75% of the systems found in the Main River basin (Appendix B7).

Another possibility would be to reduce the combined load from winter spreading and livestock access for the entire watershed to zero. A third option would be to concentrate on all three sources to reduce their combined load by the target. However, it is apparent that the most cost effective method (in terms of reducing bacteria densities at the beach) would be to implement alternative measures in those basins closest to Lake Huron first, and progress upstream until the target load reduction is achieved.

The other sources identified and modelled appeared to be of less significance in terms of their impact on fecal coliform densities at Goderich beaches. Attention to these secondary sources would not provide the necessary reductions in fecal conform bacteria delivered to Lake Huron beaches. However, they should be recognized as contributors of pollutants which are of concern to other issues of surface water quality degradation.

Farm operators first should be encouraged to reduce loading from high priority sources. Incentive programs could be designed to fund high ranked or more cost effective sources before grants are made available for lower ranked projects (e.g. manure storages).

8.2 Implementation Coals and Objectives

The MVCA Rural Beaches CURB Plan was developed to address the bacterial impairment of surface water resources of the Maitland watershed through an implementation program.

The intent of this plan is to encourage alternative waste management practices which will enhance, restore and sustain surface water resources throughout the watershed. Ontario Ministry of the Environment surface water quality objectives and guidelines can be used to define desired levels of protection. The long term goal of the MVCA Rural Beaches Study is to prevent the posting of public beaches at Goderich due to bacterial pollution originating from sources within the Maitland watershed. A reduction in the fecal coliform load delivered to Lake Huron of 2.72E+14 bacteria per year has been established as a target goal.

In working towards this goal the principle objectives are:

1. to inform watershed residents of the impacts of improper domestic sewage disposal on bacterial pollution of watercourses and to encourage proper private sewage disposal;

2. to further investigate the significance of bacterial pollution of watercourses from private sewage disposal systems;

3. to promote an awareness of the impacts of agricultural sources of pollution on water quality;

4. to encourage alternative manure and waste management practices and in particular:

   i) to encourage farm operators to restrict livestock from watercourses;

   ii) to encourage farm operators to discontinue the practice of winter spreading of manure;

   iii) to encourage the proper disposal of milkhouse waste water;

   iv) to encourage alternative storage of manure and feedlot or barnyard runoff.

5. to monitor the changes in farm waste management practices and private sewage disposal which occur and document related trends to water quality.

In order to achieve this goal, the cooperation of numerous individuals, organizations and government agencies that share a common interest in environmental resources management will be required. The MOE should be recognized as the lead agency as it has the mandate to protect the Provinces' water resources. The Ontario Ministry of Agriculture and Food (OMAF) will have a key role to play in implementing change as a number of bacterial sources are related to agricultural production. Public Health Units and Conservation Authorities can be utilized to deliver program components on a local basis.

Strategies designed to address priority and secondary sources of bacterial pollution are discussed under four components: Information and Education; Policy and Planning; Data Collection and Monitoring; and Extension. The activities which would be undertaken by the MVCA through the Rural Beaches Program over a five year period, beginning in 1990, also are proposed in each section.

The strategies contained in this plan are focused on promoting improvements to waste management practices within two target audiences, watershed residents with private sewage disposal systems and livestock farmers.

8.3 Five Year Strategy

8.3.1 Priority Sources

8.3.1.1 Septic System Failure

Domestic household waste including all human body waste and wastes from showers, tubs, sinks, laundry facilities and dishwashers (collectively called grey water) should be disposed through a proper sewage treatment system. Where a community sewage treatment facility is not available, septic tank systems are commonly used for disposal.

Septic systems which are poorly designed, located or constructed or which are not adequately maintained may cause serious environmental problems (MOE, 1982). Disposal of grey water through non—approved treatment systems also causes contamination. Septic system failure has been estimated to contribute approximately 62 percent of the total fecal coliform load delivered to Lake Huron from the Maitland watershed. Approximately 38 percent of the landowners surveyed through the Maitland Rural Beaches Study had a disposal system which was not approved by the Health Units. Ten percent of the landowners had their system cleaned out at a ten year or greater interval, while nine percent indicated that they never provided maintenance. Only 47 percent provided maintenance during the recommended five year interval.

The Ontario Ministry of the Environment is responsible for legislation which requires approvals for the construction, enlargement or alteration of private sewage disposal systems (Environmental Protection Act, 1980). Authority for the issuance of approvals has been delegated to Public Health Units. Septic tank systems installed through this procedure should not contaminate surface water resources when adequately maintained. However, all residents should be encouraged to ensure that all household waste is disposed through a properly functioning and adequately maintained septic system.

i) <u>Information and Education</u>

Over 8,200 households with private sewage disposal systems are located in the Maitland River watershed. Identification of problem systems would be difficult based on the current level of information and data available. Therefore, a general educational program should be employed to develop an awareness of the problem in the public. The potential health risks and environmental impacts caused by inadequate disposal of household sewage should be emphasized and landowners encouraged to ensure that they have a system which is functioning properly.

The Maitland Valley Conservation Authority would undertake activities to promote proper private sewage disposal among watershed residents. Such activities would include information days, presentations to interested groups, media releases and the production of information factsheets for local distribution. Areas or groups of residents such as the cottagers along the Lake Huron shoreline should be targeted for specific activities.

Cooperative working relationships should be established with the County Health Units in order to provide a coordinated effort to implement information and education activities.

ii) Policy and Planning

Consideration should be given to either increasing activity to enforce environmental legislation or to the use of financial incentives for property owners to improve private waste disposal systems. The Environmental Protection Act can be used to cause improvements to septic tank systems which are identified as contaminating surface water resources. County Health Units should increase efforts to investigate contamination from faulty septic systems and to enforce legislation to require improvements to inadequate situations.

The MOE, Health Units and Conservation Authorities should coordinate efforts to provide information to municipalities on the potential for contamination from household waste disposal and encourage discussion regarding the adoption of development controls to prevent further deterioration of water resources.

iii) Data Collection and Monitoring

Although septic system failure was identified as the largest contributor of fecal coliform bacteria, little empirical data exists as to the actual extent of the problem in the Maitland watershed. A method should be developed and implemented to determine the frequency of conditions which cause malfunction and contamination.

The impact of development along the Lake Huron shoreline on water quality, also should be investigated because of the potential for direct delivery of waste to Lake Huron. Approximately 1,400 cottages are located along the 48 kilometres of MVCA shoreline.

Changes in the use and maintenance of septic systems should be monitored to determine the effectiveness of these strategies. Consideration should be given to the development of a records system on private sewage disposal systems. Information such as age, size, location, and a maintenance schedule could be kept. Licenced disposal operations could provide the data on maintenance. These records could be maintained by the Health Units and information made available to both public and private sectors.

iv) Extension

Technical assistance and approvals for septic systems should continue to be provided to Watershed residents through the local Health Units.

8.3.1.2 Livestock Access

Livestock access to watercourses contributes to impaired water quality. Sediments are delivered to watercourses from streambanks left susceptible to erosion due to trampling by cattle. Bacterial and nutrient contamination occurs as a result of fecal deposition within the channel. Disease causing organisms associated with manures pose a health risk to downstream users. Nutrients found in manure stimulate excessive plant growth which depletes oxygen levels in the water.

Prevention of livestock access is an effective means of protecting water quality. However, there are two major impediments to the acceptance of implementing fencing across the Maitland watershed. Firstly, many farmers surveyed did not view livestock access as a significant pollution source. Thirty—seven percent of the dairy and beef farmers surveyed responded "no" when asked if restricting livestock access was an effective means of improving water quality. Secondly, in a number of cases technical difficulties were stated as the obstacle to change. These included the feasibility of fencing flood prone areas and the difficulties in providing dependable alternate water systems. In total, 44 percent of the beef and dairy operators surveyed indicated that fencing would not be an acceptable practice on their farm.

