The First Lake Total System Watershed Management Project

Phase I: Neighbourhood Stewardship

1993/94

by

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EXECUTIVE SUMMARY

First Lake in Lower Sackville, Nova Scotia, is a part of the watershed of the Shubenacadie River, which drains into the Bay of Fundy. The watershed of First Lake is approximately 3.6 km^2 in area and is largely developed as residential housing. The residents enjoy swimming and canoeing on the lake, but the swimming beach is occasionally closed because of high fecal coliform counts. A previous study identified dog feces as the likely source. On the basis of phosphorus loading (phosphorus being the nutrient limiting further growth of lake algae), the lake is borderline mesotrophic. This means that the lake is more productive of algae than comparable, pristine lakes. The residents have expressed interest in programs to protect and improve lake water quality.

TOTAL SYSTEM WATERSHED MANAGEMENT (TSWM) is a concept whereby, on a whole system basis, with community involvement, ecological technologies are employed to: reduce inputs at source, diversify landscapes, improve soil structure for increased infiltration, stabilize disturbed sites against erosion, and control pests without harming water quality. Only some aspects of the concept have been studied at First Lake to date.

The objective of the First Lake TOTAL SYSTEM WATERSHED MANAGEMENT PROJECT - Phase I is to determine whether residents can effect an improvement in the quality of stormwater by implementing practices, on and adjacent to their own properties, designed to reduce phosphorus runoff and accumulation of pet feces. The project, assisted by the Canada - Nova Scotia Cooperative Agreement on Sustainable Economic Development, is organized as a cooperative venture of four groups; the residents, Halifax County Municipality, a landscaping company, and an aquatic sciences company. It involves comparison of total phosphorus (TP) and fecal coliforms (FC) in stormwater coming off two drainage subsystems:

(i) a control subsystem where practices remained unchanged (Control Area); and (ii) an improved stewardship subsystem (Test Area). Improved stewardship includes: quick removal of pet feces from properties, regular cleaning of the street gutter, collection and composting of yard wastes, use of phosphorus-free detergents for washing vehicles; and avoidance of phosphorus fertilizers except as indicated essential by soil analysis.

Between April 19 and October 13, 1993, water samples were collected and flows measured in runoff from the Test and Control Areas at 15 minute intervals during thirteen selected rainfall events. Water samples were analyzed for total phosphorus, inorganic phosphorus, pH, nitrate, conductivity and fecal coliforms. Fluxes of total phosphorus and fecal coliforms were calculated and the average difference between Test and Control Areas was tested for statistical significance. Observed fluxes were also related to their particular class of weather conditions; this provides an estimate of the fluxes to the lake of bacteria and phosphorus by dry weather flow, by light rains and by heavy rains.

TSWM Phase I CONCLUSIONS

1) Indications are that TWSM intercepts significant sources of FC at source. It appears that pet manures are a major source of FC (and possibly also of TP) in runoff and that FC in runoff can be significantly reduced by conscientiously removing pet manure.

2) For TP, although more data are required, four findings can be reported:

   (a) These stewardship practices did appear to reduce TP flux from the Test Area during strong storms.

   (b) In one weak storm the TP flux from the Test Area was lower than the TP flux from the Control Area. Indications were that chemical fertilizer P had bene present in the Control Area. For other weak storms there was little difference between TP fluxes from the two areas.

   (c) Groundwater concentrations and dry weather fluxes of TP were both higher from the Test Area.

   (d) Reducing spillage of fertilizers and gathering up pet manure and vegetative litter from the gutters should reduce TP flux during storms. To reduce groundwater concentrations of TP, it appears that careful management of turf soils, vegetative litter and P fertilizers - lawn aeration, composting yard wastes, application of P as rock-P only as indicated from soil tests, all practised together with pet manure management - may capture the major sources of TP and, over time, reduce TP in groundwater.

3) These are non-replicated experiments so it is possible that the results are site-specific. This possibility is less likely in the case of FC since the mechanism is fairly clear - pet manure is likely the major source and it can be removed. In the case of TP, where we have not identified the particular source and stewardship practice of greatest effectiveness, we cannot have quite the same confidence that these results can be replicated, but we consider it highly probable that they can and will be replicated.

4) Residents can sustain programs which lead directly to improved environmental quality. Residents carried out a program of stewardship for the entire growing season and produced some improvements in stormwater quality. The results of this pilot project in neighbourhood stewardship are encouraging, especially in an era when municipalities are finding it difficult to provide expensive services such as stormwater treatment. This common-sense approach to reducing undesirable contaminants in stormwater, and by extension, lake water, is likely to be appropriate, not just in principle, but also in practice.

5) TSWM has been demonstrated to be capable of generating environmental benefits, i.e. storm water runoff with reduced bacterial concentrations. Environmental benefits, in terms of reduced phosphorus concentrations, and economic benefits, through employment for program coordinators and savings to municipalities, are anticipated for the future.

TSWM Phase I RECOMMENDATIONS

The goal for 1994 is to demonstrate the effectiveness of TSWM to a level acceptable for commercial applications. We recommend to the community of the First Lake watershed the following objectives for pursuing this goal:

1) That stewardship on the Test Area and monitoring on the Control and Test Areas be continued to obtain additional data regarding the effectiveness of the concept for improving stormwater quality.

2) That the Phase I stewardship practices be verified individually in laboratory-style tests on plots of turf and pavement at the fire-hall and elsewhere in the watershed.

3) That the FC part of the TSWM approach be extended to the entire watershed in summer 1994, and that, if the results of 1) and 2) above are positive, the TP stewardship also be included in this whole watershed program.

4) That the other aspects of TSWM, e.g. stabilization of newly exposed areas against erosion, improved playing field turfs, etc., should be included in future years.

LIST OF ACRONYMS

CWRS -	Centre for Water Resources Studies, TUNS
FC -	Fecal Coliforms
IP -	Inorganic Phosphorus
K -	Potassium
MPN -	Most Probable Number
N -	Nitrogen
P -	Phosphorus
SWMM -	Storm Water Management Model
TP -	Total Phosphorus
TSOM -	Total System Organic Management
TSWM -	Total System Watershed Management
TUNS -	Technical University of Nova Scotia

1.0 INTRODUCTION

1.1 TSWM Concept

This project represents the first stage in development and testing of a new approach - TSWM or Total System Watershed Management - for reversing the deterioration of urban water bodies. The First Lake situation is far from unique. Many water bodies within urban landscapes, including lakes, streams, rivers and harbours are undergoing progressive deterioration in spite of the implementation of zoning restrictions, creation of buffer zones, sewage servicing and use of non-phosphate detergents. Major causes appear to be short term but massive runoff of sediment from construction activities, runoff and leaching of urban agrochemicals, road salts and vehicle emissions, atmospheric deposition and runoff of leachates and particulates from organic refuse including conduits into the water bodies, carrying materials that might otherwise be filtered by the landscape vegetation, directly into streams, lakes and harbours (Mansfield, 1993; National Research Council, 1992).

The primary goal of Total Systems Watershed Management is to reduce inputs of sediment, organic matter, fecal bacteria, nutrients and toxins to water bodies as much as possible at source by promoting ecologically sound stewardship practices and technologies (Figure 1.1). TSWM can work in combination with existing technologies to reduce the need for much more expensive types of treatment. Many of these individual technologies are adapted from the "TSOM" (Total System Organic Management) approach to landscape management developed and proven feasible by Edmonds Environmental Services (Edmonds, 1993); others are novel, or have not been tried locally. The essence of TSWM, however, is not just its component technologies, but its overall influence within a Total Systems context, the total watershed.

A key concept of TSWM is that of using the lake (or other water body of concern) as the vehicle to mobilize and organize community concern and involvement in TSWM and sustainable development activities more generally. The lake is a commons that everyone values in small and large ways.

Its quality serves as a monitor of how the community is doing, individually and collectively, and is used to 'sell' involvement in the issue. The rewards are maintenance and improvement of a treasured resource, community pride, keeping costs to a minimum, and keeping expenditures and employment as much as possible, within the community.

This first venture in TSWM is supported by the Canada - Nova Scotia Cooperative Agreement on Sustainable Economic Development. It is organized as a cooperative venture between residents, municipal government (Halifax County Municipality), and private enterprise (Edmonds Environmental Services, a landscape management company, and Loucks Oceanology Limited, an aquatic sciences consulting firm). This metro region is especially appropriate for developing and testing the approach because of its many lakes, their high recreational value, the presence of lakes as yet undeveloped and in the process of development, and lakes that have been subjected to varying degrees of development and deterioration. It is expected that over a period of years the project will develop as appropriate, testing and implementing most of the component TSWM technologies (Figure 1.1). The lessons that are learned from the First Lake project can contribute towards improvement of all lakes in metro, and serve to develop local expertise and skills that can be applied elsewhere, in Nova Scotia and beyond.

1.2 Site

First Lake, in Lower Sackville, Nova Scotia, is a part of the watershed of the Shubenacadie River, which drains into the Bay of Fundy. The watershed of First Lake is approximately 3.6 km^2 in area and is largely developed as residential housing (Figure 1.2). This is a headwater lake, with no defined, inflowing natural water courses; it receives only storm runoff, primarily through open ditches and piped storm sewers, as well as groundwater. The residents enjoy swimming and canoeing on the lake, but the swimming beach is occasionally closed because of high fecal coliform counts. In summer, including the summer of 1993, these counts commonly exceed the health guideline (Nova Scotia Dept. of Health).

Most of the development within the First Lake watershed occurred in the 1970's and 1980's and is primarily single-family residential, with some institutional (e.g. churches, schools, community-use buildings), apartment buildings, commercial and semi-detached residential.

The developed area of the watershed is within the Serviceable Area Boundary of the Municipality. This means that virtually all of the houses and streets are provided with water, sanitary sewer and storm sewer systems. Because these services are provided, the lot sizes can be smaller than those in an unserviced area. For example, single family lots can be as small as 6000 square feet, and the average is generally not much greater than the minimum.

Like most lakes with a developing or developed watershed, there has been a deterioration in the quality of the water in the lake. The condition of the lake is not especially different from other lakes with a developed watershed. In fact, the condition of First Lake is probably better than other similar such lakes. The reason First Lake was selected for this study was not that the lake was in especially poor condition but rather because of the interest shown by the residents in the quality of the water in "their lake".

In response to the concern expressed by the residents, Halifax County Municipality commissioned a study to identify causes of deteriorating water quality in First Lake (CWRS, 1990). The study identified dog feces as the likely primary source of bacterial contamination. Also, on the basis of total phosphorus (TP) concentration, the lake was considered borderline mesotrophic. CWRS made the following recommendations:

1) consider the effectiveness and practicability of source controls and implement those that can reduce bacterial contamination of stormwater and/or lake waters.

2) identify undeveloped wetland and buffer strip areas that might be used for storage and/or treatment of stormwater.

3) design, install, and evaluate demonstration projects for stormwater quality management.

4) encourage the use of minimal amount of chemicals such as fertilizers and deicing salt.

5) discourage the placement of dead plant material, such as leaves and grass clippings, in streets or other areas subject to stormwater runoff.

This project was developed as an innovative follow-up of the CWRS study - specifically Recommendations 1,3,4 and 5, above - with the goal of formulating, testing and implementing measures that would reverse the apparent deterioration of the lake, and protect it in the future.

1.3 Phase I of the TSWM Project

Lakes are one of the components of the hydrological cycle. They are fed by water in one of several ways - direct rainfall, surface runoff and groundwater. The development of land can change dramatically the drainage patterns and flows within the watershed. Large areas of natural vegetation are typically removed and replaced with impervious surfaces - roofs, driveways, streets, parking lots - and with lawns and playing fields and other recreational facilities. Drainage systems - catch basins, pipes, drains and ditches - are installed to collect and concentrate stormwater, and to direct it away from the developed land to the natural water courses - streams, rivers, lakes.

The usual result of all of this activity is that the receiving bodies of water get more surface runoff post-development, and that surface runoff gets there much more quickly. The buffering and filtering effect of the natural vegetation is lost. Materials suspended or dissolved in the surface runoff are much more likely to be channelled to the natural watercourses. Post-development, this can include any nature of material deposited on the ground surface by people (and their pets) living, working and carrying out their normal daily activities in a watershed.

The broad objective of the First Lake TOTAL SYSTEM WATERSHED MANAGEMENT (TSWM) Project concerns improving infiltration, preventing erosion and siltation, and reducing stormwater fluxes of constituents harmful to the lake.

We have proceeded by evaluating present conditions and by working with the community, suggesting several ways to improve soil capacity to absorb and hold water, upgrade runoff water quality, and thus improve lake water quality.

The primary objective of the First Lake TSWM Project - Phase I is to determine whether residents can effect an improvement in the quality of storm runoff water by implementing practices designed to reduce phosphorus (P) and fecal coliform bacteria (FC) in runoff from their own properties. P is usually the limiting nutrient and is associated with lake eutrophication. This means that if P can be reduced, algae biomass can be reduced. Lake eutrophication is a gradual process of chronic deterioration. The timescale of reduction of P in the lake is estimated to be more than one year. Excess FC in First Lake is an acute condition associated with heavy rainfall events and leading to beach closures in summer. The timescale of reduction of FC in the lake is estimated to be approximately one month.

A secondary objective was to develop and evaluate processes for community involvement in the diagnosis and remediation efforts. The significance of storm runoff from urban areas as a major mechanism for transporting pollution loadings to local waterways has only recently begun to gain attention (Mansfield, 1993). This project invokes an approach that apparently, has not been tested before - the simple expedient of improving neighbourhood stewardship to reduce as much as possible the input of these materials into the storm sewers in the first place.

The TSWM approach has the advantages of not requiring additional land for treatment, and of allocating improvement costs to those who will reap the benefits. Phase I focuses on two inputs: phosphorus from horticultural operations, home car washes, feces and organic debris; and FC from pet feces. The project involves two similar 'sub-watersheds' on First Lake, i.e. Crimson Drive, and a portion of First Lake Drive. (A sub-watershed is a portion of a watershed, the drainage from which flows to a common point).

Two other aspects of watershed management were given preliminary examination:

(1) Several foundation drains were inspected for the accumulation of silt. These drains, which are connected to storm drainage systems, could be a source of silt and P input to the lake.

(2) The potential for improving infiltration of the particularly tight soils in the region by use of aeration, compost or other soil amendments on existing turf was tested. Improving infiltration - and turf quality generally - will result in less runoff of silt and fertilizers into the lake. A preliminary study was conducted as a result of a Sackville student at Dalhousie University expressing a wish to conduct such a study voluntarily. These studies are described in Appendices A and B.

The study began in March, 1993, and was completed in March, 1994. Community meetings were held at curbside in April, and in a meeting hall in May, and June, as well as a final meeting in spring, 1994. Training sessions were held for volunteers who participated in the sampling program. Many individual consultations were provided for homeowners on questions of yard-care with lake awareness.

2.0 METHODS

2.1 Paired Watersheds

The focus of our monitoring program was to test the hypothesis that adoption of certain stewardship practices by residents can effect an improvement (reduction) in the flux[7] of FC and TP to the lake. The paired watersheds approach (Clausen, 1991) was used to test the hypothesis. In this approach, monitoring is begun on both areas for a baseline period before new stewardship practices are implemented; then stewardship is applied to one area, the Test Area, while the other serves as a control, the Control Area. A stewardship effect is indicated if the slope of the regression line between paired data (concentrations or fluxes) from the Test Area and from the Control Area is reduced after implementation of new stewardship practices.

[7] Flux of FC or TP is defined in §2.3; in brief it is the product of flow (L/s) and concentration (e.g. μg/L) to yield export (μg/s). Thus flux can be reduced by reducing the flow (e.g. enhancing infiltration) or reducing the concentration (e.g. source controls).

Any conclusion will be a statistical inference or suggestion rather than a strict proof, since the experiment, including baseline was confined to a seven-month period (April - October) in 1993, and has not been replicated. However, this experimental design was considered superior to the 'two-watersheds' approach which does not include a baseline period (Clausen, *ibid*).

The two areas chosen for this study are Crimson Drive (Test Area) and First Lake Drive (Control Area) (Figure 2.1). Both are within the watershed of First Lake and are typical of the First Lake watershed in terms of land use and drainage characteristics. Many homes in each area are 'split' - i.e. on the boundary of the sub-watershed. The land use within both areas is fully single-family and completely developed. Both areas are fully serviced with piped water, sanitary sewer and storm sewer systems. There is the standard provision of catch basins, and house foundation drains are connected to the storm sewer. In each area, the roof downspouts of some houses are connected to the foundation drain. Other downspouts discharge directly onto the ground surface adjacent to the foundation. As well, there are a small number of French drains which are connected to the storm sewer or discharge to the street gutter.

Some of the land is paved, some roofed, some in lawns and some remaining forested - and both areas have approximately the same area (1.9 ha for the Test Area, 2.0 ha for the Control, Table 2.1), number of homes (28 and 39 respectively) and impervious fraction (e.g. pavement, roofs) (0.27 and 0.25 respectively)[8]. The Test Area has a lower mean slope, .011, compared to .047 for the Control. For each of these areas, all of the surface runoff and a component of the groundwater flows into a single storm sewer and discharges through an outfall where the flow measurements and stormwater samples were taken. The flow from each outfall continues on to First Lake as overland and ditch flow. The rainfall was measured in a relatively open space near each outfall at the time of sampling stormwater.

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[8] Impervious areas were calculated with the help of two students from the Sackville Waters Advisory Board who measured roof and driveway areas.

Table 2.1 Physical Attributes of Control and Test Areas

Attributes	Control Area	Test Area
Area (hectares)	2.0	1.9
Mean Slope	0.047	0.011
Number of homes	39	28
Fraction of surface impervious	0.25	0.27

The baseline period lasted for approximately one month - April 24 until May 23. During this period residents in both areas were asked to refrain from applying lawn fertilizers. Otherwise stewardship practices were as usual. The baseline period was short because residents were eager to begin spring fertilizer applications.

A survey of all residents was carried out to determine their lawn fertilizer usage and to estimate the source strength of pet feces in each area. The numbers and sizes of pets were documented as well as the proportion of time that they left their wastes outdoors, permitting estimation of a source strength score (number x approximate weight x time fraction) for each area. A similar, follow-up survey was conducted at the conclusion of the study in December. A copy of the survey form is included as Appendix D.

2.2 Stewardship Practices

The effectiveness of this experiment was highly dependent on the support, cooperation and participation of the residents. Project staff endeavoured to earn that support by establishing an office in the area, by providing consultations on questions of lawn and yard care, by working with the residents on the sampling teams, and by keeping residents informed and updated through periodic leaflets and community meetings.

To reduce the fecal coliform bacteria available for wash-off, residents were asked to regularly pick up all pet feces for disposal in their toilet or garbage.

The stewardship practice adopted for reducing the total phosphorus available for wash-off had more component activities. It included regular cleaning of the gutter at curbside to pick up feces, vegetative litter and road dust, collection and composting of vegetative yard waste and feces, use of P-free detergents for washing vehicles; and use of P-free fertilizers, except as indicated essential by soil analyses. This horticulture program, to be acceptable, had to preserve the aesthetic appearance of lawns.

Soil samples for each participating residence on the Test Area were taken on May 20 and 21 and analyzed by A & L Laboratories, London, Ontario, using a Mehlich III extraction technique. A report was prepared for each residence and a consultation was held. P-fertilizer, where a requirement was indicated, was applied only as required and as coarse rock-P rather than the more soluble superphosphate (Appendix B.1).

Twenty-seven out of the twenty-eight homes in the Test Area chose to participate in the project. Unfortunately, the non-participating property did receive applications of P-fertilizers from a lawn-care company during the test period, one application just prior to the rain storm sampled on May 28.

In the Control Area residents were asked to continue with their normal stewardship practices for pets and lawns for the full duration of the project. For lawns these ranged from minimum maintenance without lawn fertilizers to regular attention form lawn-care companies.

2.3 Monitoring Fluxes

The experimental design allowed assessment on a within-storm basis and on an overall basis of the statistical significance of any differences between the two areas in mean concentrations, and fluxes, of FC and total phosphorus.

Flow measurements and stormwater samples were taken at 15 minute intervals, simultaneously, or nearly so, at the two storm outfalls for 2.5 hours at the beginning of a rainstorm. The intention was to capture the 'first flush' of bacteria and phosphorus (soluble or bound to sediment) accumulated over the previous dry period.

The bulk of phosphorus is usually transported to surface water by sediment transport during runoff (Walker and Branham, 1993). However, depending on timing of application of fertilizers and phosphorus content of surface vegetation and organic residues, soluble phosphorus losses in surface runoff may be relatively high (Anderson et al, 1989). One task which often proved difficult was to decide when to mobilize the sampling teams; rainstorms often started as just a drizzle for several hours, or produced much less precipitation than had been forecast, or, on rare occasions, much more.

Ten sequential samples, plus some duplicates as checks on analyses, were collected at each area. (On two occasions an eleventh sample pair was collected because rainfall increased near the expiry of the usual sampling period.) As well as flow measurements, rainfall was measured at each site for the purpose of calculating flows in the event that the measurement procedure should fail. Water samples were analyzed for FC, total and inorganic P, pH, conductivity and nitrate, the latter on selected samples only. The sampling was often done with the involvement of resident volunteers who had attended training sessions. The analyses were conducted at the Environmental Chemistry and Water Bacteriology Laboratories of the Victoria General Hospital, Halifax, for phosphorous[9] and bacteria; at the laboratory of the Mill Cove Pollution Control Plant, Bedford, for bacteria; and at the Biology Department, Dalhousie University, *for pH*, conductivity and nitrate.

Low flows were measured by observing the time required to fill a two-litre container, using a stopwatch. For high flows, the depth of the flow was measured and the flow was estimated using the Manning formula.

There were two occasions when flows could not be measured in the field - one when the stop watch failed (Storm 2, May 6, 1993), the other when the flow was extremely large and the sampling teams were not equipped for measuring the depth of flow (Storm 8, June 28, 1993).

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[9] As samples were received they were transferred to glass bottles and acidified to pH<2.

In both cases flows were inferred from the stormwater runoff model, SWMM (U.S. EPA, 1988), based on rainfall measurements - taken either at the Atmospheric Environment Service weather office approximately five km away in Bedford or on-site. The key parameters used for setting up SWMM are those in Table 2.1.

The flux of bacteria and phosphorus for each area at each of the ten sampling times during a storm was calculated as the (instantaneous) product of the flow (L/s) and the concentration of bacteria (MPN/100 ml) or phosphorus (μg/L). The mean flux for each area is the mean of the results of the ten sample sets in the 2.5 hour sampling period. To estimate the error in mean flux from the ten sample series, we used standard formulae (Topping, 1972) for the propagation of random uncertainties in products and sums. The difference between mean concentrations (and mean fluxes) for the two areas was tested for statistical significance using the t-test for matched pairs (Miller & Freund, 1965).

As well as an overall statistical analysis of the effect of stewardship in the paired areas, an additional analysis was carried out to distinguish between the flux conveyed by the mean flow and the flux conveyed by the fluctuating flow.

2.4 Lake Observations

In 1989, FC and TP data were recorded for First Lake as part of the CWRS study. The Soil and Water Conservation Society surveyed the lake for TP in 1992. Data on FC in First Lake in recent years were obtained from the Nova Scotia Department of Health. Samples for phosphorus analysis were taken from the lake's outlet, Sucker Brook, several times in the October-December period, 1993 (Appendix C.2).

3.0 RESULTS AND INTERPRETATION

The storm-sewer sampling results measuring the effectiveness of the stewardship practices are presented in this section. Examination of foundation drains for siltation is described in Appendix A. (Some of the drains examined were found to be clogged almost completely.) Sample soil reports for the Test and Control Areas are given in Appendix B.1. The Fire Hall turf amendment study is given in Appendix B.2.

The data on runoff hydrology and chemistry are tabulated in Appendix C.1. Lake data are tabulated in Appendix C.2. **3.1 Paired Sub-watersheds - Soils, Hydrology and Pets**

Soil reports for the Test Area taken in May, 1993, (Appendix B.1) showed that the structure of soils in this area permits only limited infiltration of air or water. The soil also indicated high levels of P in most turfs. For only 2 of the 28 properties was additional P required in 1993. The other 26 had ample or excessive supplies of P. Residents were encouraged to aerate turfs in spring, and at our suggestion, a number of residents in the Test Area rented and shared an aerator. The aerator pulls small plugs out of the turf. At a density of eight per square foot we estimate more than 200,000 small holes were created on Crimson Drive, allowing better access of air, water and fertilizers to roots. This was also designed to increase the capacity of soils to hold moisture. Enhanced infiltration can be expected to reduce surface runoff and improve water quality through filtration and adsorption in soils.

Soil samples for the Control Area, together with some repeat samples for the Test Area, were taken in November, 1993. The Control samples were partitioned into those for which P fertilizer was applied in the fall of 1993 (5 properties; average TP, 35.2 ± 6.7 mg/kg) and those for which fertilizer was not applied this fall (4 properties; average TP, 18.3 ± 2.8 mg/kg). (One sample for which no fertilizer was applied, but for which TP concentrations were the highest of all samples, was excluded. We speculate that this single anomalous value may be explained by the regular presence of the resident dog.) The ten Test Area November samples showed average concentrations of 33.4 ± 4.1 mg/kg. In May the average concentration in twenty-four samples was 38.8 mg/kg. The results, though not sampled extensively enough to be statistically conclusive, suggest that Test Area properties, which did not receive P fertilizer, show concentrations in the same range as those on the Control Area which did. Indeed both unfertilized Test Area properties and fertilized Control Area properties show concentrations twice as large as Control Area properties not recently fertilized.

There were 17 cats and dogs in the Test Area and 14 in the Control. This information together with the weights and outdoor habits of the pets suggested that the source strength for fecal coliform bacteria from pets in the Test Area is approximately 40% larger than that for the Control. This was consistent with the fluxes measured during the baseline period - those from the Test Area were higher than those from the Control (discussed in §3.3.3). Thus, the distribution of pets would bias unadjusted results against demonstrating a beneficial effect of stewardship. Initially we present fecal coliform results unadjusted for pet populations.

An experiment set up at the Fire Hall turf (Appendix B.2) showed that the fertilizers recommended for the Test Area - feather-meal to provide nitrogen, and as appropriate, rock phosphate to provide P, and potassium sulphate to provide potassium, were highly effective on the tight soils characteristic of this area.

3.2 Community Involvement

There was active support in the community for this project. From our final survey, residents in the Test Area spent an average of approximately one additional hour per week on their own properties on project-related stewardship. In addition residents from both Test and Control Areas distributed and collected survey forms. Some residents also volunteered to participate in conducting some of the storm runoff sampling. In this they were offered training and field support by the Project Coordinator. For storms occurring at awkward times of the work-week or at night, the Project Coordinator and other project staff carried out the sampling .

The yard-care stewardship practices suggested by project landscape staff in order to minimize leaching of P from vegetative litter and from P fertilizer from the Test Area elicited strong interest among the residents. Residents gathered and composted yard wastes in proper compost boxes with rain-lids. In most cases these compost boxes were supplied for a nominal fee by the project. A small number of residents already had backyard composters. There were special provisions made to provide lawn-care virtually without adding P fertilizer and without pesticides.

Residents de-thatched and aerated their lawns, and applied nutrients as required according to soil tests provided by the project - nitrogen via a feather-meal fertilizer, potassium as K_2SO_4, and phosphorus, where necessary, as rock-P, which dissolves only very slowly. There were many other issues addressed as well - chinch bug infestations in lawns, mowing techniques, pruning, soil-building, etc.

There was evidence in the final survey that some residents in the Control Area were stimulated to improve stewardship practices by the project, which also would tend to bias results against demonstrating a beneficial effect of stewardship. One resident in the Control Area for example, refrained from using fertilizer in the belief that it would help the project. It was also noted that some residents in the Control Area were picking up more pet feces as the season progressed.

3.3 Stormwater Quality

Examination of the results of chemical analysis as the baseline period progressed (Appendix C.1) suggested after three storms that the two areas were sufficiently similar in their hydrology and runoff chemistry so as to constitute a comparable pair for the purposes of this experimental project. Although the base period was, in hindsight, too short, there were also the community's wishes to consider - urging us to conclude the baseline period so that they could proceed with spring lawn fertilization.

Sample time series results are shown for a very low-flow storm (Figures 3.1 and 3.2), a slightly-higher-flow storm (Figures 3.3 and 3.4) and a high-flow storm (Figures 3.5 and 3.6). The complete data set is tabulated in Appendix C.1.

3.3.1 Time-series observations made during storms (stewardship period)

Plots are shown of flows and phosphorus concentrations for three representative storms. Figures 3.1 and 3.2 show data for a very-low-flow storm. The Test Area shows higher TP concentrations and IP/TP ratios.

Figures 3.3 and 3.4, are for a slightly higher flow storm. The flow was stronger from the Control Area and exhibited a 'first-flush' pulse of high concentration TP and high IP/TP ratio.

Figures 3.5 to 3.6 are for a high-flow-storm. IP/TP ratios are not high.

SWMM simulated flows compared favourably with measured flows for a calibration storm (Storm 9), although there is uncertainty associated with the fact that this SWMM calibration is being used to simulate flows for Storm 8 where flows were much higher. However, both Test and Control Area flows were simulated so their relationship should be preserved.

Random uncertainties in concentrations and fluxes are estimated (Topping, 1972) to be ±20% standard deviation in flow, ±10% in total P, and ±70% in FC - the latter two estimates are derived from the duplicate analyses. Then the standard deviation uncertainty in storm-mean concentration of TP is ±3%, and of FC is ±22%. The uncertainty in storm-mean flux estimates is ±7% for total P and ±23% for FC. In Storm 8 where simulated flow was used, the possibility exists for a systematic error in flow; nevertheless the relationship between fluxes from the Control and Test Areas would be preserved.

3.3.2 Water quality parameters versus flow

3.3.2.1 Instantaneous water quality parameters

Figure 3.7 is a plot of instantaneous observations of TP and IP versus flow from the Control Area during the stewardship period. One groundwater observation is included (near A). The envelope of the IP values is drawn. This envelope exhibits extreme modes at A, B and C. Mode A may be characterized as practically a dry weather or groundwater mode - very low flow and low IP. Mode B, a low flow mode, exhibits high IP. Mode C, a high flow mode, shows intermediate values of IP. Storms 6 (Figures 3.1 and 3.2), 12 (Figures 3.3 and 3.4) and 8 (Figures 3.5 and 3.6) tend to cluster near Modes A, B, and C respectively. Storms 6 and 12 differ, on the Control Area, chiefly in IP concentrations, due possibly to the presence of spillage of fertilizer on impervious surfaces. The observer witnessed one Control Area resident applying fertilizer just before the rain started, although very little spillage on the pavement was noticed.

Figure 3.8 is the corresponding plot for the baseline period, with the envelope repeated from Figure 3.7. Although limited to low and very low flows, it does provide an interesting contrast. The range of TP was constrained to low values during the baseline period when residents were requested to refrain from fertilizing lawns; much higher and more variable values occurred during the stewardship period when this constraint was relaxed (Fig. 3.7).

Figure 3.9, from the Test Area, corresponds to Figure 3.7 for the Control. The envelope shown is again the IP envelope unchanged from Figure 3.7. The groundwater mode, A, is at first puzzling; IP values were higher than in the Control Area. This appears to be related to the high soil TP values in the Test Area (Appendix B.1). Mode B, significantly, was completely absent; there was no 'first flush' of phosphorus from the Test Area. This is consistent with the practice of minimizing P fertilizers and sweeping gutters. Mode C shows IP and TP reduced in the Test Area compared to the Control. Figure 3.10, from the Test Area in the baseline period, corresponds to Figure 3.8. For the range of flows experienced, the TP values tended to be very slightly lower than those in Figure 3.9 for the Test Area in the stewardship period, and considerably higher than those for the Control in the baseline period, Figure 3.8.

Although no assay of IP/TP ratios in possible source materials was undertaken here, it is expected that most chemical fertilizers have IP/TP = 1, that vegetative material has IP/TP ~ 0.4, and that these sources are related - i.e. TP and IP levels in leaves increase as fertilizer phosphorus supplied to the plant is increased (e.g. Marschner, 1986). A value for the IP/TP ratio in pet feces has not been identified. Figure 3.11 from the Control Area in the stewardship period shows that those data near Mode B had high IP/TP ratios, suggesting a chemical fertilizer component, together with yard waste (vegetative litter). Modes A and C showed much lower IP/TP ratios, suggesting that yard waste may have been the predominant component. Figure 3.12 from the Test Area in the stewardship period shows that the many observations falling between Modes A and B exhibited the high IP/TP ratios suggestive of a chemical fertilizer component (as well as vegetative litter) even though little or no fertilizer P was applied.

(Soil tests did reveal a large stock of soil P (Appendix B.1).

Figure 3.13 shows a tentative association of stewardship practices with runoff modes. For example, the use of non-P detergents for washing cars should reduce TP in dry weather, Mode A, and use of a drop spreader for P fertilizer (if it is necessary that it be applied) should reduce TP and IP in Mode B, the 'first-flush' mode. Gathering yard wastes under cover in a composter and removing pet feces should reduce TP in mode C.