Alternative practices should be promoted to those farmers who allow livestock access throughout the Maitland watershed. The costs, technical feasibility and the water pollution control benefits of alternative fencing, crossings and water systems should be considered on an individual basis. In some instances alternate land use may be an option. Limited access sites do not appear to greatly reduce bacteria or phosphorus pollution, therefore, total restriction should be encouraged wherever possible.

i) <u>Information and Education</u>

Success of efforts to implement fencing projects will depend on the acceptance of the need for improvements and on the practices being offered as alternatives. The first step must be to promote the benefits associated with preventing livestock access. Information and education messages can be delivered at the local level through the MVCA.

Activities similar to those discussed under Septic System Failure would be undertaken in addition to the promotion of on farm demonstrations.

ii) <u>Policy and Planning</u>

The use of existing legislation and/or new enforcement alternatives to regulate livestock access to watercourses could be considered for a future period if a certain degree of voluntary adoption of alternative practices was not achieved through education and extension activities.

Amendments to the Drainage Act which would encourage the fencing of livestock from municipal drains as new reports were prepared would address a large number of existing sites. Enhanced subsidies could be offered to those landowners required to implement improvements.

iii) Data Collection and Monitoring

The rate of adoption of alternative practices should be monitored to evaluate the level of success of information, extension or incentive programs. The number of sites and the types of measures implemented through incentive programs should be provided to Authorities participating in the Provincial Rural Beaches Strategy. This information could then be used to estimate pollutant load reductions or compared to water quality trends to track the effectiveness of programs. As well, the economic, social and technical factors which influence the acceptance of fencing alternatives by farmers should be monitored.

iv) Extension

Adoption of alternative practices will depend upon acknowledgement by farmers that livestock access is a significant source of contamination. Financial incentives may be required to assist farmers in implementing fencing projects because the benefits are Largely thought of as societal and are not closely related to production. Therefore, a grant covering a minimum of 50 percent of the project costs should be available to farmers who restrict livestock access to watercourses.

Raised or low level crossings should be made eligible for assistance under future incentive programs in order to restrict cattle completely from streams.

Cooperative extension programs between MVCA and county OMAF offices could be utilized to deliver technical information and assistance to landowners.

8.3.1.3 Winter Spread Manure

Surface runoff from fields where manures have been winter spread delivers both bacteria and nutrients to watercourses. The degree of contamination depends upon a number of factors including: the volume of manure spread, distance to a watercourse, physical site and climatic conditions.

Approximately sixteen percent of the farm operators surveyed in the Maitland River watershed winter spread some portion of their manure. Lack of manure storage space did not appear to be the dominant reason for winter spreading as two-thirds of those farmers indicated that they had a minimum of four months of manure storage. Convenience, timing and concerns for soil compaction may be of more significance than concerns for environmental contamination and loss of nutrients.

Livestock farmers in the Maitland watershed should be encouraged to utilize existing storage capacities and limit the practice of winter spreading of manure.

i) Information and Education

Alternative manure storage and handling practices should be promoted which would maximize the value of manure as a soil additive and protect water quality. As the survey results indicated manure storage size does not appear to significantly influence the decision of farmers to winter spread manure. This would suggest that the most significant load reduction may be realized by promoting the adoption of alternate management practices. This would include the more efficient utilization of existing storage areas. If winter spreading is necessary, fields should be selected where the combination of distance, slope and ground cover would mitigate the impacts of runoff. Construction of improved storages could be considered when other factors such as manure stack and barnyard runoff are also of concern.

Activities undertaken by MVCA to promote alternative practices would include press releases, presentations and/or workshops, information day topics, and preparation of a factsheet.

ii) Policy and Planning

Local and county municipalities should be encouraged to adopt by-laws which would ensure that new storages would have sufficient capacity so that winter spreading would not be required. Provincial guidelines for developing progressive by-laws concerning manure storage and handling would be of value to those municipalities.

A system should be developed whereby farmers involved in an incentive program would be encouraged to attend a training workshop. In the case of environmental protection projects, topics related to soil and water conservation could be covered.

iii) Data Collection and Monitoring

The number of farms where winter spreading was practiced was determined from the farmer survey. Further information regarding the winter spreading practices of farmers should be gathered to refine the predictive load (ie. volume spread, field characteristics). The technical, social and economic factors which govern a farmers decision to winter spread manure also should be investigated.

Research on transport of manure pollutants from field to watercourse and on bacteria decay in field spread situations should be considered by the Ministries of the Environment and Agriculture and Food.

Changes in manure handling and storage practices which occur throughout the watershed over the five year period should be monitored to assess the success of information and extension activities.

iv) Extension

A grant should be available to farmers to encourage the construction of manure storages which provide environmental protection through containment of manure and runoff and allow for the timeliness of application. An extension package which includes information on environmentally sound manure storage and application methods should be developed and provided to interested farmers, especially those involved in incentive programs.

8.3.2 Secondary Sources

8.3.2.1 Milkhouse Waste Disposal

Contamination of watercourses occurs when milkhouse drains are directly connected to a watercourse or to a field drainage system. Milkhouse waste water contains both nutrients and bacteria. A study by Hayman (1987) estimated that the annual total phosphorus loadings from eight dairy farms averaged 35.2 kilograms per year. When milkhouse wastes are disposed of through a drain, a 300 to 600 fold increase in the number of bacteria discharged at the tile outlet occurs (Hayman and Briggs, 1987). A 500 fold increase was used to estimate total annual bacteria load from MVCA watershed dairy farms.

Sixty-two percent of the dairy operators surveyed in the Maitland Watershed indicated that they did not use an adequate milkhouse waste disposal method (MVCA, 1986 and 1987).

i) Information and Education

An education program should be developed and implemented to encourage dairy farmers to adopt proper milkhouse waste disposal practices. Three alternatives can be promoted:

1) the use of a sediment tank treatment trench system;
2) collection of waste in a storage tank for land disposal;
3) storage of the waste in a manure storage system.

Activities similar to those stated in previous sections would be undertaken to promote alternative practices.

ii) Policy and Planning

Active enforcement of existing legislation to require the adoption of a suitable milkhouse disposal method should be considered by the MOE following a period of additional educational and extension activities.

iii) Data Collection and Monitoring

The adoption of alternative disposal systems should be monitored by the MVCA in order to evaluate the level of success achieved through information and extension activities.

iv) Extension

Technical information and assistance should be provided to landowners through cooperative extension programs between the county OMAF offices and the MVCA.

A financial incentive should continue to be offered to farmers to assist in the construction of milkhouse waste water disposal systems.

8.3.2.2 Manure Storage and Feedlot Runoff

Precipitation on solid manure stack areas, feedlots and barnyards generates runoff which is contaminated by animal wastes. Problems occur when this contaminated runoff or manure is transported to a watercourse via surface flow or through a tile system. Manure runoff contains microorganisms, nutrients and organic matter which are detrimental to water quality. Although manure stack and feedlot runoff does not contribute significantly to bacteria loads at Lake Huron, it may impact local water quality conditions.

Eighty two percent of the manure storages on farms surveyed through the Maitland Rural Beaches Study had no runoff containment. Efforts should be expended to assist farm operators in reducing the impact of runoff from these systems.

i) Information and Education

An education program should be developed and implemented to encourage livestock farmers to adopt alternative manure storage and feedlot runoff containment practices. In addition to systems which contain manure and/or runoff, practices which reduce the volume of runoff by diverting clean water should be promoted.

ii) Policy and Planning

Municipal governments should be encouraged to adopt by-laws which ensure that new manure storage facilities are adequately designed and constructed to prevent environmental contamination. Provincial guidelines for developing manure storage by-laws would be of assistance to these municipalities.

iii) Data Collection and Monitoring

As with other practices, the adoption of alternative manure storage practices by livestock farmers should be monitored at the watershed level. Information on the technical, social and economic factors which influence decisions made by farmers regarding the adoption of environmentally better waste management practices should also be collected. This information would enable the agencies involved to evaluate the effectiveness of program activities.

iv) Extension

Technical information and assistance should be provided to landowners through existing OMAF engineering and extension services.

A financial incentive should continue to be offered to farmers to assist in the construction of environmentally proper manure storage and runoff containment systems.

8.3.2.3 Spring, Summer, Fall Overspreading

Surface runoff from fields where manure has been over applied can deliver bacteria and nutrients to watercourses. Over application may result when an operation produces a manure volume greater than that which should be applied to its land base, or as a result of poor management.

Based on MVCA farm survey data, over application due to lack of land base should not be a significant problem in the Maitland watershed. Therefore, efforts should be directed towards promoting spreading practices which maximize the value of manure as a soil additive.

i) Information and Education

An education program should be developed and implemented to promote the value of manure as a soil additive. Management practices which minimize the potential of over application should be stressed.

ii) Policy and Planning

The MOE should continue to prosecute those operators who cause surface water contamination through blatant over application of manure. The Province should consider the development of a policy (or by-law) which limits the number of animal units per hectare of arable land.

iii) Data Collection and Monitoring

As with other practices the adoption of improved manure spreading practices should be monitored at the local level.

iv) Extension

Technical information and assistance should be provided to landowners through cooperative extension programs between OMAF and Conservation Authorities.

8.4 MVCA Project Requirements

An annual workplan would be submitted to the MOE's Provincial Rural Beaches Program from the MVCA Steering Committee. These workplans would detail annual activities and resources required to work towards the study objectives as outlined in the Implementation Plan. The annual activities would be developed from the strategy as discussed by source under the four components: Information and Education, Policy and Planning, Data Collection and Monitoring and Extension.

An estimate of the annual resources required by the MVCA to undertake activities to reduce loading from the priority sources would include:

One and a quarter staff persons;
Vehicle rental and operations; Office overhead;
Technical supplies.

Approximate annual cost — $45,000.

The need for additional resources should be determined by the level of program activity for a given year. Special projects should be considered on a separate basis. Projects which benefit multiple agencies or involve overlapping boundaries or jurisdictions should be jointly submitted and funded by the appropriate ministries.

9.0 MODEL EVALUATION

9.1 Sensitivity Analysis

The algorithms used to predict the fecal coliform loads in this report are arithmetic equations. In an attempt to demonstrate the relative significance of individual factors, the sensitivity of the algorithms to changes in individual parameter values was completed for the agricultural sources and septic system failure for sub-basin number six. A single parameter was varied per test and the resultant load delivered to watercourses determined. This resultant load was then expressed as a ratio of the original load. The results of these calculations are given in Appendix C.

Certain parameters in the equations were considered as constants for this sub-basin and, therefore, were not tested. Other parameters were found to vary by orders of magnitude. The ranges of parameter values used to conduct the test were determined from a literature review or were based on assumptions made by the authors.

In general, the concentration of fecal coliform bacteria was shown to be the most significant parameter. Variations to the fecal coliform concentrations resulted in changes of one order of magnitude to each of milkhouse waste, livestock access, feedlot runoff, stack runoff, and septic system failure loads. Alterations to the other parameters gave loading ratios within the same order of magnitude as the base calculation.

Variations to the stack decay and delivery factor caused the most significant change to the load delivered from winter spreading. When the average stack time was decreased from fifteen to one day (ie. daily spreading) the stack decay factor became one. This resulted in a corresponding twenty fold increase in the winter spreading load. As would be expected a decrease in the percent delivery factor from ten to one percent resulted in a one order of magnitude decrease to the load.

No single parameter tested for spring, summer and fall over spreading appeared to have a more significant impact on the load calculated than the others. Doubling the number of operations assumed to be over spreading doubled the load. Reducing the percent delivery from five to one (80 %) reduced the load delivered by a corresponding eighty percent.

9.2 Comparisons of Predicted vs Measured Loads at Selected Stations

In order to evaluate the accuracy of the model predictions, a comparison of predicted fecal coliform loads versus measured loads at specific stations on the Maitland River was completed. Measured loads were based on stream discharge and water quality data. Three points were chosen for comparison: Brussels on the Middle Maitland River (Station 150), Summerhill on the South Maitland River (Station 241), and Benmiller on the main branch of the River (Station 310).

Comparisons near Brussels

The predicted annual fecal coliform load delivered to the outlet of sub-basin 15 at Brussels, based on the model algorithms, was estimated to be 4.05E+14 bacteria.

Stream discharge data from the MVCA/Environment Canada Belgrave gauging station located at the outlet of sub-basin 17 was used to estimate stream discharge at Brussels. The mean daily flow for each month in cubic metres per second was reduced by 10.4 percent to account for an increase in discharge entering the river between the gauging and sampling stations. Sub-basin 17 represents 10.4 percent of the land area upstream of the Belgrave gauging station.

Mean densities of fecal coliform bacteria at Station 150, at Brussels, were determined for each month of the year. The number of samples collected per month was variable.

Loads were calculated for each month based on the mean daily discharge and the mean fecal coliform concentration (Appendix D). Mean monthly loads were then summed to provide a 'measured' annual fecal coliform load. These measured loads were estimated to be 1.18E+15 and 5.46E+14 bacteria for 1987 and 1988 respectively. Note that mean monthly bacteria loads were not calculated for the months of January and February 1987 as water samples were not collected. Due to technical problems with the gauging equipment, loads were not calculated for March, June and August 1988.

The ratio of predicted versus measured annual fecal coliform loads was 0.34 for 1987 and 0.74 for 1988 (Table 6). The estimate of the annual load would be greater for both years if data had been available for all months. A decrease in the respective ratio could then be expected.

Table 6: Comparisons of Predicted Versus Measured Annual Fecal Coliform Loads at Selected Sites

Station Location	Year	Predicted Annual Load	Measured Annual Load	Ratio of Predicted vs. Measured
Brussels	1987	4.05E+14	1.18E+15	0.34
	1988	4.05E+14	5.46E+14	0.74
Summerhill	1988	2.21E+14	6.70E+14	0.33
Benmiller	1987	5.93E+14	9.93E+14	0.60
	1988	5.93E+14	8.41E+14	0.71

Comparison at Summerhill

The predicted annual fecal coliform load delivered to Summerhill from the South Maitland subwatershed was estimated to be 2.21E+14 bacteria.

Stream discharge data from the MVCA/Environment Canada gauging station, located at Summerhill was used to determine the mean discharge (C.M.S.) for each month. Mean fecal coliform densities were determined for each month from sampling data. No samples were collected at this station during January and February.

The measured fecal coliform load for the March through December period of 1988 was estimated to be 6.70E+14 bacteria. The ratio of predicted versus measured load for this period equals 0.33.

Comparison at Benmiller

The predicted annual fecal coliform load at Benmiller of 5.93E+14 bacteria was determined by taking the total load delivered to Lake Huron from the Maitland watershed minus the load delivered from sub-basin 31 (3.28E+13).

A MVCA/Environment Canada gauging station was not installed on the main Maitland River until the fall of 1988. Therefore, in order to estimate the mean daily stream discharge at Benmiller, data were compiled from three upstream gauging stations. These stations are located on the Maitland River below Wingham, on Blyth Brook and on the South Maitland River at Summerhill.

Mean monthly fecal coliform counts were determined from sampling data. No samples were collected during January and February of either year. Total annual loads for these ten month periods were estimated to be 9.93E+14 and 8.41E+14 bacteria for 1987 and 1988 respectively. A comparison of the predicted versus the measured loads gave ratios of 0.60 and 0.71 for the two years.

9.3 Conclusions

A number of factors combine to make predictive modelling of indicator bacteria loads a complex exercise. These include: the number and variability of sources, the number of contributing sites per source, the size and degree of variability of the watershed and the physical, chemical, and biological processes which affect indicator bacteria populations. Considering these factors the comparison of the predicted versus the measured loads at these stations would appear to indicate that the order of magnitude of the predicted load is acceptable.

Given the range over which individual factors used in the algorithms can vary, the predicted loads from each source should be interpreted as estimates and not as absolute values. However, the relative ranking of sources should be accepted until additional research or information becomes available to indicate otherwise.

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APPENDIX A

APPENDIX A1: Equivalent Animal Units

Animal Type	Weight (kg)	EAU P	EAU FC
Beef Cow		1.04	1.04
Slaughter Steer	455	1.00	1.00
Yearling Beef	365	0.78	0.71
Beef Calf	180	0.53	0.48
Dairy Cow		1.50	1.62
Young Dairy/Heifer	318	0.75	0.71
Dairy Calf	136	0.46	0.36
Sow/Boar		0.60	---
Feeder Pig	22-90	0.40	0.36
Sheep	45	0.17	0.02
Turkeys	4.5	0.03	---
Chicken/Duck	1.8	0.02	---
Horse	455	1.20	0.013

P = phosphorus;   FC = fecal coliform

From Ecologistics, 1998.