Figure 3.14 and 3.15 show electrical conductivity and IP versus flow for the stewardship period from Control and Test Areas respectively. The conductivity values, indicating the concentration of dissolved ions, were comparable in the two areas, suggesting that the two exhibited similar runoff processes. IP, which is a minor contributor to conductivity, was quite different in the two areas, suggesting that the P regimes were distinct. The P regimes were determined by the initial stocks of P and by TP stewardship through the growing season as discussed above.

Figures 3.16 and 3.17 show a similar modal framework applied to fecal coliform data in the stewardship period. Again the envelope is drawn for Control Area data. Water quality is shown to be better on the Test Area than on the Control Area in Modes B and C.

3.3.3 Water quality parameters versus time on the scale of months

Figures 3.18 to 3.21 compare mean concentrations from the two areas over time on a storm-by-storm basis. (Time is measured as days after March 31, 1993.) In Figure 3.18 for FC, the baseline period (ending on Day 54 and the stewardship period beginning on Day 55), and the health limit for swimming or body contact - 200 MPN/100 mls - are indicated. Arrows show directions of largest differences between Control Area and Test Area means. The mean concentrations in runoff varied over a wide range and often exceeded the health limit. In the baseline period, mean fecal coliform fluxes to the lake are greater in runoff from the Test Area than from the Control for all three storms but significantly so ($p=0.02$) only in the third storm, Day 43.

In the stewardship period, fluxes are reduced in the Test Area compared to the Control for four storms, on Days 59 ($p=0.42$), 67 ($p=0.06$), 89 ($p<0.01$), 179 ($p=0.07$) where the probabilities for observed differences occurring by chance are given in parentheses.

Figure 3.19 for total P shows the 'lake health' limit for an oligotrophic lake - 35 mg P/m^3 in stormwater, taking into account the retention of P in the lake. (Retention via sedimentation - approximately 70% in this case (Dillon et al, 1986) - accounts for the fact that lake P concentration can remain below $\sim$14 mg P/m^3, indicating an oligotrophic state (Kerekes, 1983), while stormwater supplies water at 35 mg P/m^3.) From the figure, the mean concentrations in the runoff varied over quite a wide range and often exceed this 'lake health' limit.

In the baseline period, for all three storms, mean TP concentrations are greater from the Test Area and mean TP fluxes are significantly greater ($p<0.05$) in runoff from the Test Area. In the stewardship period, concentrations and fluxes are reduced in the Test Area for four storms, on Days 67, 89, 179, and 196, significantly so for fluxes during the storms of days 67 ($p=0.05$), 77 ($p<0.01$), 89 ($p<0.01$) and 179 ($p=0.03$).

Focusing on differences in concentrations in stormwater between the Test and the Control Area, Figures 3.20 and 3.21 show the percentage reduction (increase) of concentration in the Test Area in comparison with the Control. The zero on the y-axis indicates no difference between concentrations in stormwater from the two areas. The difference for a particular storm is indicated by a circle where the size of the circle is proportional to the flux from the Control Area and the probability that the reduction (increase) in a particular storm could arise by chance is printed above the symbol (e.g. $p<0.10$ indicates a rather significant difference). After implementation of stewardship, storms were more likely to exhibit reductions in the concentrations of FC and TP from the Test Area. Correspondingly, as Figure 3.20 indicates, the occurrence of instances where Test Area concentrations exceeded Control Area concentrations appears to have been reduced as the stewardship period progressed, even though concentrations were higher in the Test Area during the baseline period.

Figure 3.21 is the corresponding plot for total P, which exhibited a pattern very similar to that for FC, i.e. the number of occasions where Test Area concentrations exceeded Control Area concentrations appears to have been reduced as the stewardship period progressed, even though concentrations were also higher in the Test Area during the baseline period.

4.0 DISCUSSION

4.1 Fecal Coliform Concentrations in Stormwater

Figure 3.22 shows reductions in FC observed in storm runoff from the Test Area in selected storms. The FC fluxes were first adjusted for FC source strength based on our survey of pets. Only storms in the stewardship period were considered. Of these, only storms with FC concentrations greater than 200 MPN/100 ml, the bodily contact guideline, were selected, i.e. concentrations that would potentially restrict the use of the lake. By this criterion Storms 6 & 7 were eliminated. Of the remaining six storms, four show Test Area fluxes reduced to less than 20% of those on the Control Area. Two storms show Test Area fluxes comparable with fluxes from the Control Area, which may serve to suggest that the stewardship must be sustained for consistently good results. Nevertheless the implication is that there is an improvement in runoff water quality arising because of the pet feces management practised by the residents in the Test Area.

FC flux measurements for individual storms may also be combined according to weather conditions to produce seasonal totals for bacteria exported toward the lake (Table 4.1).

Table 4.1 Classes of weather conditions, associated average FC fluxes (adjusted for pet population), and seasonal FC flux export budgets, with standard errors, for Control and Test Areas. (Dry weather fluxes are not available.)

Weather Class		Dry Weather	Light Rain	Heavy Rain	TOTAL
Fraction of time, April 1 to October 31		.9626[10] ±.0047	.0327[11] ±.0047	.0047[12] ±.0008	1.0000
Instantaneous FC Flux (MPN ha^{-1} s^{-1}) - averages from the data set					
	Control Area		12±6[13]	10500±2200[14]	
	Test Area		8±5[4]	1250±330[5]	
7-month Total TP export (10^6MPN/ha) - average instantaneous fluxes x fraction of time					
	Control Area		7±4	910±250	920±250
	Test Area		5±3	110±30	115±30

[10] From Environment Canada weather records for Halifax-Dartmouth, April to October, 1993, total rainfall was calculated - 766 mm. This rain was estimated to fall at an average rate of 4±0.5 mm/h. Thus an estimate was obtained of the hours of rain (192±24) and hence of the hours of dry weather (4944).

[11] The fraction of time with light rain is estimated as the difference between hours of rain and the estimated duration of heavy rain.

[12] From the daily precipitation records for Halifax/Dartmouth, taking 20 mm/day or greater as indicative of heavy rain, there are six days when heavy rain probably occurred. We estimate four hours duration of heavy rain on each occasion for a total of 24±4 hours or a fraction of 0.0047 in the April to October period.

[13] Average flux for Storms 4,5,6,7,10,11,& 12

[14] Average flux for Storms 8 & 13

The table indicates that, for the period sampled, heavy rainstorms account for more total FC export than do light rainstorms and that FC exported from the Control Area are significantly more numerous than those exported from the Test Area. Figure 3.23 illustrates these total FC exports.

In order for an improvement in runoff water quality to translate into a significant improvement in lake water quality, there are other processes to consider. Processes of dilution and bacterial die-off in the lake operate to reduce lake concentrations below runoff values. Fecal coliform concentrations in runoff ranged higher than 20,000 MPN/100 ml (Table C.9). Runoff is diluted after entering the lake and bacteria die with exposure to ultra violet from sunlight. Fecal coliform concentrations in First Lake, in 1989 through 1993 range up to 2000 MPN/100 ml - suggesting approximately ten dilutions, but still ten times over the guideline for swimming (200 MPN/100 ml). Since the present stewardship practices appear to have achieved 90% reduction when the flux was largest, then, provided other sources of pathogens, e.g. ducks in First Lake, do not become too plentiful, pet feces management shows promise of preserving the suitability for swimming. We suggest that, with the interception of bacteria from pet feces which Test Area residents have demonstrated, beach closures would be required less frequently.

4.2 Total Phosphorus Concentrations in Stormwater and Groundwater

The results (Figures 3.19, 3.21) can be used to construct a table of the TP flux budget which is informative. The frequency domain approach is used. The fluxes observed under various classes of conditions are multiplied by the frequency of occurrence of these classes. Thus one may obtain estimates of the total growing season fluxes and the relative contributions from various classes for the Control and Test Areas.

Table 4.2 Classes of weather conditions, associated average TP fluxes, and seasonal TP flux export budgets, with standard errors, for Control and Test Areas.

Weather Class		Dry Weather	Light Rain	Heavy Rain	TOTAL
Fraction of time, April 1 to October 31		.9626 ±.0047	.0327±.0047	.0047 ±.0008	1.0000
Instantaneous TP Flux (μg/ha/s) - averages from the data set					
	Control Area	1.6±.6[15]	37±16[16]	1690±330[17]	
	Test Area	4.4±1.6[6]	24±17[7]	610±110[8]	
7-month Total TP export (g/ha) - average instantaneous fluxes x fraction of time					
	Control Area	30±10	20±10	150±40	200±40
	Test Area	80±30	15±10	50±10	150±35

In terms of instantaneous fluxes from the Control Area, TP fluxes increase with flow. Similarly within the Test Area, fluxes increase with flow. Comparing the two Areas, the data suggest that, while dry weather flux is greater from the Test Area, storm fluxes are greater from the Control Area.

In terms of total TP export over the period of observation from the Control Area, heavy rainstorm exports are the largest contribution while dry weather and light rainstorm contributions are less. For the Test Area, the dry weather export is largest, although not significantly larger than that from heavy storms.

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[15] Estimated from Table C.1 as the product of the average dry weather flow and the average dry weather TP concentration divided by the area. Data is sparse.

[16] Average flux for Storms 4,5,6,7,10,11,& 12

[17] Average TP flux for Storms 8 & 13

The 7-month export of TP is partitioned between heavy rain periods, light rain periods and dry weather periods. as illustrated in Figure 3.24. These stewardship practices appear to have had good effect during heavy rains and some effect during light rains; export from the Test Area is reduced under those conditions. During dry weather, there is a substantial export from the Test Area - greater than that from the Control Area - due, we hypothesize, to a soil reservoir of TP in the Test Area which is inaccessible to these stewardship practices although they could prevent its recurrence in the future.

The prevention referred to above is entirely in the spirit of sustainable development - 'substituting information for saturation'. The idea is to perform soil tests and apply fertilizers only as required, rather than importing and applying more material than needed only to have it move to pollute lakes and streams.

A more detailed overview of the TP results is provided in the Figure 3.25. This figure shows the TP data, in ratio form, arranged by the corresponding Control Area flow along the x-axis. The y-axis is the ratio of TP flux from the Test Area over the TP flux from the Control Area, measured within ten minutes. The data above the line at $y = 1$ are supportive of the hypothesis - i.e. TP flux is larger from the Control Area. The data below the line, where TP flux is stronger from the Test Area are, we suggest, inaccessible to these stewardship practices in the short space of one growing season, but likely accessible over the long term.

The data are further classified by the ratio of inorganic phosphorus (IP) to total phosphorus. A ratio of IP/TP less than approximately 0.6 suggests a vegetative litter or pet feces source, while an IP/TP ratio greater than 0.6 suggests a strong chemical fertilizer component. The data points are partitioned into three classes based on IP/TP ratio: IP/TP > 0.6 in the Control Area samples (*), IP/TP > 0.6 in the Test Area samples (+), and IP/TP $\leq$ 0.6 (□).

Where IP/TP exceeds 0.6 in the Control Area samples (*), flows are moderate, and the flux ratio is usually much larger than one. Our interpretation is that chemical fertilizer was spilled onto pavement in the Control Area and washed into the storm sewer.

At very high flows, the flux ratio is also larger than one, but IP/TP is less than 0.6 (□). Our interpretation is that any fertilizer spilled on pavement prior to such a storm would be swept into the storm sewer previously, during the 'build-up' to the large flows.

Where IP/TP exceeds 0.6 in the Test Area (+), flows are low and the flux ratio is usually less than one. Our interpretation is that the low flow and dry weather flux from the Test Area, which from the previous figure is the largest contribution of TP flux from the Test Area, reflects a chemical fertilizer source exposed to ground water, consistent with the unusually high TP levels found in soil tests there[18]. This is the contribution which can be reduced by prevention through using soil tests and applying P fertilizer only as required.

There are four points, marked by triangles, which are above the main band of data, yet are not high IP/TP points. These points (3 from June 6, 1 from Sept 10) are high because of low flows and fluxes from the Test Area. There is an approximate ten-minute delay between samples on the two areas. This could contribute to the low flows, but there is also the possibility that low flows from the Test Area on June 6 arose because several lawns were recently aerated and the aeration process promotes infiltration over surface runoff.

To the extent that the interpretations prove correct, the phosphorus flux data show that the basket of stewardship practices is effective for high flows, and holds promise over the long-term for being effective at low flows by reducing P stocks in soils.

These estimates for the seven-month growing season are approximately consistent with other estimates. The Soil and Water Conservation Society (1993) quotes Waller (1977) and Waller and Novak (1981) as providing TP flux values of 520 and 1100 g ha^{-1} y^{-1} respectively for serviced residential areas.

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[18] We are suggesting that rainfall percolates through the soil, accumulating P concentration from the excess stock of P fertilizer, and flows through the topsoil and subsoil to French drains or foundation drains. The French drains lead to the street gutter and hence to the storm sewer, the foundation drains are connected directly.

The Chesapeake Bay watershed has been intensively studied because of serious degradation of important fisheries in the Bay. The observed efflux of P from urban areas in the Chesapeake Bay watershed is 650 g ha^{-1} y^{-1}, which is approximately half of the rate of flux from crop and pasture lands (Shuyler, 1993).

4.3 Lake Phosphorus

Average phosphorus concentrations in First Lake in recent years have ranged from 9 to 13 mg/m^3 (Soil and Water Conservation Society, 1992); samples in autumn 1993 from the lake outlet are in the range, 9 to 16 mg/m^3 (Appendix C.2). These concentrations straddle the mesotrophic threshold, e.g. 14 mg/m^3 (Kerekes, 1983). This is consistent with the assessment of CWRS (1990) and has important implications for P concentration in runoff.

Since calculations for phosphorus retention (Dillon et al, 1986) applied to First Lake suggest that 70% of the phosphorus load will be retained in the sediments, one can infer that, after accounting for P in precipitation over the lake, an average concentration of no more than 35 mg/m^3 in runoff can be tolerated in order to keep the average concentration in the water column at <13 mg/m^3. Concentrations of total P in runoff measured from the Test Area were never as low as 35 mg/m^3, although the potential for substantial reductions was demonstrated, e.g. Storms 8 and 12, Figure 3.21). Concentrations from the Control Area were only occasionally this low.

5.0 CONCLUSIONS

1) Indications are that these TSWM stewardship practices intercept significant sources of FC at source. It appears that pet feces are a major source of FC (and possibly also of TP) in runoff and that FC in runoff can be significantly reduced by conscientiously removing pet feces. In spite of a data gap during dry weather conditions, results over the seven-month sampling season suggest that heavy rains account for much more FC flux than light rains and that the FC export from the Control Area was eight-fold greater than that from the Test Area.

2) Although more phosphorus data are required, it can be reported that: a) These stewardship practices did appear to reduce TP flux during strong storms. b) TP flux was also reduced from the Test Area during a weak storm where indications are that chemical fertilizer P had been present on pavement in the Control Area. c) For other storms there was little difference between TP fluxes from the two areas. d) Over the seven-month growing season it appears that, although total TP fluxes from the two areas were approximately equal, storm fluxes were larger from the Control Area while dry weather fluxes were larger from the Test Area. This is consistent with the fact that groundwater concentrations of TP from the Test Area are relatively high. Reducing spillage of fertilizers and sweeping up vegetative litter from the gutters should reduce TP flux during storms. To reduce groundwater concentrations of TP, it appears that careful management of turf soils, vegetative litter and P fertilizers - lawn aeration, composting yard wastes, application of P as rock-P only as indicated from soil tests, - all practised together with pet feces management, may capture significant sources of total P and, over time, reduce P in groundwater.

3) These are non-replicated experiments so it is possible that the results are site-specific. This possibility is less likely in the case of FC since the mechanism is fairly clear - pet feces is likely the major source and it can be removed. In the case of TP, where we have not identified the particular source and stewardship practice of greatest effectiveness, we cannot have quite the same confidence that these results can be replicated, but we consider it highly probable that they can and will be.

4) Residents can sustain programs which lead directly to improved environmental quality. Residents carried out a program of stewardship for the entire growing season which resulted in improvements in stormwater quality. The results of this pilot project in neighbourhood stewardship are encouraging, especially in an era when municipalities are finding it difficult to provide expensive services such as stormwater treatment. This common-sense approach to reducing undesirable contaminants in storm runoff, and by extension, lake water, is likely to be appropriate, not just in principle, but also in practice.

5) TSWM has been demonstrated to be capable of generating environmental benefits e.g. stormwater runoff with reduced bacterial concentrations. Environmental benefits, in terms of reduced phosphorus concentrations, and economic benefits, through employment for program coordinators and savings to municipalities, are anticipated for the future.

6.0 RECOMMENDATIONS

The goal for 1994 is to extend the scope and scale of TSWM demonstrations to a level acceptable for commercial applications. We recommend to the community of the First Lake watershed the following actions for pursuing this goal:

1) That stewardship on the Test Area and monitoring on the Control and Test Areas be continued to obtain additional data regarding the effectiveness of the concept for improving runoff of TP. A complete schedule of fertilizer applications by residents in the Control Area will be essential since 1993 results suggest a strong influence on runoff TP due to spillage of fertilizer on impervious surfaces, depending on whether or not fertilizer was applied since the last rain.

2). That the Phase I stewardship practices be verified individually in laboratory-style tests on plots of turf and pavement at the Fire-hall and elsewhere in the watershed. This will involve setting up test plots as in 1993 - with and without fertilizer, with and without pet feces. These plots will be sprinkled with rain water. Then runoff will be collected and analyzed for FC and TP.

3) That one part of the TSWM approach - the Fecal Coliform part - be extended to the entire watershed in 1994. The strategy here is to seek evidence of the effectiveness of TSWM on the lake itself by inviting the whole watershed community to participate by managing pet feces for a limited period of perhaps four storms. At present First Lake is known to exhibit high bacteria counts after rainstorms. The hypothesis is that within a few weeks this major source of FC will be diminished in the watershed and that lower-than-usual values i.e. less than the health guideline will be observed in the lake itself.

4) If the results of 1) and 2) above are positive, the TP stewardship should also be included in this whole watershed program.

5) That the other aspects of TSWM e.g. stabilization of newly exposed areas against erosion, improved playing field turfs, etc., should be included in future years.

7.0 ACKNOWLEDGEMENTS

We are pleased to acknowledge the residents of Crimson Drive, who participated willingly as the Test Area and the residents of First Lake Drive and Cavendish Drive, who played the part of Control Area for this experiment. Their concern for First Lake motivated this project. Their dedication to sampling in the rain helped it actually produce results.

Greg Sharam, an honours biology Student at Dalhousie and a local resident, volunteered to conduct the turf trials at the fire-hall in the First Lake Watershed. The Atmospheric Environment Service of Environment Canada provided special weather forecasting services. The Sackville Waters Advisory Board and the Sackville Rivers Association welcomed this project and helped it materialize. The Nova Scotia Department of Health shared fecal coliform data. All these supporters and contributions are gratefully acknowledged.

We are also pleased to acknowledge those who reviewed and provided advice on drafts of the report - Shalom Mandaville, Paul Mandell, Dr. Neil Hutchinson, Dr. Joseph Kerekes, and Dr. D. H. Waller, P. Eng.

We also acknowledge the support of the Canada/Nova Scotia Sustainable Economic Development Agreement, which provided partial funding for the project, and especially Brad Hodgins, Provincial Coordinator.

8.0 REFERENCES

Anderson, J.L., J.C. Balogh & M. Waggoner. 1989. Soil Conservation Service Procedure Manual: Development of Standards and Specifications for Nutrient and Pesticide Management. Section I & II. USDA Soil Conservation Service. State Nutrient and Pesticide Management Standards and Specification Workshop, St. Paul, MN, July 1989, 453 pp.

Clausen, John C., 1991. Developing a monitoring system for rural surface waters: individual BMP'S, Nonpoint Source Watershed Workshop Seminar Publication, Office of Research and Development, Office of Water, U.S. EPA, p.99.

Centre for Water Resource Studies, Hart, W.C. and D. H. Waller, 1990. Examination of sources of bacterial and chemical contamination: First Lake, Halifax County, N.S., CWRS internal Report 90-9.

Dillon, P.J., K.H. Nicholls, W.A. Scheider, N.D. Yan and D.S. Jeffries. 1986. Lakeshore Capacity Study, Ministry of Municipal Affairs, Ontario, 89 pp.

Edmonds Environmental Services Division. 1993. Total system organic management for turfs, Highlights of The Oaks Experiments, Year II. Greenfacts Special Research Edition, Vol. 5, 14p.

Kerekes, J., 1983. Predicting trophic response to phosphorus addition in a Cape Breton Island lake. Proc. N.S. Inst. Sci., 33, p. 7-18.

Mansfield, M. 1993. Implementing a stormwater management program for water quality. Environmental Sciences and Engineering, November 1993, pp 60-62.

Marschner, H., 1986. Mineral Nutrition of Plants. Academic Press.

Miller, I. and J.E. Freund. 1965. Probability and Statistics for Engineers, Prentice-Hall, Englewood Cliffs, N.J., 432 p.

National Research Council, 1992. Restoration of Aquatic Ecosystems. Science, Technology and Public Policy. National Academy Press, Washington, DC.

Shuyler, L. R., 1993. Non-point source programs and progress in the Chesapeake Bay, Agriculture, Ecosystems and Environment, 46. 217-222.

Topping, J., 1972. Errors of Observation and Their Treatment. Chapman & Hall.

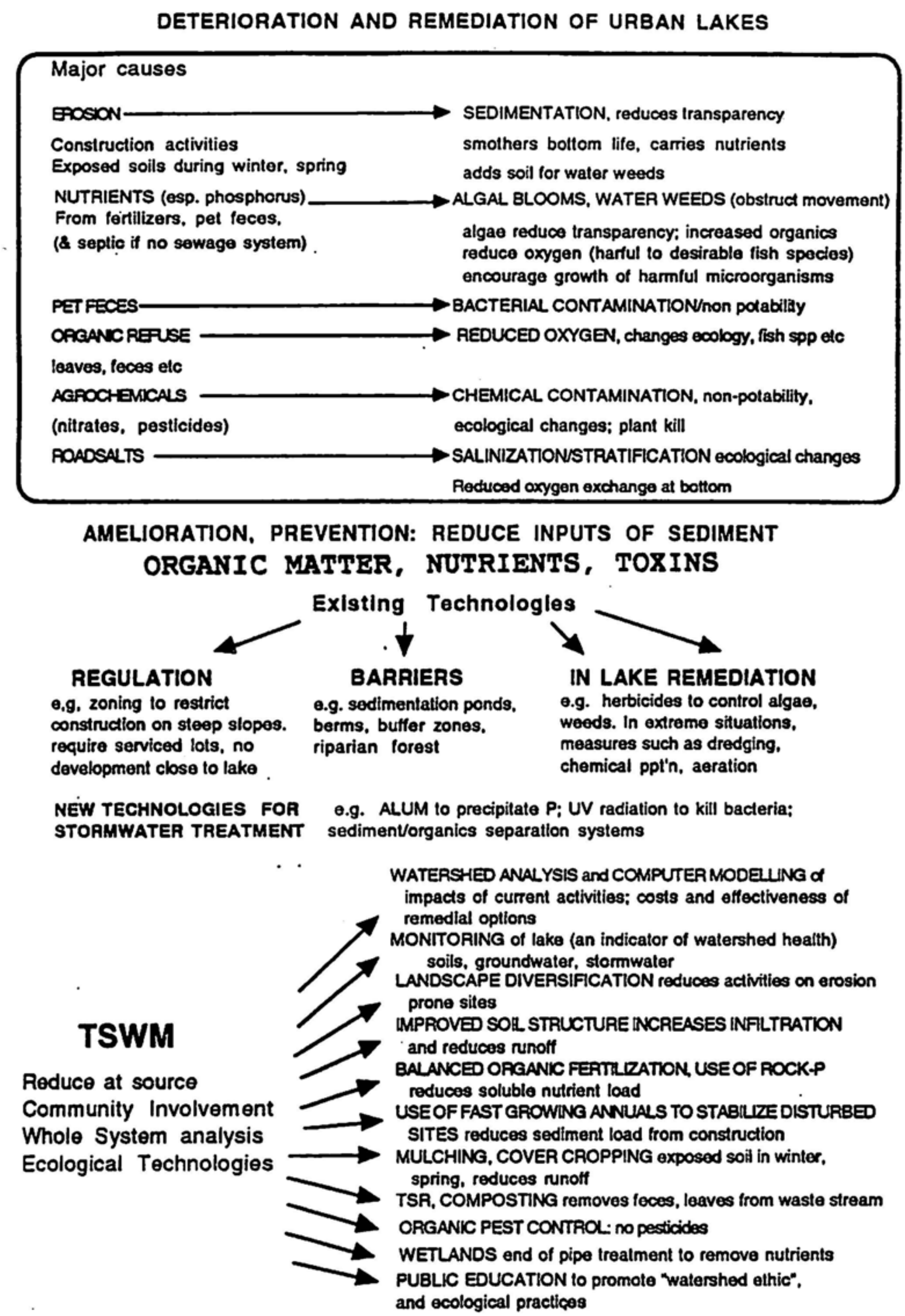
Soil & Water Conservation Society of Metro Halifax, 1992. Theoretical phosphorus loading in 27 Halifax County lakes, 71 p.

U.S. EPA. 1988. Storm Water Management Model, Version 4. Environmental Research Laboratory, Office of Research and Development, Athens, Ga.

Walker, W.J. and B. Branham. 1993. Environmental impacts of turf grass fertilization. Chap. 3 in Golf Course Management and Construction, Environmental Issues, eds. James C. Balogh and William J. Walker. Lewis Publishers, Ann Arbor.

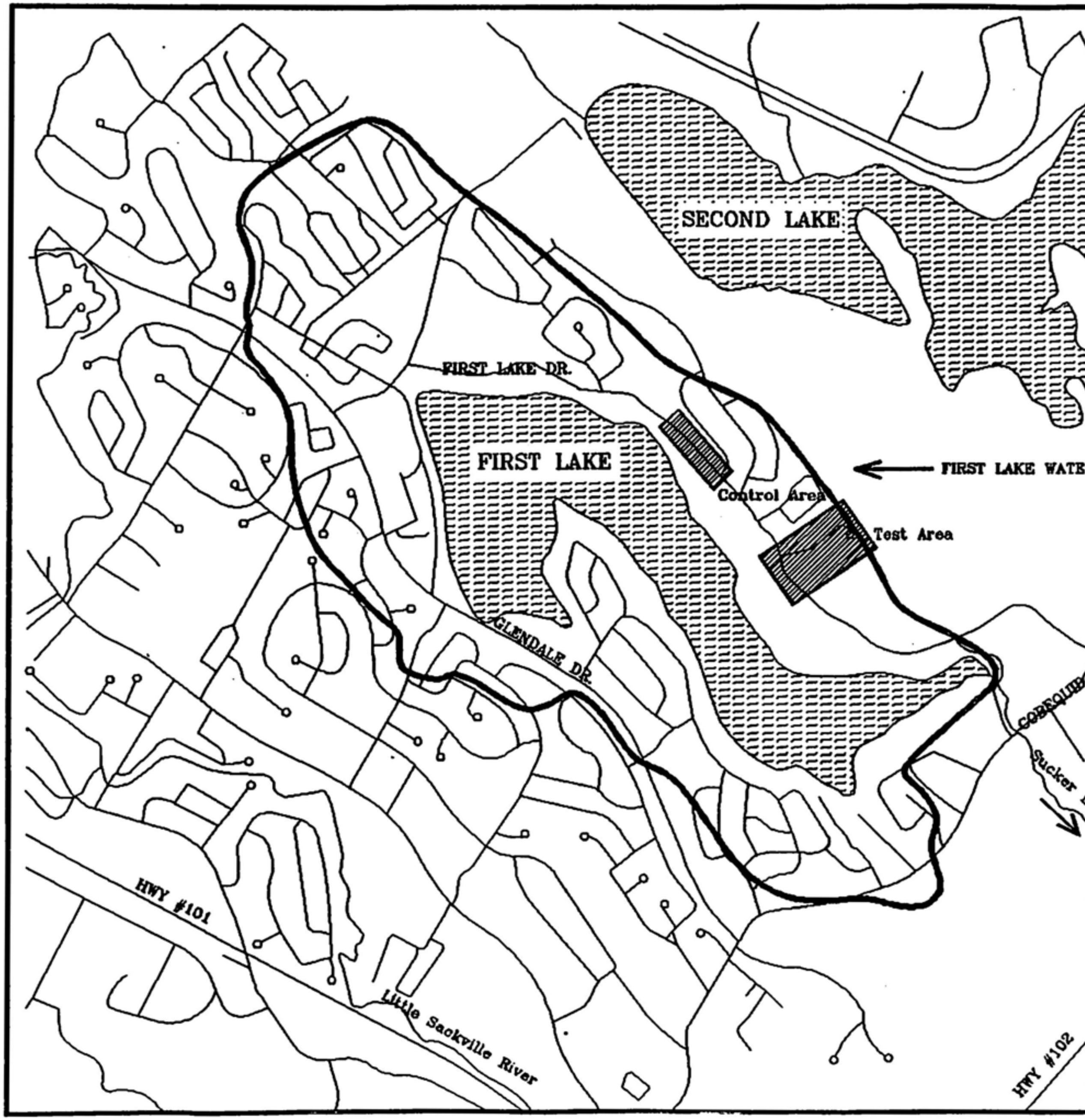
FIGURES

List of Figures



Some of the causes of deterioration of urban lakes, and remedial measures. TSWM is a whole system approach the goal of which is to maximize use and effectiveness of ecological techniques for control at source. It is complementary to other approaches, maximizing effectiveness of existing remedial and protection measures, and reducing the need for introducing more expensive technologies to maintain good lake quality.

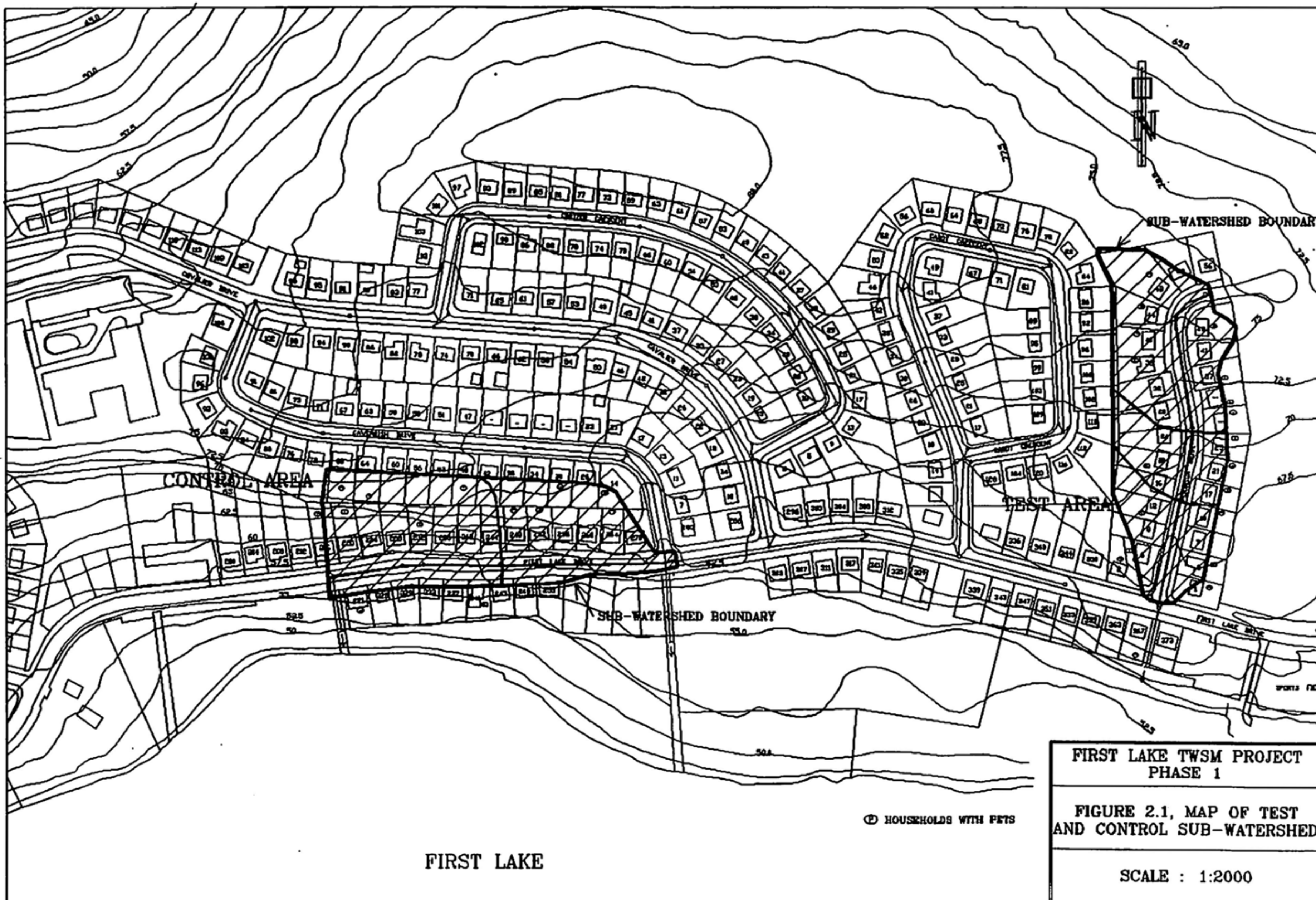
Figure 1.1 TSWM Concept



FIRST LAKE TWSM PROJECT
PHASE 1

FIGURE 1.2
FIRST LAKE WATERSHED
LOWER SACKVILLE, N.S.