APPENDIX A2: Manure Production Per Day By Animal Type

ANIMAL TYPE	PRODUCTION m^3/day
Beef or Dairy	
6-15 months	0.0170
15-24 months	0.0227
Beef cows (550 kg)	0.0340
Dairy cows - free stall	0.0581
- tie stall	0.0616
Swine	
Weaners	0.0023
Feeders	0.0071
Sows & litter	0.1700
Chicken - broilers	0.0001
Turkeys - broilers	0.0003
- breeders & toms	0.0007
Sheep	0.0042
Horses	0.0566

Based on Manure Storage Proposal Field Sheet.

APPENDIX A3: Average Fecal Coliform Densities In Animal Feces

ANIMAL	Fecal Coliforms per gram*	Fecal Coliforms per mL
Cattle	5.0×10^{5}	5.0×10^{11}
Swine	1.0×10^{7}	1.0×10^{13}
Chickens	9.9×10^{7}	9.9×10^{13}
Sheep	1.6×10^{7}	1.6×10^{13}
Horses	9.7×10^{4}	8.7×10^{10}

* Provided by M. Young, MOE, Toronto.

APPENDIX A4: Times Of Travel Of Flow From Sub-basins To Lake Huron

MAJOR BASIN	Sub-basin	FLOW TRAVEL TIMES (days)		
		Base Flow		Event
		Fall, Winter, Spring	Summer	
North Maitland				
	1	6.81	11.84	3.76
	2	5.51	9.22	3.46
	3	5.26	8.72	3.38
	4	4.35	6.89	2.92
	5	3.97	6.25	2.73
Little Maitland				
	6	6.81	12.50	3.20
	7	5.96	10.76	3.04
	8	4.17	7.20	2.59
	9	3.39	5.65	2.20
Middle Maitland				
	10	7.58	13.45	4.31
	11	6.45	11.19	4.00
	12	5.80	9.89	3.75
	13	7.87	12.84	4.67
	14	6.50	10.78	4.36
	15	5.31	8.92	3.50
	16	5.84	9.98	3.59
	17	4.41	7.11	2.90
	18	3.45	5.65	2.36
South Maitland				
	25	4.04	9.45	1.80
	26	4.14	7.85	1.80
	27	3.24	6.04	1.55
	28	2.29	4.14	1.10
Main Maitland				
	19	3.00	4.87	2.12
	20	2.72	4.45	1.54
	21	1.89	3.07	1.22
	22	3.09	5.32	1.38
	23	2.30	3.75	1.13
	24	1.61	2.61	0.98
	29	1.84	3.33	0.62
	30	1.00	1.64	0.40
	31	0.55	0.89	0.30
Lakeshore Str.				
	51	0.28	0.55	0.14
	52	0.43	0.87	0.22

APPENDIX A5

NAME:
ADDRESS:
TOWNSHIP:
LOT:
CONE:
PHONE NO:

DATE: ______________

MANURE STORAGE PROPOSAL - FIELD SHEET

GENERAL LIVESTOCK OPERATION TYPE:

Existing Storage (circle): Solid or Liquid or Semi-Solid; Open or Roofed; Runoff Stored or Not Stored

Future Plans (circle): Solid or Liquid or Both Systems; Open or Roofed; Undecided

ANIMAL TYPE (include all animals on this farmstead)	NUMBER AT A TIME		ANIMAL TYPE	NUMBER AT A TIME		ANIMAL TYPE	NUMBER AT A TIME	
	NOW	5 YR. FORECAST		NOW	5 YR. FORECAST		NOW	5 YR. FORECAST
BEEF			SWINE			TURKEYS		
6-15mo.			weaner			broiler		
15-24mo.			feeder			breeder		
24mo. + (1200 lb/550kg)			sow			heavy tom		
DAIRY			CHICKENS			OTHER		
6-15mo.			broiler			sheep		
15-24mo,			layer			horses		
freestall (1500 lb/700 kg)			started					
tiestall (1500 lb/700 kg)			pullets					

ADDITIONAL WATER

I) From Barn Estimate (gallons/day)

1) Floor wash x 0.16 = ____ ft.^{3} /day
2) High Pressure Wash x 0.16 = ____ ft.^{3} /day
3) Milkhouse/Parlour Wash x 0.16 = ____ ft.^{3} /day

Sub-Total _____ ft.^{3} /day

Indicate Volume (ft.^{3}/day) not to go to manure storage.

Explain alternate management plan

Sub-Total_________ (ft^3 /day) = TOTAL_____ft^3/day

II) Precipitation <u>length(ft) x width(ft)</u>

1) Barnyard/Feedlot/Exercise Yard a) x 0.0075 = _____ ft^3 /day
additional b) x 0.0075 = _____ ft^3 /day

2) Roof Area without eavestrough
sloping to above a) x 0.0075 = _____ ft^3 /day
Additional b) x 0.0075 = _____ ft^3 /day

Sub-Total ________ (ft^3 /day)

indicate Volume (ft./day)not to go to manure storage

Explain alternate management plan

Sub-Total_________ (ft^3 /day) = TOTAL_____ft^3/day

PROPOSED STORAGE

TYPE (check choices)

1)	Concrete Pad	Concrete walls Earthen Walls	Open Roofed
2)	Concrete Tank	Open Covered	Conc. Floor Earth. Floor
3)	Steel Tank		
4)	Earthen Pond (2:1 side slopes)	6 ft. deep 8 ft. deep	

5) Combination of Type _______ & Type ________

6) Other (specify)_____________________________

DISTANCE (ft.) to Nearest:

1)	River/Creek/Stream:	5)	Catchbasin:	
2)	Open Ditch:	6)	Pond:	
3)	Waterway:	7)	Well-	Dug:
4)	Tile Drain:			Drilled:

SKETCH OF PROPOSED WORK (include buildings, dimensions and distance between structures)

STORAGE DIMENSIONS (from Page 4)	
storage type	size (ft.)

DO YOU HAVE A SET OF ENGINEERED PLANS? YES ☐ NO ☐

WOULD YOU LIKE A STANDARD PLAN? YES ☐ NO ☐

PROPOSED STORAGE - SIZING CALCULATIONS

(Minimum Requirements)

ANIMAL TYPE	INITIAL SOLID STORAGE: ft^3 manure production over 200 days	x animal number	= solid manure production	COMPLETELY LIQUID STORAGE: ft^3 manure production over 200 days	x animal number	= liquid manure production
BEEF OR DAIRY						
6-15 mo.	120	x	=	140	x	=
15-24 200	160	x	=	220	x	=
Beef cows (550 kg.)	240	x	=	280	x	=
Dairy cows (770 kg.)						
free stall	410	x	=	530	x	=
tie stall	435	x	=	580	x	=
SWINE						
weaners	16	x	=	16	x	=
feeders	50	x	=	50	x	=
sows & litter	120	x	=	120	x	=
CHICKENS						
broilers	0.7	x	=	N/A	x	=
laying hens	N/A	x	=	1.8	x	=
pullets	N/A	x	=	0.7	x	=
TURKEYS						
broilers	1.8	x	=	N/A	x	=
breeders & toms	4.8	x	=	N/A	x	=
SHEEP	30	x	=	N/A	x	=
HORSES	400	x	=	N/A	x	=
		A) Sub-Total	___________		**B) Sub-Total**	____________

* More than 200 days storage is highly recommended for case of management. If this is desired, multiply sub-total by preferred storage time / 200 days.

________ + 200 (# days of storage Desired) x _______________ (Sub-Total A or B) = ______________________ ft^3 (manure production Sub-Total for more than 200 days)

PROPOSED STORAGE - SIZING FOR _____ DAYS

A. SOLID STORAGE

a) Sub-total (from pg. 3) ___________ ft^3

AREA FOR:	a) Sub-total	÷	stack height (wall height + 2')	=	area ft^2
4' walls		÷	6	=	ft^2
6' walls		÷	8	=	ft^2

DIMENSIONS FOR:

4' walls ________ ft. x _________ ft.

6' walls ________ ft. x _________ ft.

N.B. - TRANSFER SELECTED DIMENSIONS TO PAGE 2
- go to section B to calculate runoff containment

B. LIQUID STORAGE AND / OR RUNOFF CONTAINMENT

b) Sub-total (from pg. 3) (this value Is zero if solid storage) = ____________ ft^3

From barn (from pg. 1) __________ ft^3 x ______ Days = ____________ ft^3

Precipitation (from pg. 1) ________ ft^3 x ______ Days = ____________ ft^3

* Precipitation on solid Storage _______ ft^2 x 0.0075 x ______ Days = ____________ ft^3

* Runoff from roof to solid storage _______ ft^2 x 0.0075 x ______ Days = ____________ ft^3

TOTAL VOLUME (V) = _____________ ft^3

* these values are zero if solid storage is roofed

DIMENSIONS FOR:

TANK DIAMETER (ft.)

6' depth $\sqrt{\frac{V}{4.68}}$ = _________ft.

8' depth $\sqrt{\frac{V}{6.24}}$ = _________ft.

10' depth $\sqrt{\frac{V}{7.8}}$ = _________ft.

N.B. - add 2 ft. to the depth for open tank dimensions to allow for direct precipitation and free board
TRANSFER DIMENSIONS TO PAGE 2

POND (Volume [ft^3] for manure) length of side (ft.) for square pond

	30'	40'	50'	60'	80'	100'	120'
6' depth	882	2592	5202	8712	18432	31752	48672
8' depth	901	2891	6180	10770	23851	42131	65611

DIMENSIONS ARE: _______ ft. x _______ ft. x ___________ (L x W x Depth)

Volume of pond = $L \times W \times D - 2D^2\ (L+W) + 16\ D^3/3\ - L \times W\ 1.5$

L = length (ft)i W= Width (ft) D = Depth (ft)

from OMAF factsheet order no. 85-020

N.B. - calculations allow far the addition of 1.5 ft. of precipitation directly on the earthen pond with 2:1 side slopes
- if sizing for more than 200 days increase precipitation accordingly
- 1 gallon = 0.16 $ft.^3$
- 1 ft^3 = 6.25 gallons

TRANSFER DIMENSIONS TO PACE 2

APPENDIX B

B1: Annual Fecal Coliform Loads Delivered To Streams By Sub-basin And Source

B2: Annual Fecal Coliform Loads Delivered To Lake Huron By Sub-basin And Source

B3: Annual Fecal Coliform Loads Delivered To Lake Huron By Major Basin And Source

B4: Capital Costs For Remedial Measures By Sub-basin

B5: Capital Costs For Remedial Measures By Major Basin

B6: Cost Effectiveness For Remedial Measures At Lake Huron By Major Basin

B7: Percent Of Target Load Reduction Achieved Through 100 Percent Implementation Of Remedial Measures By Major Basin

APPENDIX B1: Annual Fecal Coliform Loads Delivered To Stream By Sub-basin And Source

	Fecal Coliform Load x 10^{10}										
	Milkhouse Waste	Livestock Access	Feedlot Runoff	Manure Stack Runoff	Winter Spread Manure	Spr.-Fall Spread Manure	Manure Spills	Septic System Failure	Urban Non-Point Sources	Urban STP	TOTAL
Maitland River Sub-basins											
1	454	33336	5	60	3174	83	0	16000	645	41	53799
2	470	5223	0	76	1381	35	0	13114	0	0	20299
3	250	2794	4	30	151	4	0	11669	0	0	14892
4	382	145	4	55	2940	73	0	14334	0	0	17933
5	162	2978	4	50	1247	47	0	29532	0	0	33620
6	910	4307	37	117	2335	71	0	21700	893	3	30372
7	281	4555	56	93	4113	107	0	12600	0	0	21905
8	15	1157	50	10	1077	22	0	6339	0	0	9671
9	52	612	119	27	139	3	0	4830	0	0	5789
10	469	3442	21	47	2796	104	0	11654	1276	0	20409
11	456	4850	164	40	3645	35	654	11400	0	1050	22354
I2	304	347	88	32	1282	33	0	20400	0	0	22486
13	1116	3074	89	102	2273	57	0	29400	300	642	37053
14	375	2308	4	28	911	23	0	9236	0	0	12879
15	44	1624	15	24	1283	33	0	7920	0	0	10943
16	152	4507	9	22	686	17	0	12789	0	0	19191
17	24	884	0	7	208	7	0	5270	722	43	7125
18	44	1424	2	3	469	11	0	2469	0	0	4423
19	205	1443	38	43	2465	54	0	15411	753	2550	23973
20	132	839	39	16	148	3	817	10536	0	0	12624

APPENDIX B1 (cont'd)

	Fecal Coliform Load x 10^{10}										
	Milkhouse Waste	Livestock Access	Feedlot Runoff	Manure Stack Runoff	Winter Spread Manure	Spr.-Fall Spread Manure	Manure Spills	Septic System Failure	Urban Non-Point Sources	Urban STP	TOTAL
21	129	2429	5	36	830	22	0	5680	0	0	9130
22	44	1370	3	12	207	5	0	4125	0	0	5767
23	206	1780	8	28	138	3	0	6881	772	38	9954
24	310	2958	0	16	7241	199	0	21400	243	0	32356
25	147	4361	21	21	378	9	0	7297	0	0	12224
25	74	1780	7	14	197	32	0	9812	0	0	11921
27	99	1844	0	42	1392	36	0	7513	224	0	11150
29	215	2794	11	33	3130	91	0	16637	0	0	22901
29	29	502	30	8	407	10	0	4110	0	0	5096
30	44	229	0	8	879	25	0	6233	0	0	7419
31	29	22	0	2	9	0	0	4788	0	0	4851
Sub-total	7681	99868	833	1104	48031	1340	1471	361171	6428	4368	532259
%	1	19	<1	<1	9	<1	<1	68	1	1	100
LAKESHORE STREAMS											
51	59	903	9	15	2518	65	0	12241	2000	92	17992
52	149	4471	16	33	1145	24	0	17239	0	0	23077
Sub-total	208	5374	25	48	3663	89	0	29430	2000	82	40969
%	1	13	<1	<1	9	<1	0	72	5	<1	100
Total	7889	105242	858	1152	51694	1393	1471	390651	8428	4450	573227
%	1	18	<1	<1	9	<1	<1	68	1	1	100

APPENDIX B2: **Annual Fecal Coliform Loads Delivered To Lake Huron By Sub-basin And Source**

	Fecal Coliform Load x10^{10}										
	Milkhouse Waste	Livestock Access	Feedlot Runoff	Manure Stack Runoff	Winter Spread Manure	Spr.-Fall Spread Manure	Manure Spills	Septic System Failure	Urban Non-Point Sources	Urban STP	TOTAL
MAITLAND RIVER Sub-basin											
1	9	284	<1	7	562	7	0	309	70	2	1250
2	18	78	0	10	281	4	0	503	0	0	814
3	11	61	<1	4	32	<1	0	512	0	0	821
4	27	6	<1	10	740	11	0	1030	0	0	1821
5	14	148	<1	10	525	8	0	2520	0	0	3226
6	18	37	6	18	535	9	0	420	134	<1	1126
7	9	65	9	15	1010	15	0	383	0	0	1516
8	1	49	11	2	327	4	0	498	0	0	893
9	7	44	32	7	50	<1	0	584	0	0	724
10	6	18	2	4	384	7	0	151	150	0	722
11	11	51	16	4	578	7	49	267	0	34	1020
12	10	5	10	3	228	3	0	671	0	0	931
13	13	14	6	7	265	3	0	328	20	6	660
14	9	24	<1	2	122	1	0	210	0	0	368
15	2	34	2	3	256	4	0	338	0	0	678
16	5	69	1	3	131	2	0	412	0	0	621
17	5	32	0	1	55	1	0	365	129	2	591
19	5	98	<1	<1	158	2	0	289	0	0	552
19	31	134	11	12	929	16	0	2470	212	394	4218
29	23	94	15	6	73	1	295	1880	0	0	2363