SCALE = 1:10000


SUB-WATERSHED BOUNDARY
CONTROL AREA
TEST AREA
SUB-WATERSHED BOUNDARY
Ⓟ HOUSEHOLDS WITH PETS
FIRST LAKE
FIRST LAKE TWSM PROJECT
PHASE 1
FIGURE 2.1, MAP OF TEST AND CONTROL SUB-WATERSHED
SCALE : 1:2000

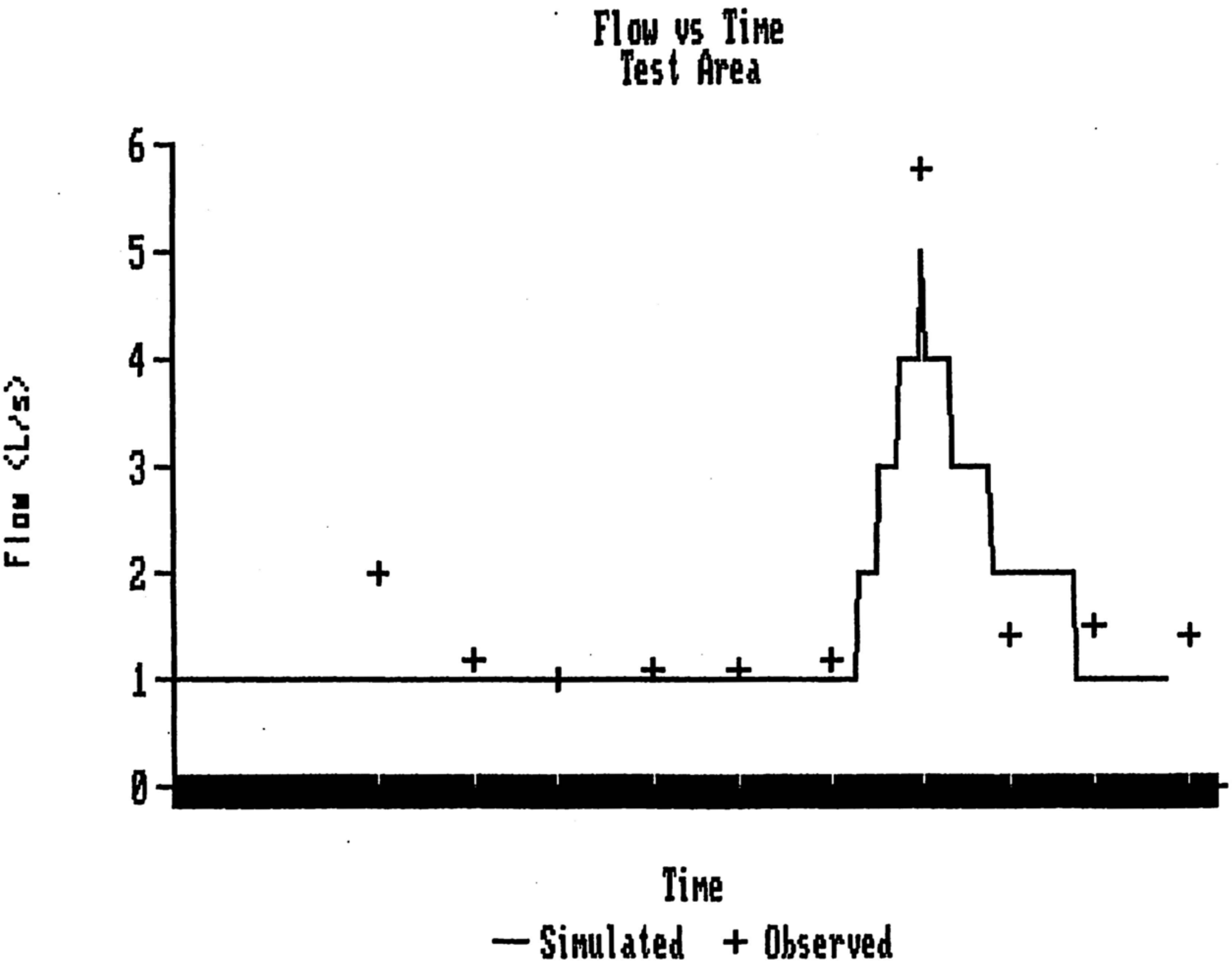


Figure 2.2
Calibration Curve for SWMM - Storm of July 30, 1993

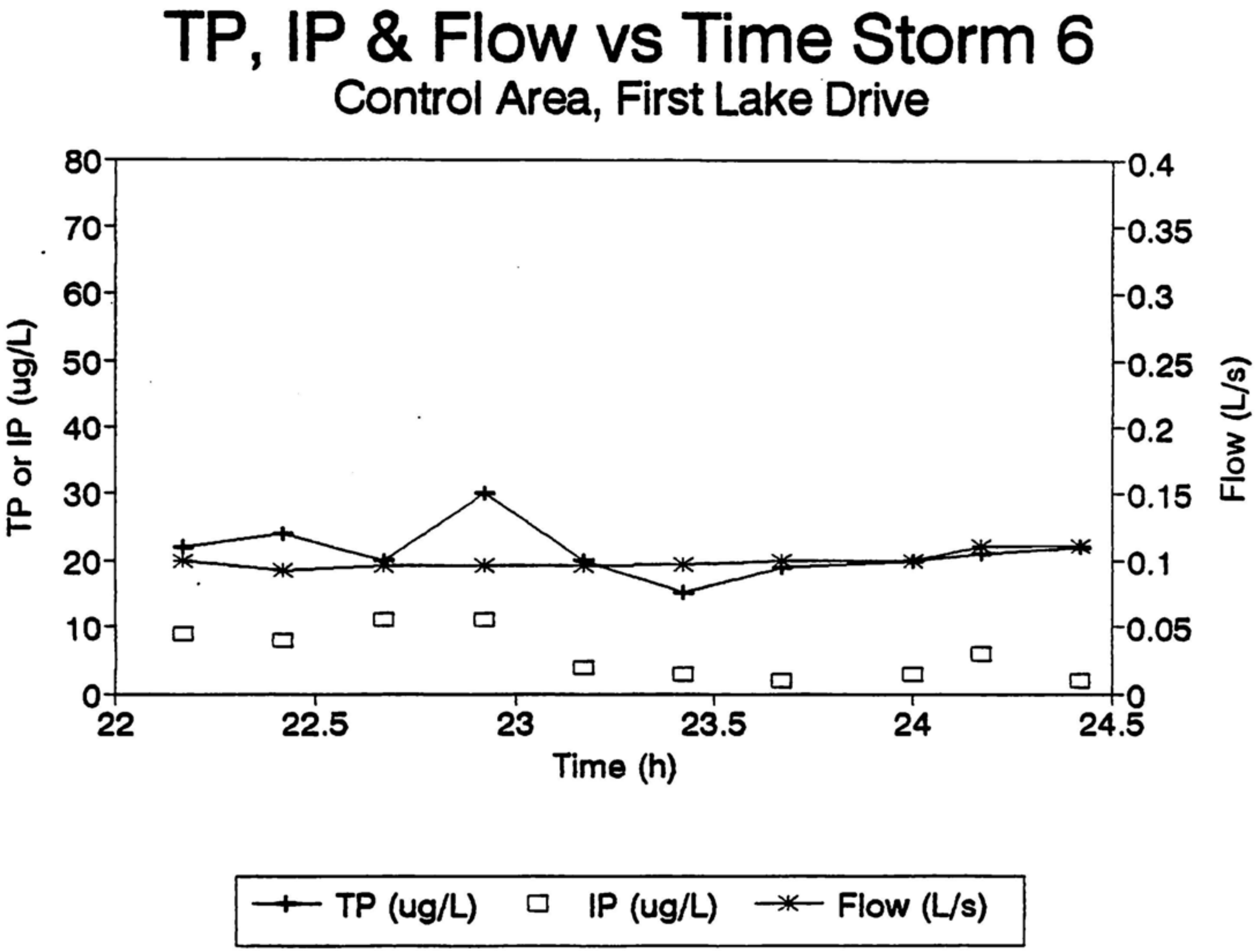


Figure 3.1
Time Series of TP, IP and Flow from the Control SW
for Storm 6 (very low flow)

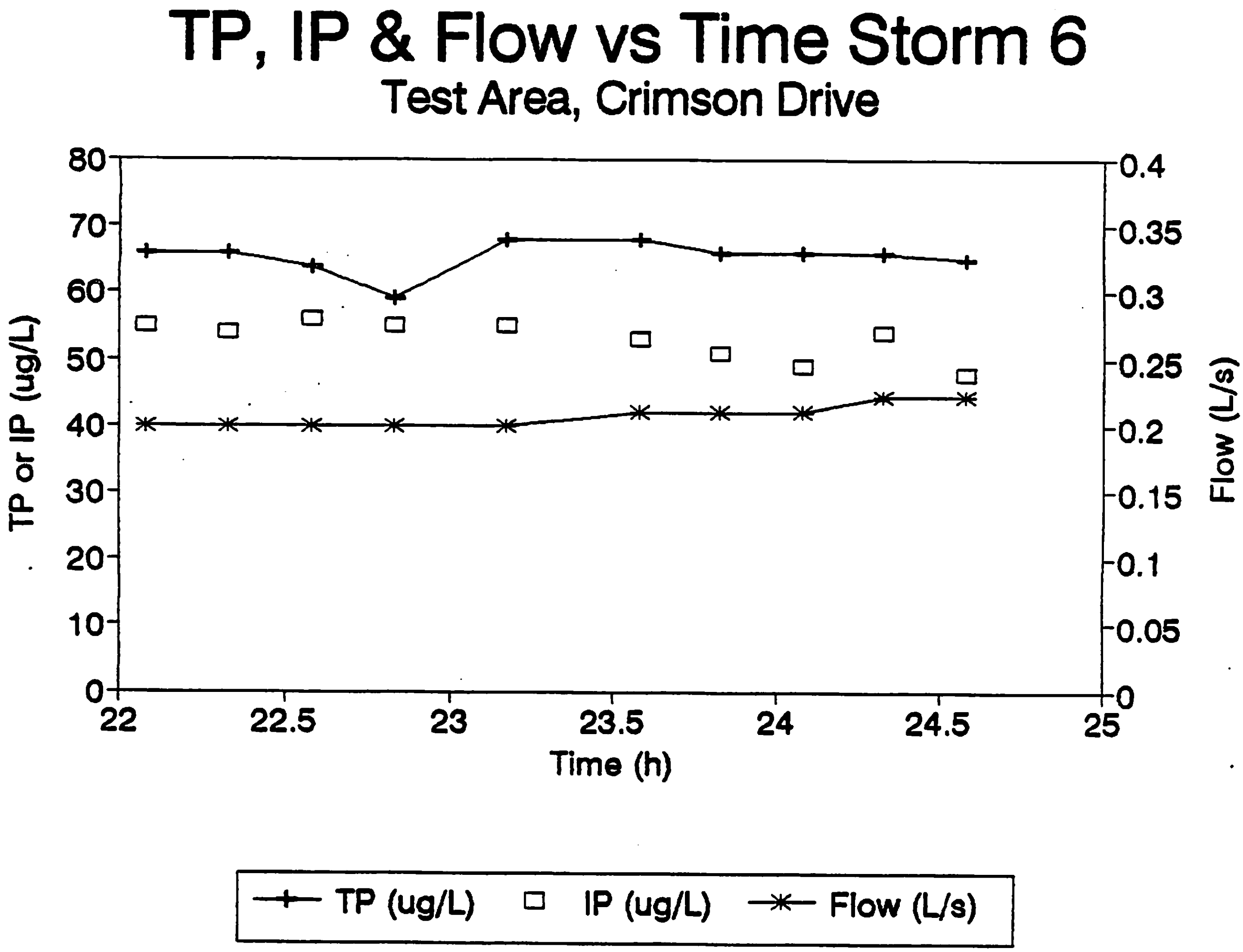


Figure 3.2
Time Series of TP, IP and Flow from the Test SW
for Storm 6 (very low flow)

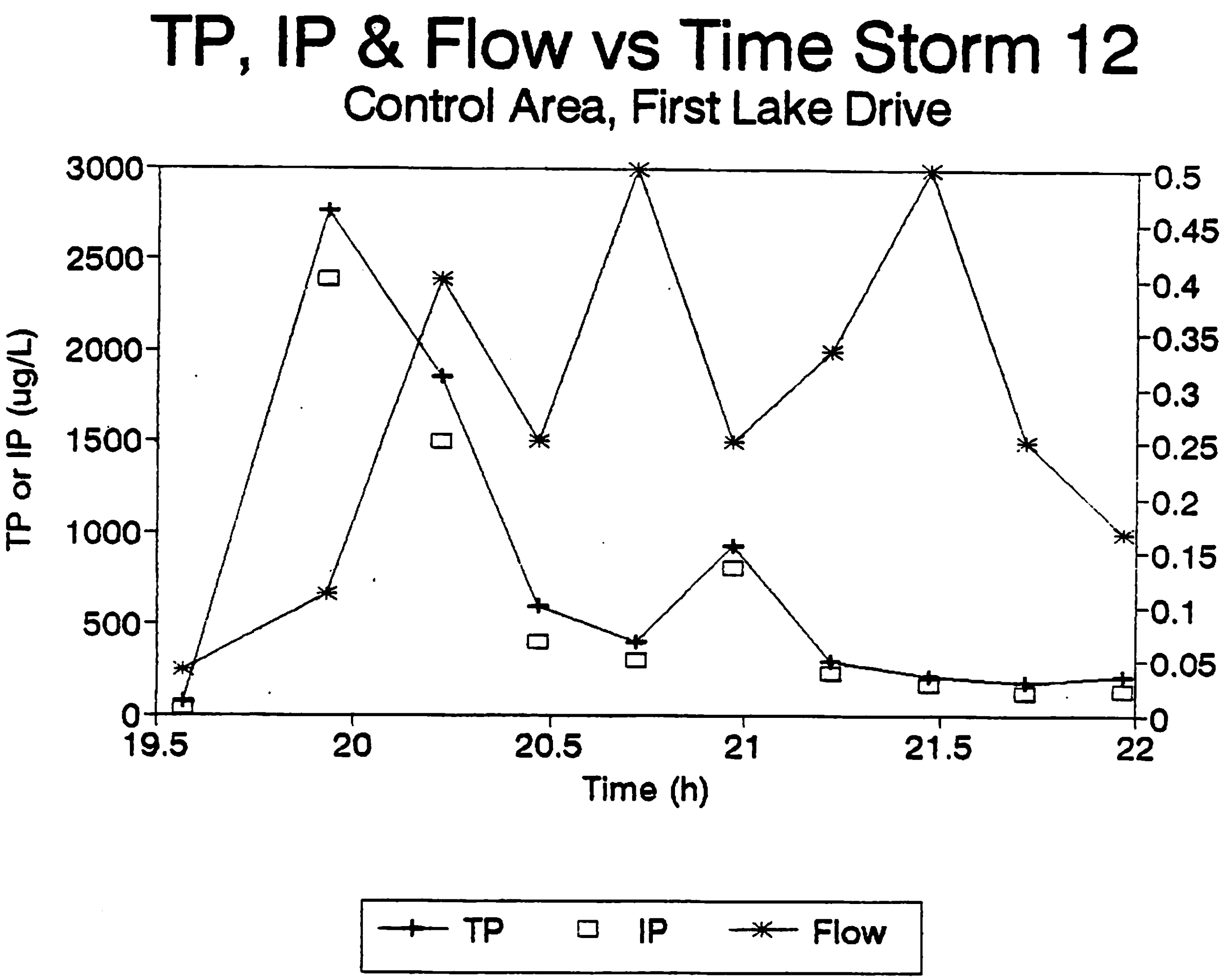


Figure 3.3
Time Series of TP, IP and Flow from the Control SW
Storm 12 (low flow)

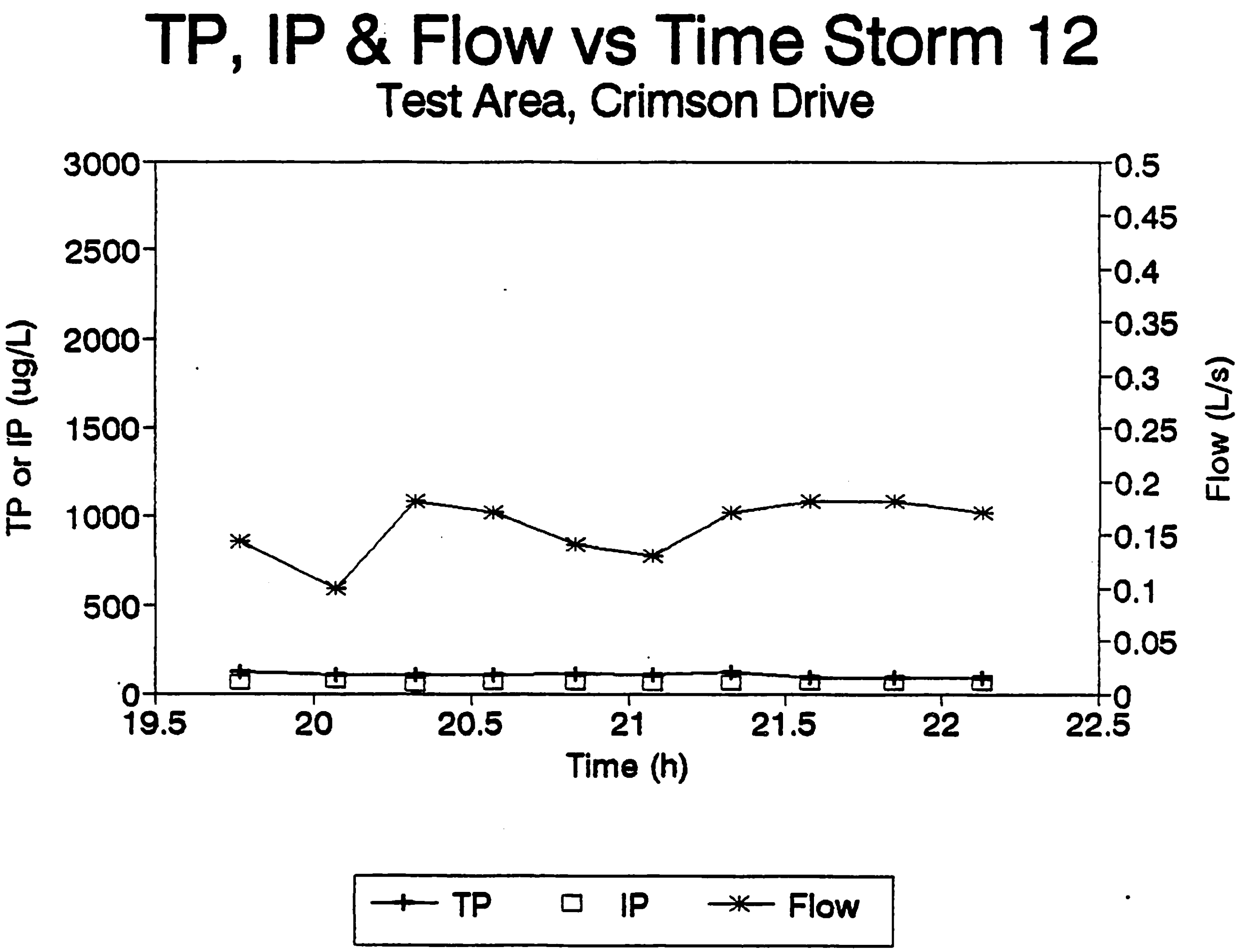


Figure 3.4
Time Series of TP, IP and Flow from the Test SW
for Storm 12 (low flow)

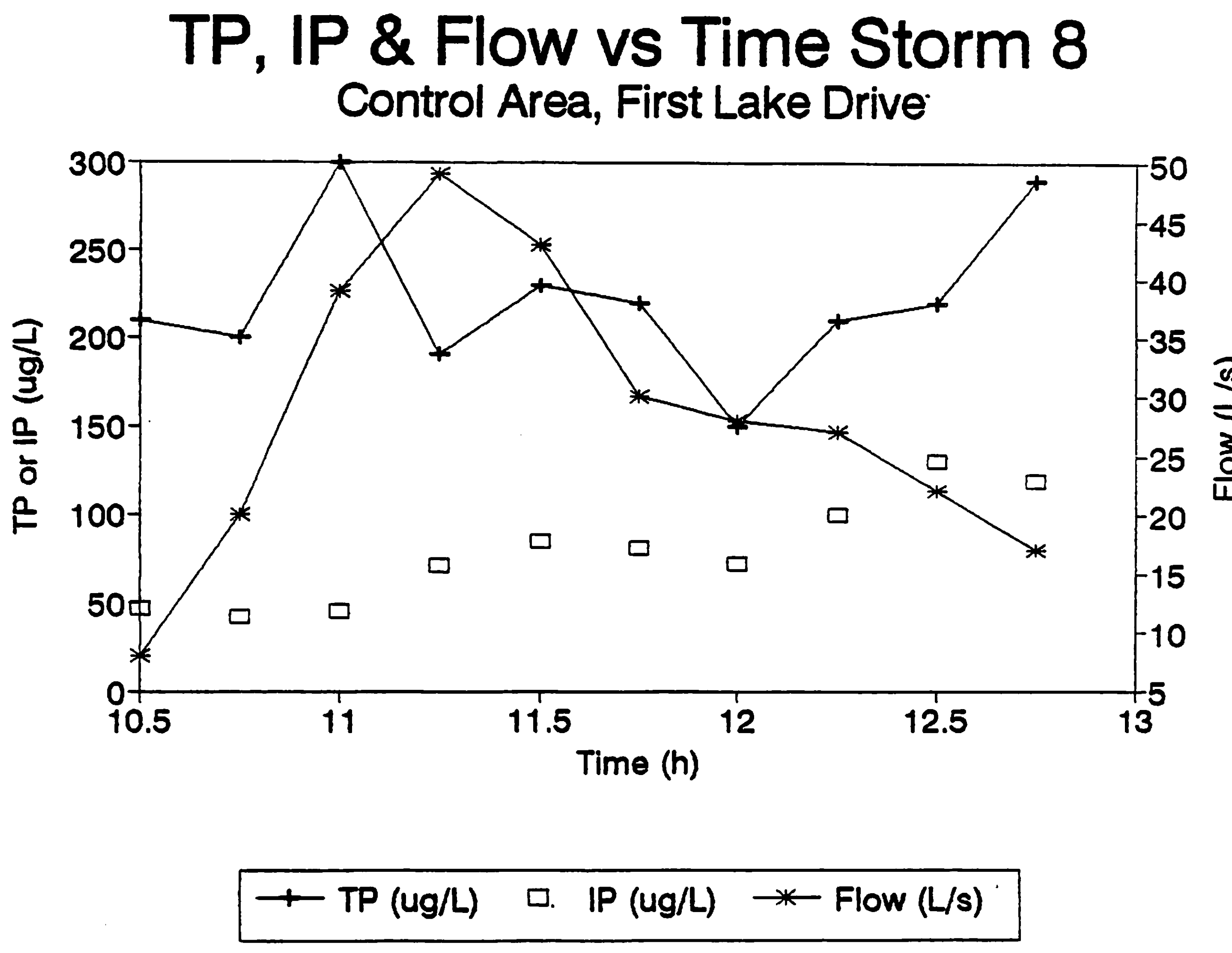


Figure 3.5
Time Series of TP, IP and Flow from the Control SW
for Storm 8 (high flow)

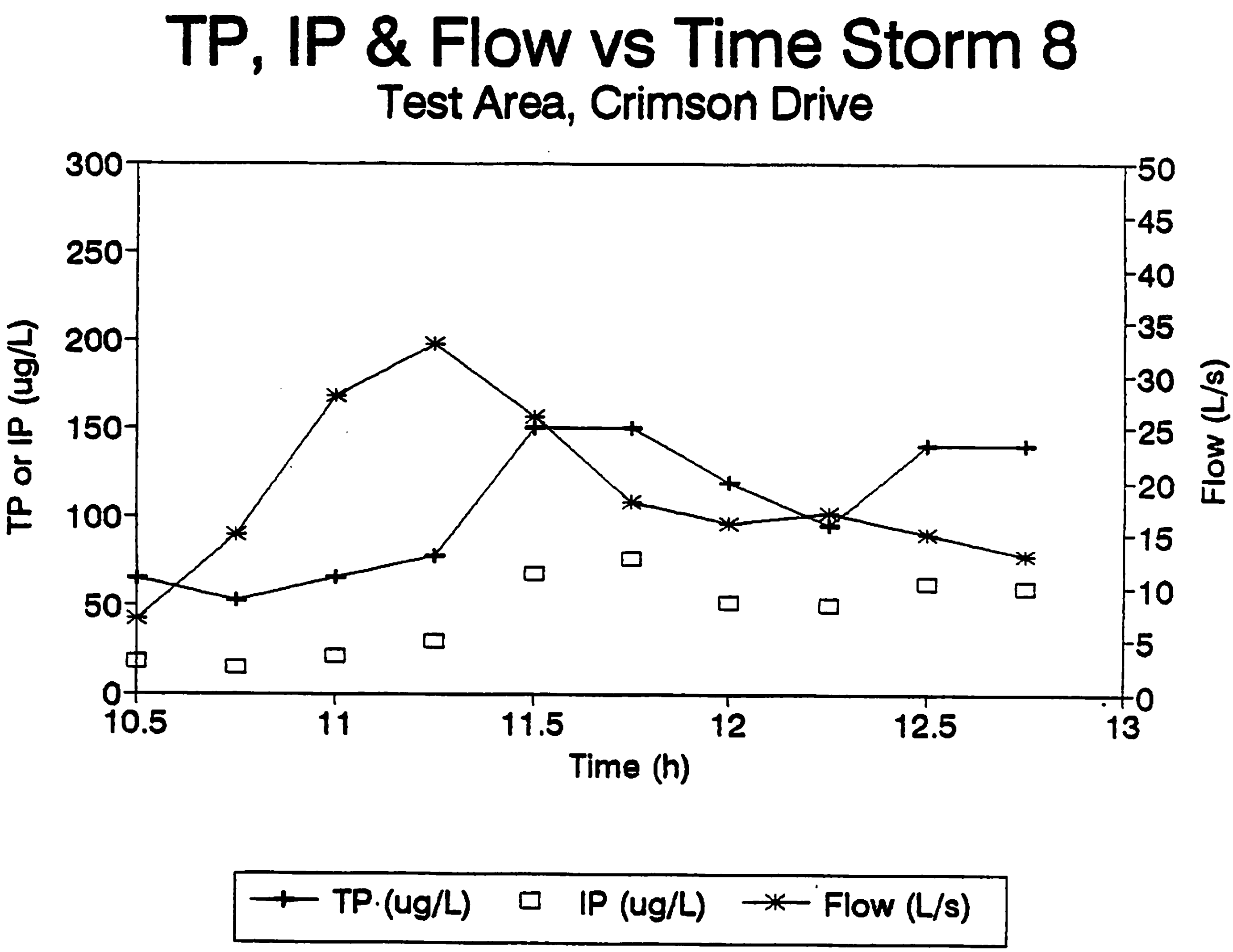


Figure 3.6
Time Series of TP, IP and Flow from the Test SW
for Storm 8 (high flow)

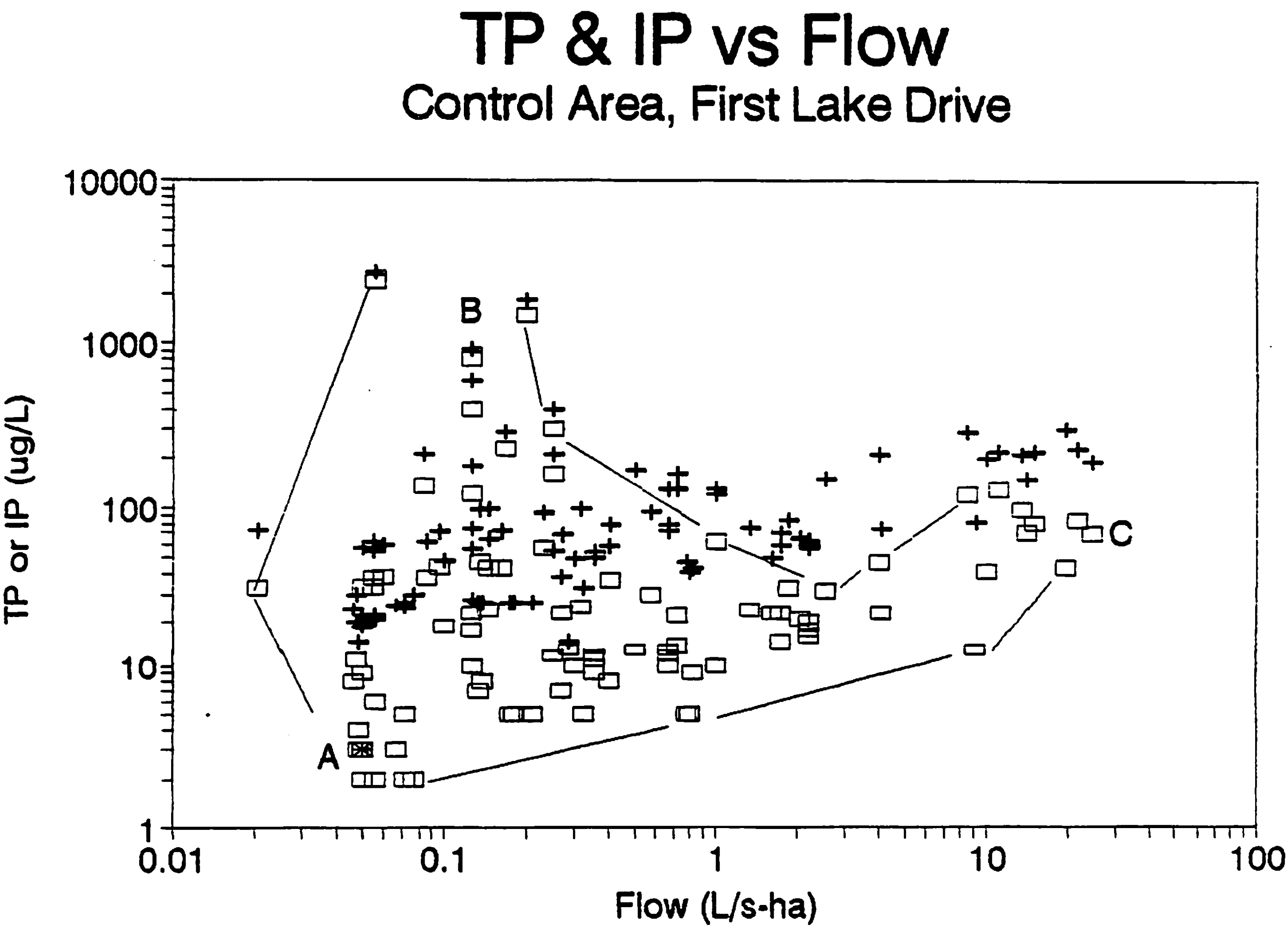


Figure 3.7
TP and IP Versus Flow from the Control Area in the Stewardship Period. The Envelope of IP is Delineated. The Groundwater Datum, near A, is indicated by the Symbol,*.