APPENDIX B2 (Cont'd)

	Fecal Coliform Load x 10^{10}										
	Milkhouse Waste	Livestock Access	Feedlot Runoff	Manure Stack Runoff	Winter Spread Manure	Spr.-Fall Spread Manure	Manure Spills	Septic System Failure	Urban Non-Point Sources	Urban STP	TOTAL
21	37	494	2	17	473	10	0	1630	0	0	2660
22	6	17	1	5	110	2	0	587	0	0	829
23	46	268	4	14	62	1	0	1550	390	9	2360
24	106	745	0	9	4610	100	0	7290	134	0	13000
25	12	195	8	7	165	3	0	609	0	0	999
26	6	76	3	5	86	10	0	781	0	0	966
27	23	140	0	15	682	13	0	977	96	0	1930
28	48	404	6	17	1890	40	0	3710	0	0	6110
29	9	100	21	5	306	7	0	1190	0	0	1640
30	22	94	0	7	721	19	0	3110	0	0	3980
31	20	13	0	2	8	<1	0	3240	0	0	3280
Sub-total	559	4011	164	232	16384	311	343	38814	1335	438	62591
%	1	6	<1	<1	26	1	1	62	2	1	100
LAKESHORE STREAMS											
51	47	671	9	14	2360	59	0	9820	1840	82	14900
52	106	2840	14	29	1030	21	0	12300	0	0	16400
Sub-total	153	3511	23	43	3390	80	0	22130	1840	82	31252
%	<1	11	<1	<1	11	<1	0	71	6	1	100
Total	712	7522	187	275	19774	391	343	60944	3175	520	93843
%	1	8	<1	<1	21	<1	<1	65	3	1	100

APPENDIX B3: Annual Fecal Coliform Loads Delivered To Lake Huron By Major Basin And Source

	Fecal Coliform x 10^{10}										
MAJOR BASIN	Milkhouse Waste	Livestock Access	Feedlot Runoff	Manure Stack Runoff	Winter Spread Manure	Spr.-Fall Spread Manure	Manure Spills	Septic System Non-Point Failure	Urban Sources	Urban STP	TOTAL
North Maitland (1-5)	79	597	2	41	2140	30	0	4874	70	2	7935
Little Maitland (6-9)	35	195	58	42	1922	28	0	1895	134	<1	4299
Middle Maitland (10-18)	66	345	32	27	2177	30	48	3031	299	43	6104
Main Maitland (19-24, 29-31)	300	2059	54	77	7322	156	295	22947	736	393	74338
South Maitland (25-201	79	815	17	44	2923	66	0	6977	96	0	10017
Sub-total	559	4011	169	231	16384	310	343	38814	1335	439	62594
Lakeshore Str. (51-52)	153	3511	23	43	3390	80	0	22130	1840	82	31252
Total	712	7522	192	274	19774	390	343	60944	3175	520	93846

APPENDIX B4: Capital Casts For Remedial Measures By Sub-basin

	Costs x 1000$											
	Milkhouse Waste					Feedlot Runoff			Manure Stack Runoff			
	Earthen Star.	Conc. Star.	Trtmt Trench	Covered Conc. Stor.	Access	Earthen Star.	Conc. Stor.	Covered Conc. Stor.	Earthen Stor,	Conc. Star.	Covered Conc. Star.	Septic Systems
MAITLAND RIVER Sub-basin												
1	79	122	87	177	164	3	8	11	61	70	81	318
2	82	126	90	185	307	0	0	0	59	70	81	269
3	46	71	51	104	110	3	8	11	61	70	81	246
4	71	109	78	159	142	3	8	11	54	63	72	306
5	30	46	33	67	241	7	15	23	105	122	140	615
6	147	227	162	330	141	13	20	45	281	334	385	417
7	49	76	54	110	120	10	23	34	228	269	309	244
9	3	4	3	6	65	10	23	34	33	38	43	153
9	11	17	12	25	40	10	23	34	57	64	72	100
10	76	118	84	171	124	7	15	23	95	114	131	234
11	74	113	81	165	98	3	8	11	113	136	157	226
12	49	76	54	110	6	3	8	11	82	101	116	407
13	175	269	192	392	69	20	45	68	282	236	386	541
14	60	92	66	135	51	3	8	11	100	122	141	184
15	8	13	9	18	49	7	15	23	78	88	101	158
16	55	84	60	122	161	7	15	23	87	102	117	254
17	14	21	15	31	17	0	0	0	15	16	18	109
18	8	13	9	18	56	7	15	23	23	27	31	50
19	38	59	42	86	73	7	15	23	81	92	105	339
20	25	37	27	55	33	10	23	34	33	36	40	212
21	22	34	24	49	27	3	8	11	72	85	98	109
22	8	13	9	18	45	3	8	11	43	51	58	85
23	35	55	39	80	58	7	15	23	74	89	102	132
24	49	76	54	110	104	0	0	0	51	59	68	518
25	27	42	30	61	19	7	15	23	51	62	71	136
26	14	21	15	31	113	7	15	23	55	64	73	185
27	16	25	18	37	63	0	0	0	38	42	48	146
28	38	59	42	86	95	3	8	11	90	94	108	331
29	5	8	6	12	25	3	8	11	12	14	15	79
30	8	13	9	18	19	0	0	0	30	32	26	217
31	5	8	6	12	16	0	0	0	0	0	0	150
Sub-total	1,330	2,045	1,461	2,983	2,644	168	376	566	2,437	2860	3286	7,468
LAKESHORE STREAMS												
51	11	17	12	24	40	3	8	11	35	42	48	252
52	27	42	30	61	150	10	22	34	65	113	130	596
Sub-total	38	59	42	85	190	13	30	45	100	155	178	848
Total	1,368	2,104	1,503	3,068	2,834	181	406	611	2,537	3,015	3,464	8,316

APPENDIX B5: Capital Costs For Remedial Measures By Major Basin

MAJOR BASIN	Costs x 1000 $											
	MILKHOUSE WASTE				Access	FEEDLOT RUNOFF			MANURE STACK RUNOFF			Septic Systems
	Earth. Star.	Conc. Star.	Trmt Trench	Covered Star.		Earth. Star.	Conc. Star.	Covered Star.	Earth. Stor.	Conc. Star.	Covered Stor.	
North Maitland (1-5)	308	475	339	693	964	17	38	57	341	395	454	1,753
Little Maitland (6-9)	210	323	231	471	366	44	98	147	599	705	810	914
Middle Maitland (10-18)	519	798	570	1,162	633	57	128	193	877	1,041	1.197	2,162
Main Maitland (19-24, 29-31)	197	302	216	441	390	34	75	113	369	457	523	1,942
South Maitland (25-28)	96	147	105	214	291	17	38	57	224	262	301	797
Sub-Total	1,330	2,045	1,461	2,983	2,644	168	376	566	2,409	2,860	3,286	7,468
Lakeshore Str. (51-52)	38	59	42	86	191	13	30	45	100	155	178	848
Total	1,368	2,104	1,503	3.069	2,835	181	406	611	2,509	3,015	3,464	8,316

APPENDIX B6 : Cost Effectiveness For Remedial Measures At Lake Huron By Major Basin

MAJOR BASIN	No. of Fecal Coliform bacteria (x 10^5) reduced per $1 spent											
	MILKHOUSE WASTE				Access	FEEDLOT RUNOFF			MANURE STACK RUNOFF			Septic Systems
	Earth. Stor.	Conc. Star.	Trtmt Trench	Covered Star.		Earth. Stor.	Conc. Star.	Covered Star.	Earth. Star.	Conc. Star.	Covered Stor.	
North Maitland (1-5)	26	17	23	11	86	12	5	4	12	10	9	278
Little Maitland (6-9)	17	11	15	7	53	133	59	39	7	6	5	206
Middle Maitland (10-18)	13	8	12	6	55	67	30	20	3	3	2	140
Main Maitland (19-24, 29-31)	153	99	139	68	528	161	72	48	21	17	15	1240
South Maitland (25-28)	83	54	75	37	280	101	45	30	20	17	15	762
Mait. Average	42	27	32	19	152	101	45	30	10	8	7	520
Lake-shore Str. (51-52)	400	260	364	179	1840	172	77	51	43	28	24	2610
Water-shed Average	52	34	47	23	265	105	47	31	11	9	8	733