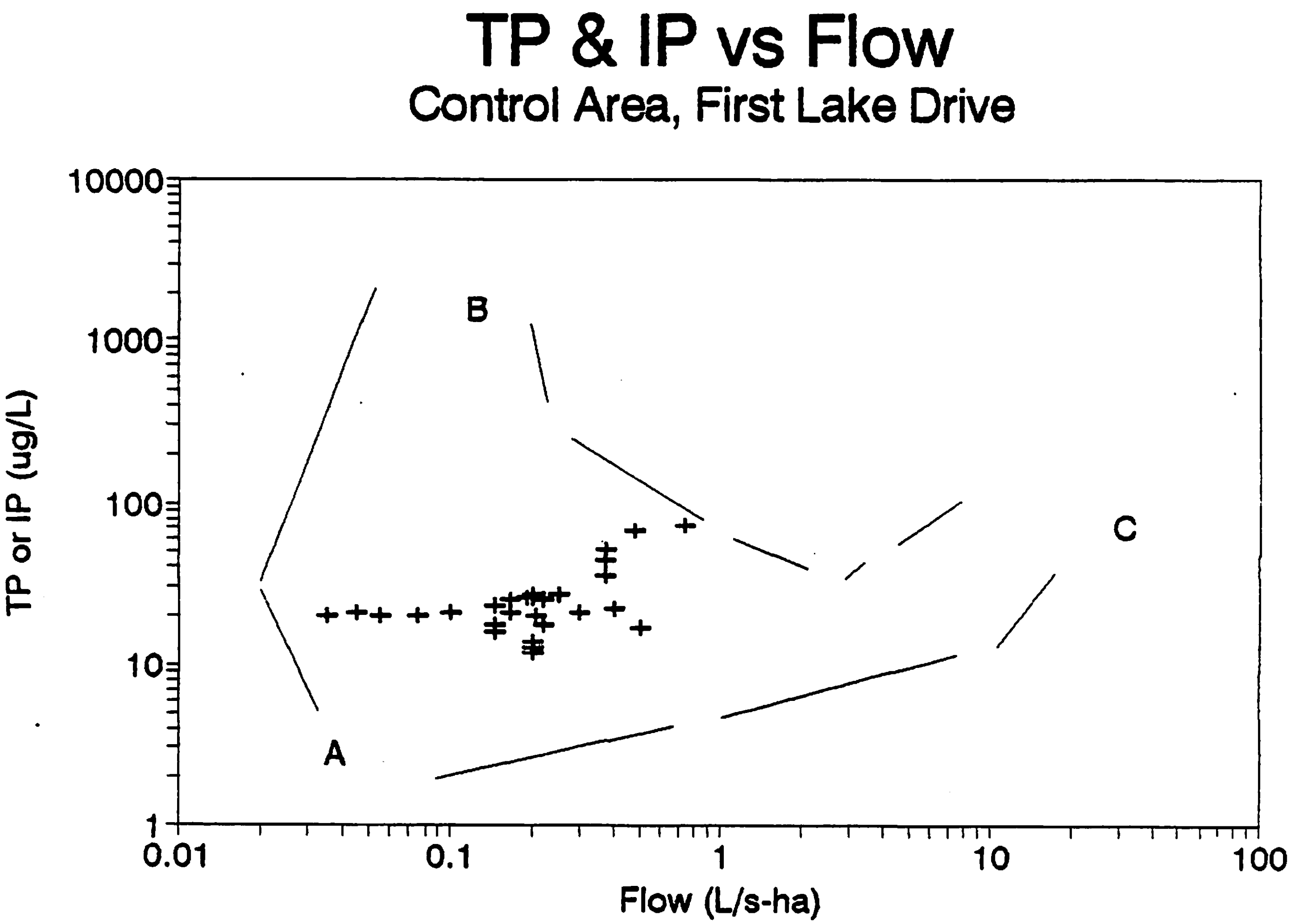


Figure 3.8
TP and IP Versus Flow from the Control Area in the Baseline period. The IP Envelope from Figure 3.13 is Shown.

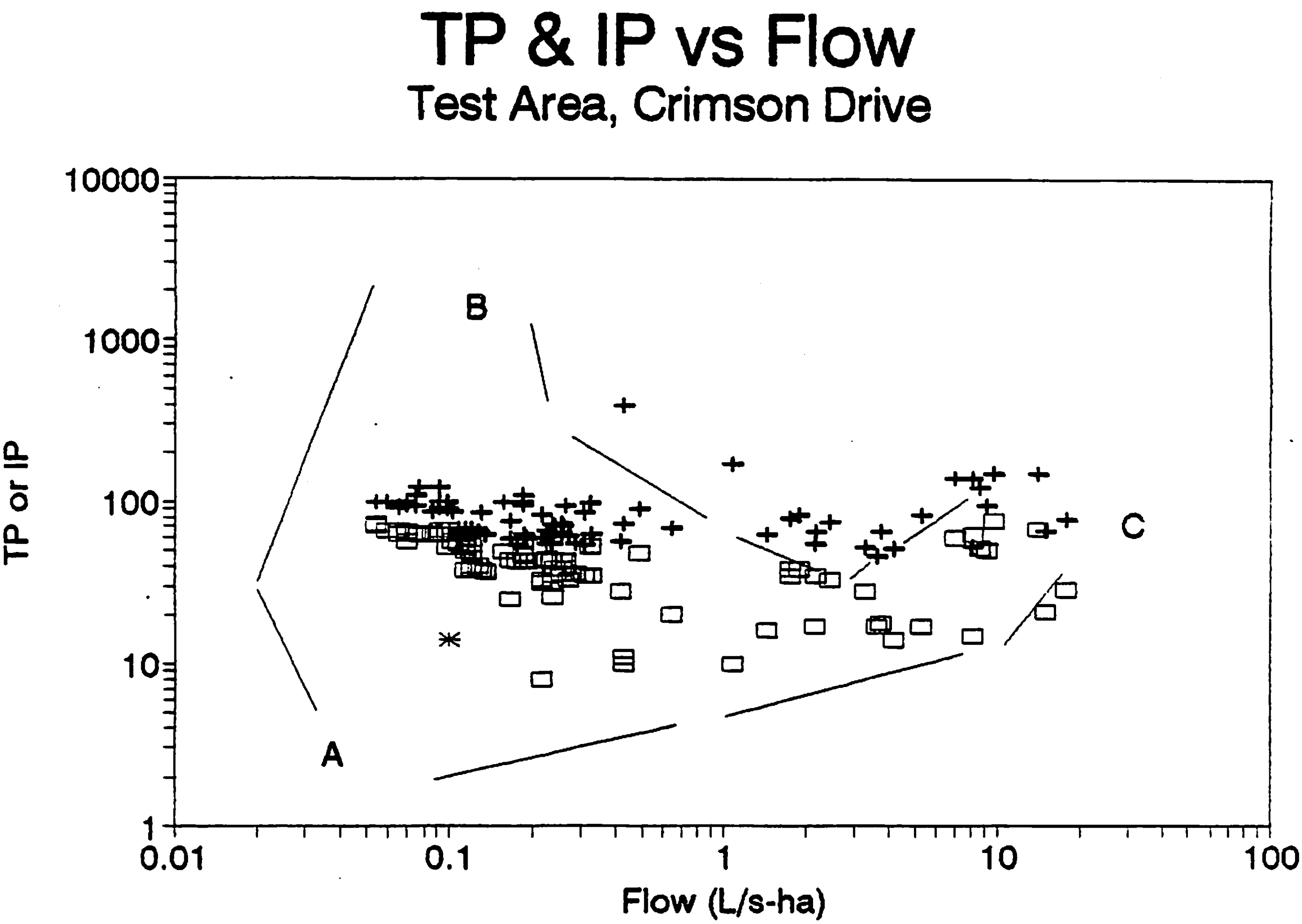


Figure 3.9
TP and IP Versus Flow from the Test Area in the Stewardship Period. The Envelope of IP is Delineated. The Groundwater Datum, Near A, is Indicated by the Symbol, *.

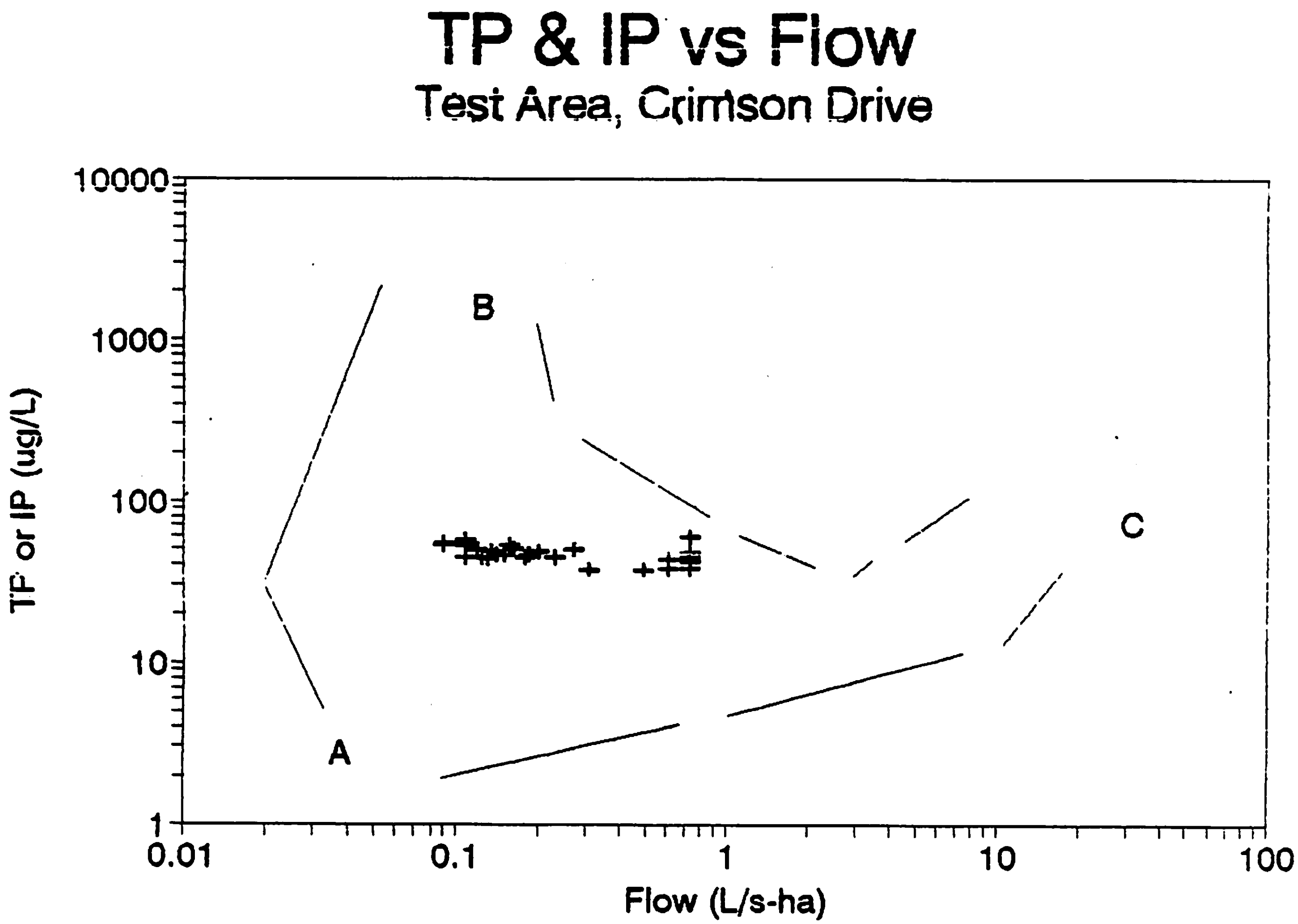


Figure 3.10
TP and IP Versus Flow from the Test Area in the Baseline Period. The IP Envelope from Figure 3.13 is shown.

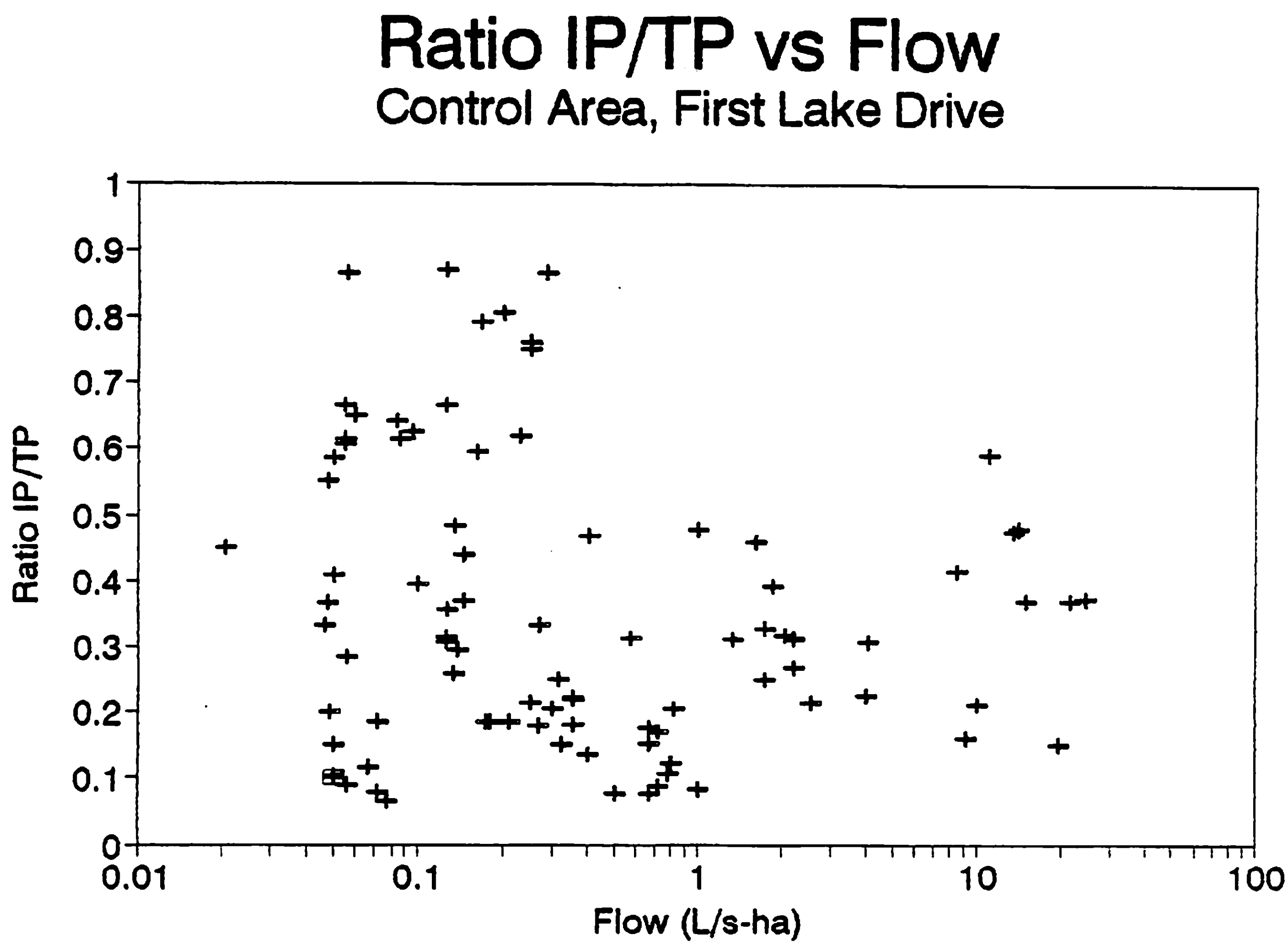


Figure 3.11
IP/TP Versus Flow from the Control Area in the Stewardship Period. The Groundwater Datum is Indicated by the Symbol, ⌑.

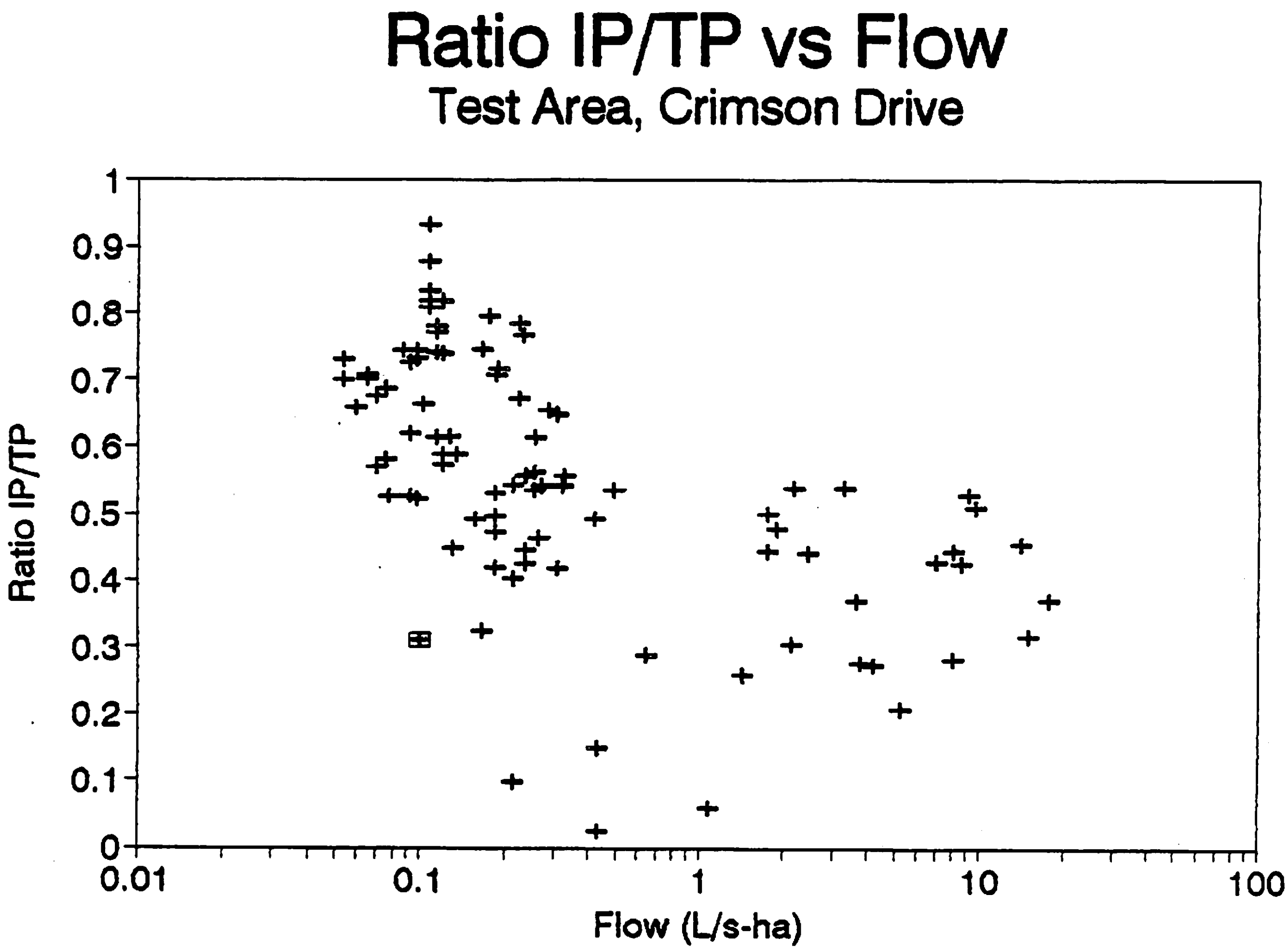


Figure 3.12
IP/TP Versus Flow from the Test Area in the Stewardship Period. The Groundwater Datum is Indicated by the Symbol, ◻.