APPENDIX B7: Percent Of Target Load Reduction Achieved Through 100 Percent Implementation Of Remedial Measures

MAJOR BASIN	Milkhouse Waste	Livestock Access	Feedlot Runoff	Manure Stack Runoff	Winter Spread Manure	Spr.-Fall Spread Manure	Manure Spills	Septic System Failure	Urban Nonpoint Sources	Urban STP
North Maitland (1-5)	<1	3	<1	<1	12	<1	-	28	<1	<1
Little Maitland (6-9)	<1	1	<1	<1	12	<1	-	11	1	<1
Middle Maitland (10-18)	<1	2	<1	<1	13	<1	<1	18	2	<1
Main Maitland (19-24, 29-31)	2	12	<1	<1	43	1	2	133	4	2
South Maitland (25-28)	<1	5	<1	<1	16	<1	-	35	<1	-
Maitland River Watershed	3	23	1	1	95	2	2	226	8	3
Lakeshore St. Sub-basins	2	35	<1	<1	34	I	-	221	18	1

APPENDIX C

C1: Sensitivity Analysis For Milkhouse Waste Load

C2: Sensitivity Analysis For Livestock Access Load

C3: Sensitivity Analysis For Feedlot/yard Load

C4: Sensitivity Analysis For Manure Stack Load

C5: Sensitivity Analysis For Winter Spreading Load

C6: Sensitivity Analysis For Spring, Summer And Fall Spreading Load

C7: Sensitivity Analysis For Septic System Load

APPENDIX C1: Sensitivity Analysis For Milkhouse Waste Load

LOAD = Conc. x Vol./ cow/day x 4 cows x 265 days x Delivery

Concentration (FC/100 mL)	Volume (1/cow)	# cows	# days	Delivery (%)	LOAD	RATIO
200	13.0	35	365	50000	9.10×10^{12}	1.0
2000	13.0	35	365	50000	9.10×10^{13}	10.0
20	5.6	25	365	50000	3.92×10^{12}	0.4
200	32.8	35	365	50000	2.30×10^{13}	2.5
200	13.0	35	365	30000	5.46×10^{12}	0.6
200	13.0	35	365	60000	1.09×10^{13}	1.2

Concentration range from Bos, 1988.

Volume range from Hayman, 1987.

Percent delivery range from Hayman and Briggs, 1987.

APPENDIX C2: Sensitivity Analysis For Livestock Access Load

LOAD = Conc. x EAU x Prob. x Access events/day x LF x # animals x # days

Conc. (FC/def.)	EAU	Prob.	Access evt./day	Location factor	# animals	# days	LOAD	RATIO
8.9×10^{8}	#	0.18	2.5	#	#	#	4.31×10^{17}	1.0
6.2×10^{8}	#	0.18	2.5	#	#	#	3.00×10^{17}	0.7
3.8×10^{10}	#	0.18	2.5	#	#	#	1.86×10^{15}	43.0
8.9×10^{8}	#	0.01	2.5	#	#	#	2.39×10^{12}	0.1
8.9×10^{8}	#	0.31	2.5	#	#	#	7.42×10^{17}	1.7
8.9×10^{8}	#	0.18	1.0	#	#	#	1.72×10^{17}	0.4
8.9×10^{8}	#	0.18	4.0	#	#	#	6.39×10^{17}	1.6

numbers Vary with individual farms

Concentration range from Ecologistics, 1988 and MVCA.

Probability range from Demal, 1982.

Access events/day range from Demal, 1982.

APPENDIX C3: Sensitivity Analysis For Feedlot/yard Load

LOAD = Conc. x AMP x Runoff x Delivery

$$AMP = \frac{\text{AMA/yard area}}{67{,}180\ \text{kg/ha}}$$

AMA = [# animals x EAU x 1.31kg/hr x Feedlot hrs/day x # days between scraping] / 2

Concentration (FC/ha-mm)	AMP	Feedlot hr/day	Runoff (%)	Delivery (%)	LOAD	Ratio
7.5×10^{9}	#	W-3;S-16	60	90	3.75×10^{11}	1.0
7.5×10^{8}	#	W-3;S-16	60	80	3.75×10^{16}	0.1
7.5×10^{10}	#	W-3;S-16	60	90	3.75×10^{12}	10.0
7.5×10^{9}	#	W-5;S-20	60	80	4.04×10^{11}	1.1
7.5×10^{9}	#	W-1;S-12	60	80	2.28×10^{11}	0.6
7.5×10^{9}	#	W-3;S-16	40	80	2.50×10^{11}	0.7
7.5×10^{9}	#	W-3;S-I6	80	80	5.00×10^{11}	1.3
7.5×10^{9}	#	W-3;S-16	60	70	3.28×10^{11}	0.9
7.5×10^{9}	#	W-3;S-16	60	90	4.22×10^{11}	1.1

Concentration range from Coote and Hore, 1978.

Percent runoff range from Coote and Hore, 1978.

Variations in feedlot hours/day and percent delivery were estimations made by authors.

APPENDIX C4: Sensitivity Analysis For Manure Stack Load

LOAD = Conc. x ASA x Runoff x Delivery

Concentration (FC/ha—mm)	ASA	Runoff (%)	Delivery (%)	LOAD	Ratio
7.5×10^{9}	#	60	80	1.17×10^{12}	1.0
$7.5 \times l0^{3}$	#	60	80	1.17×10^{11}	0.1
7.5×10^{11}	#	60	80	1.17×10^{13}	10.0
7.5×10^{9}	#	40	80	7.91×10^{11}	0.7
7.5×10^{9}	#	80	80	1.56×10^{12}	1.3
7.5×10^{9}	#	60	70	1.03×10^{12}	0.9
7.5×10^{9}	#	60	90	1.32×10^{12}	1.1
7.5×10	#	60	80	3.94×10^{12}	3.4

\# numbers vary with individual farm

Concentration range from Coote and Hore, 1978.

Percent runoff range from Coote and Hore, 1978.

Variation in percent delivery and ASA were estimations made by authors.

APPENDIX C5 : Sensitivity Analysis For Winter Spreading Load

LOAD = (# bacteria winter spread x DD x CD x Delivery x Stack decay x Field decay

bacteria winter spread varies with FC concentration by animal type and volume of manure winter spread.

Drain Density (DD) remains constant at 1.09 km/sq. km

Volume (%)	Critical Distance (m)	Delivery (%)	Stack Decay	Field Decay	LOAD	Ratio
25	150	10	0.05	0.63	2.73 $\times 10^{13}$	1.0
19	150	10	0.05	0.63	1.77 $\times 10^{13}$	0.8
30	150	10	0.05	0.63	2.80 $\times 10^{13}$	1.2
25	30.5	10	0.05	0.63	4.75 $\times 10^{12}$	0.2
25	305	10	0.05	0.63	4.75 $\times 10^{13}$	2.0
25	150	1	0.05	0.63	2.34 $\times 10^{12}$	0.4
25	150	34	0.05	0.63	8.00 $\times 10^{13}$	3.4
25	150	10	1.0	0.63	4.67 $\times 10^{14}$	20.0
25	150	10	0.01	0.63	4.67 $\times 10^{12}$	0.2
25	150	10	0.05	0.37	4.67 $\times 10^{12}$	0.2

Volume range from Robinson and Draper, 1978.

Critical distance range from Robinson and Draper, 1978.

Percent delivery range from Robinson and Draper, 1978.

Stack decay range from Thelin and Gifford, 1983.

Variation in Field decay was estimated by authors.

APPENDIX C6 : Sensitivity Analysis For Spring, Summer And Fall Spreading Load

LOAD = Volume x DD x CD x Delivery x Stack decay x Field decay

Volume is dependant on # bacteria produced, # bacteria winter spread, access load, volume of manure overspread and % of operators overspreading.

Drain Density (OD) remains constant at 1.09 km/sq.km

% Volume overspread	% Operators overspreading	Critical Distance (m)	Delivery %	Stack Decay	Field Decay	LOAD	Ratio
25	5	150	5	0.01	0.63	7.11×10^{11}	1.0
10	5	150	5	0.01	0.63	2.85×10^{11}	0.4
40	5	150	5	0.01	0.63	1.14×10^{12}	1.6
25	1	150	5	0.01	0.63	1.42×10^{11}	0.2
25	10	150	5	0.01	0.63	1.42×10^{12}	2.0
25	5	30.5	5	0.01	0.63	1.44×10^{11}	0.2
25	5	305	5	0.01	0.63	1.44×10^{12}	2.0
25	5	15	1	0.01	0.63	1.42×10^{11}	0.2
25	5	150	15	0.01	0.63	2.13×10^{12}	3.0
25	5	150	1	0.05	0.63	3.56×10^{11}	0.5
25	5	50	1	0.05	0.30	4.18×10^{11}	0.6

Variations in percent volume spread, percent of operators overspreading, percent delivery and field decay were estimations made by authors.

Critical distance range from Robinson and Draper, 1978.

Stack decay range from Thelin and Gifford, 1983.

APPENDIX C7: Sensitivity Analysis For Septic System Load

LOAD = Conc. x Vol./person/day x Pop'n x Failure rate x Delivery

Concentration (FC/L)	Volume/ person/day (L)	Pop'n	Failure Rate	Delivery (%)	LOAD	Ratio
1 $x10^{7}$	275	#	0.3	50	2.17 $x10^{14}$	1.0
1 $x10^{8}$	275	#	0.3	50	2.17 $x10^{15}$	10.0
$1X10^{7}$	275	#	0.6	50	4.30 $x10^{14}$	2.0

Concentration range from Bos, 1988.

Variation in Failure rate was estimated by authors,

APPENDIX D

D1: 1987 Measured Load At Brussels

D2: 1988 Measured Load At Brussels

D3: 1988 Measured Load At Summerhill

D4: 1987 Measured Load At Benmiller

D5: 1988 Measured Load At Benmiller

APPENDIX D1: 1987 Measured Load At Brussels
(from water quality and streamflow data)

Month	Mean Daily Flow/Month (cm)	L/day	Days/ Month	Mean Monthly FC conc./L	Load
Jan.	6.9	5.96×10^{8}	31	-	-
Feb.	4.3	3.72×10^{8}	28	-	-
Mar.	26.0	2.25×10^{9}	31	4720	3.29×10^{14}
April	12.9	1.11×10^{9}	30	1530	5.09×10^{17}
May	1.5	1.30×10^{8}	31	720	2.90×10^{12}
June	1.4	1.21×10^{8}	30	2540	9.22×10^{12}
July	9.6	8.29×10^{8}	31	22120	0.68×10^{14}
Aug.	4.6	3.97×10^{8}	31	6000	7.38×10^{17}
Sept.	0.8	6.03×10^{7}	30	4640	9.51×10^{12}
Oct.	3.4	2.94×10^{8}	31	490	4.47×10^{12}
Nov.	8.4	7.26×10^{8}	30	2000	4.36×10^{13}
Dec.	14.9	1.29×10^{8}	31	2190	8.76×10^{13}
TOTAL					1.18×10^{15}

APPENDIX D2: 1988 Measured Load At Brussels

(from water quality and streamflow data)

Month	Mean Daily Flow/Month (cms)	L/Day	Days/ Month	Mean Monthly FC conc./L	Load
Jan.	15.5	1.34×10^{9}	31	560	2.33×10^{17}
Feb.	25.2	2.18×10^{9}	29	760	4.80×10^{17}
Mar.	-	-	31	2400	-
April	9.4	8.12×10^{8}	30	230	5.60×10^{17}
May	5.5	4.75×10^{8}	31	950	1.40×10^{17}
June	-	-	30	760	-
July	0.3	2.59×10^{7}	31	1130	9.08×10^{14}
Aug.	-	-	31	360	-
Sept.	1.1	9.50×10^{7}	30	3080	8.78×10^{15}
Oct.	3.8	3.28×10^{8}	31	10730	1.09×10^{14}
Nov.	17.6	1.52×10^{8}	30	7200	3.28×10^{14}
Dec.	10.9	9.42×10^{8}	31	570	1.52×10^{13}
TOTAL					5.46×10^{14}

APPENDIX D3: 1988 Measured Load At Summerhill

(from water quality and streamflow data)

Month	Mean Daily Flow/Month (cms)	L/Day	Days/ Month	Mean Monthly FC conc./L	Load
Jan.	8.55	7.43×10^{8}	31	-	-
Feb.	12.23	1.05×10^{9}	29	-	-
Mar.	23.97	2.07×10^{9}	31	400	2.57×10^{13}
April	6.52	5.62×10^{8}	30	600	1.01×10^{13}
May	2.56	2.25×10^{8}	31	1580	1.08×10^{13}
June	0.61	5.27×10^{7}	30	1410	2.23×10^{12}
July	0.27	2.33×10^{7}	31	2360	1.71×10^{12}
Aug.	0.30	2.59×10^{7}	31	1420	1.14×10^{12}
Sept.	0.53	4.58×10^{7}	30	4230	5.81×10^{12}
Oct.	13.17	1.14×10^{9}	31	14990	5.29×10^{14}
Nov.	18.95	1.64×10^{9}	30	1580	7.76×10^{13}
Dec.	12.98	1.12×10^{9}	31	160	5.56×10^{12}
TOTAL					7.06×10^{14}

APPENDIX D4: 1987 Measured Load At Benmiller

(from water quality and streamflow data)

Month	Mean Daily Flow/Month (cms)	L/day	Days/ Month	Mean Monthly FC conc./L	Load
Jan.	22.35	1.93×10^{9}	31	-	-
Feb.	15.53	1.34×10^{9}	28	-	-
Mar.	91.73	7.93×10^{9}	31	87	2.14×10^{14}
April	46.91	4.05×10^{9}	30	33	4.01×10^{17}
May	7.51	6.49×10^{8}	31	17	3.42×10^{12}
June	7.34	6.34×10^{9}	30	67	1.27×10^{17}
July	16.69	1.44×10^{9}	31	40	1.79×10^{17}
Aug.	11.00	9.50×10^{8}	31	780	2.30×10^{14}
Sept.	4.59	3.97×10^{8}	30	70	8.34×10^{12}
Oct.	12.47	1.08×10^{8}	31	72	2.41×10^{17}
Nov.	41.54	3.59×10^{9}	30	179	1.93×10^{13}
Dec.	69.60	6.01×10^{9}	31	134	2.50×10^{14}
TOTAL					9.93×10^{14}

APPENDIX D5: 1988 Measured Load At Benmiller

(from water quality and streamflow data)

Month	Mean Daily Flow/Month (cms)	L/Day	Days/ Month	Mean Monthly FC conc./L	Load
Jan.	48.90	$4.22X10^{9}$	31	-	-
Feb.	49.12	$4.24X10^{9}$	29	-	-
Mar.	93.91	$8.11X10^{9}$	31	80	$2.10 x10^{14}$
April	39.60	$3.42X10^{9}$	30	19	$1.95 x10^{13}$
May	16.07	$1.39X10^{9}$	31	43	$1.85 x10^{12}$
June	4.89	$4.22X10^{8}$	30	13	$1.65 x10^{12}$
July	2.96	$2.56X10^{8}$	31	53	$4.21 x10^{13}$
Aug.	3.63	$3.14X10^{8}$	31	125	$1.22 x10^{13}$
Sept.	4.14	$3.58X10^{8}$	30	140	$1.50 x10^{13}$
Oct.	35.78	$3.09X10^{9}$	31	425	$4.07 x10^{14}$
Nov.	65.31	$5.64X10^{9}$	30	100	$1.69 x10^{14}$
Dec.	43.15	$3.73X10^{9}$	31	8	$9.25 x10^{12}$
TOTAL					$8.41 x10^{14}$