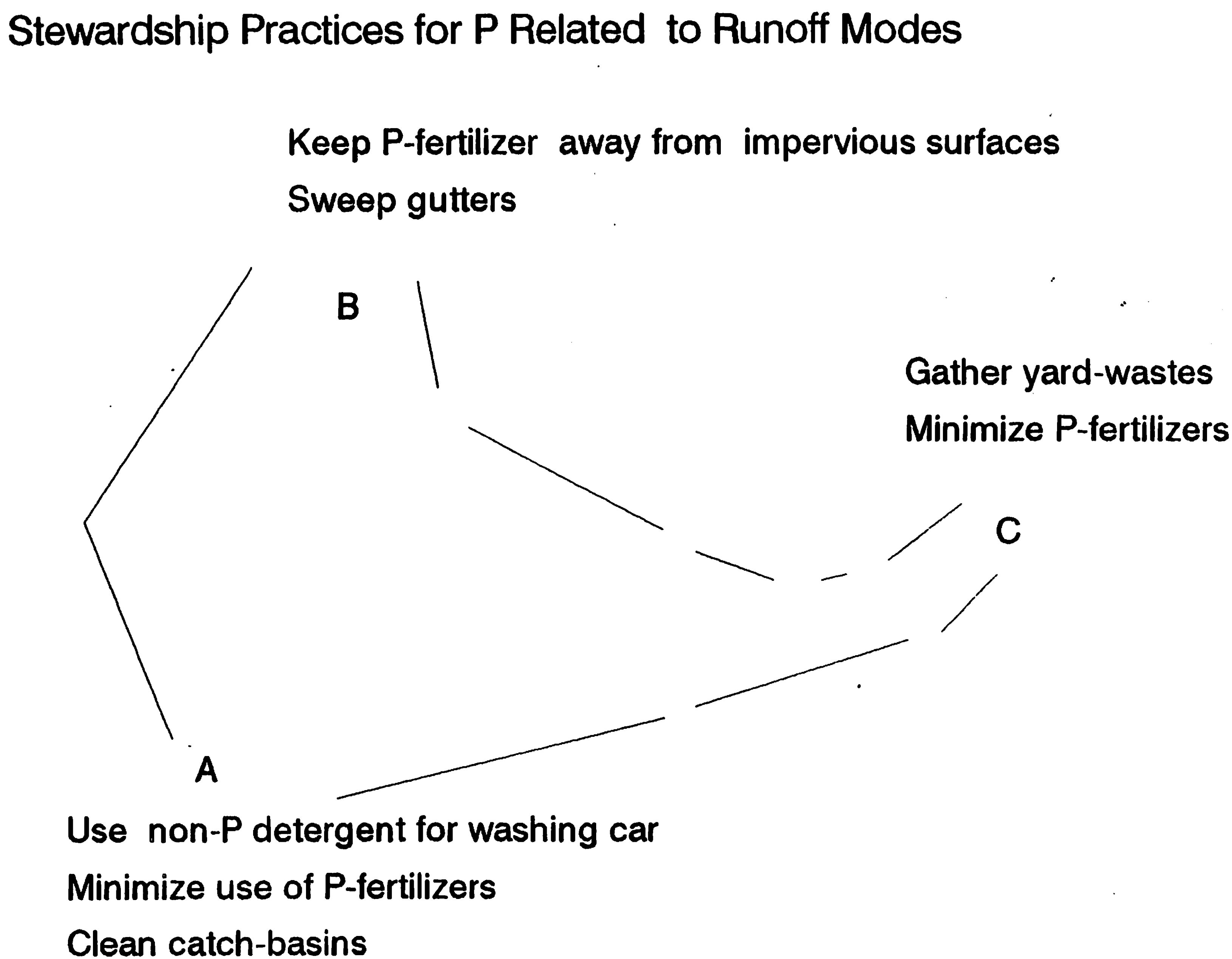


Figure 3.13
Stewardship Practices for P Related to Runoff Modes.

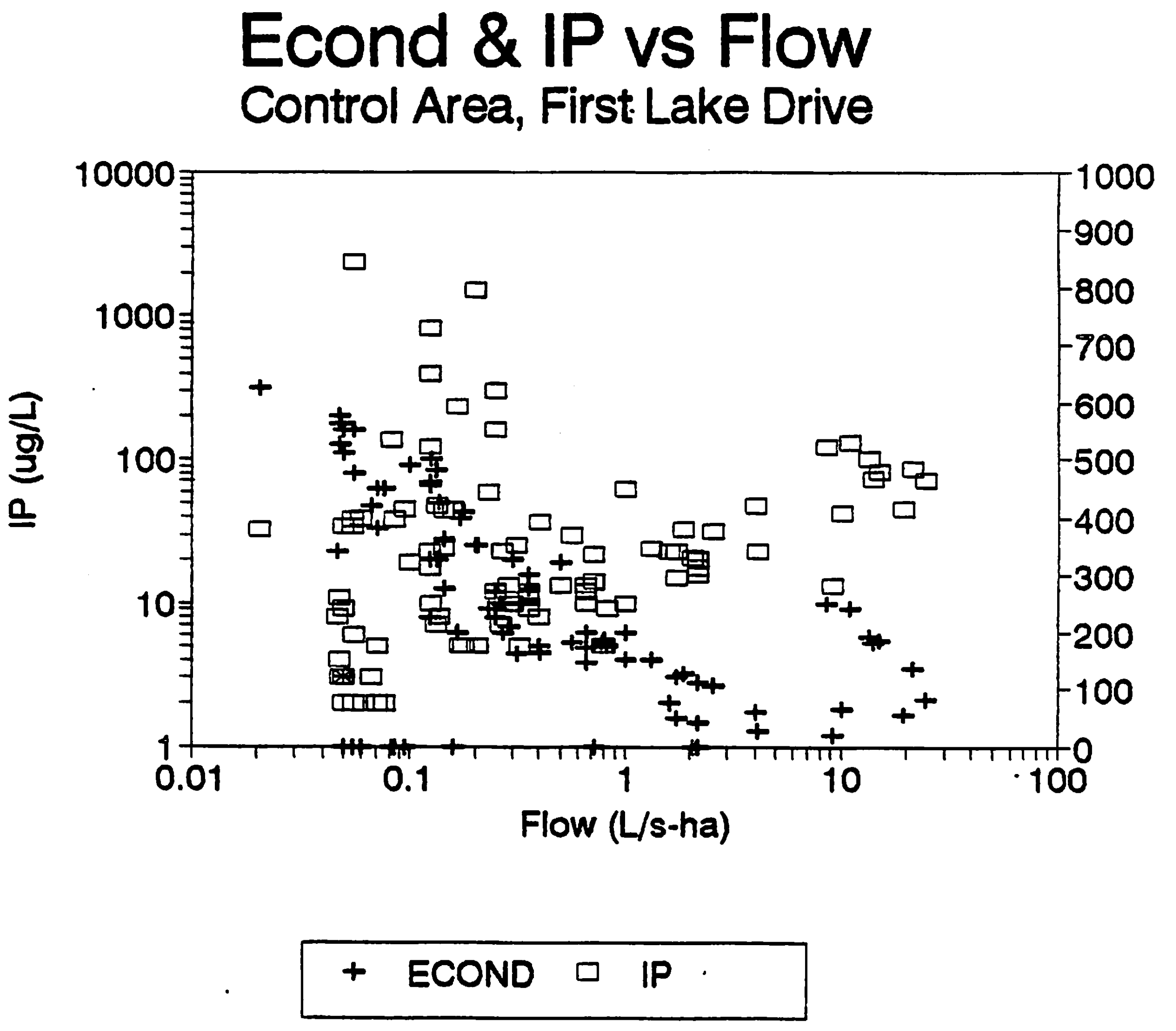


Figure 3.14
Electrical Conductivity and IP Versus Flow - Control Area, Stewardship Period. The Groundwater Datum for IP is Indicated by the Symbol, *.

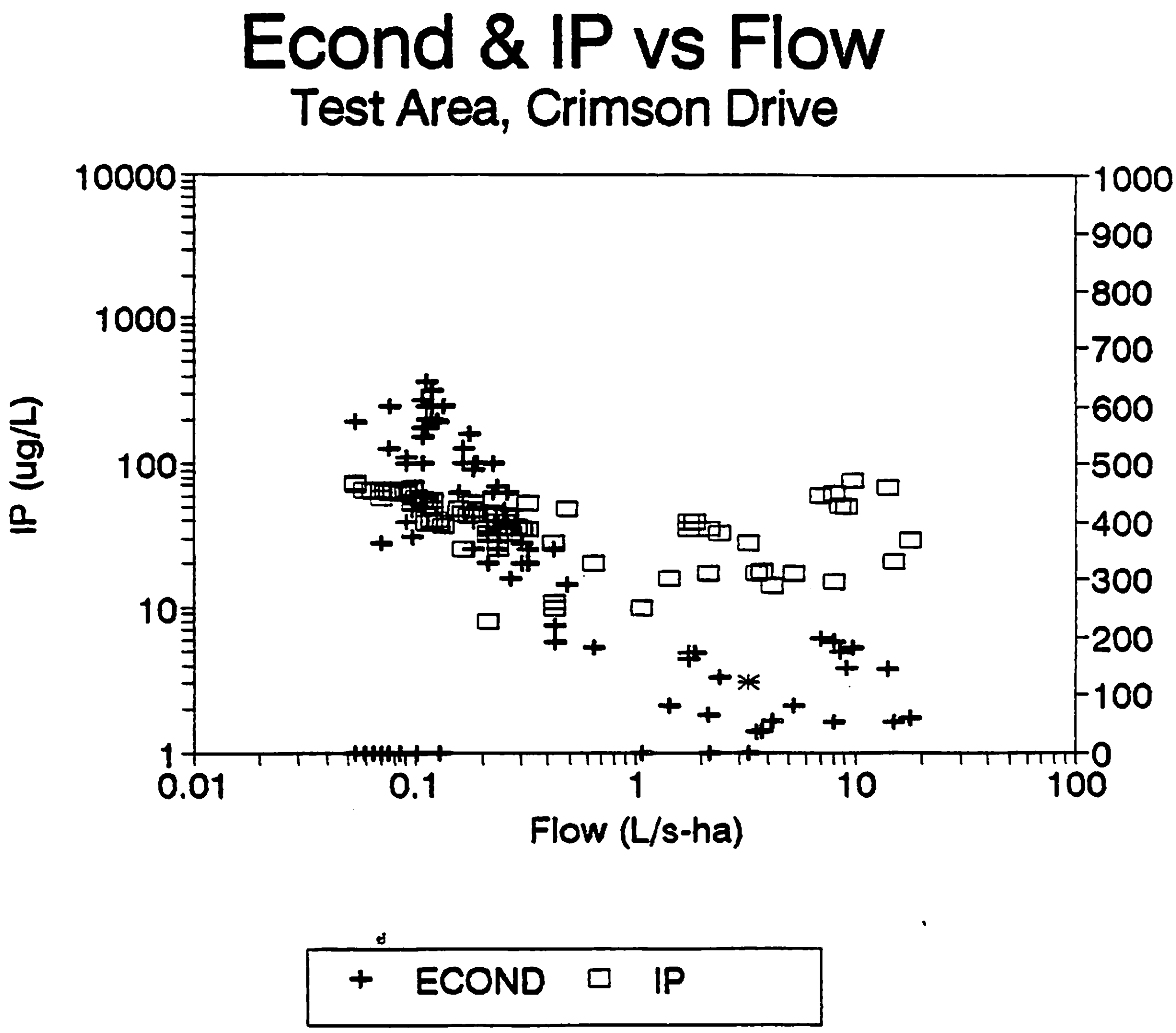


Figure 3.15
Electrical Conductivity and IP Versus Flow -
Test Area, Stewardship Period
The Groundwater Datum for IP is indicated by the Symbol, *.

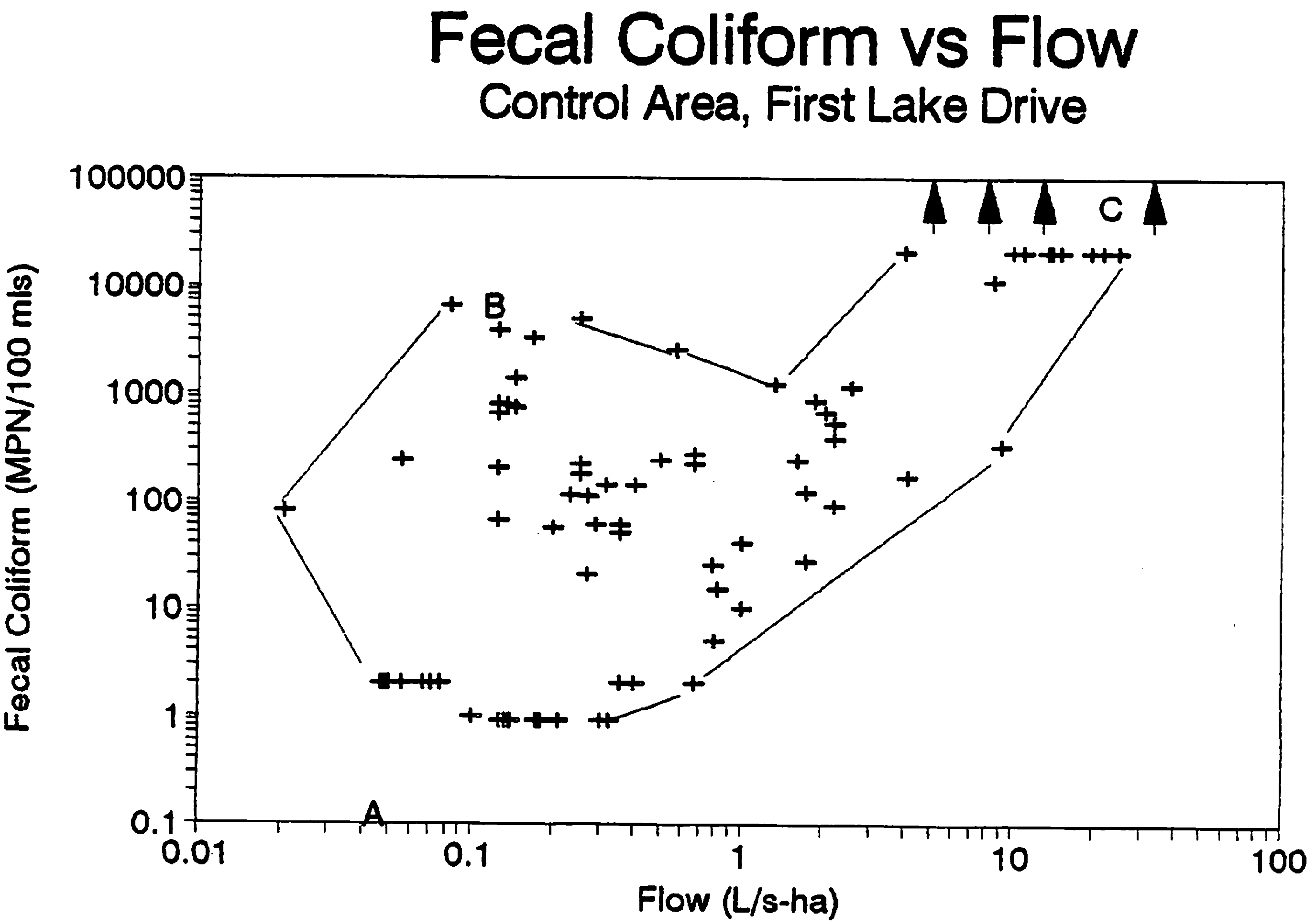


Figure 3.16
Fecal Coliform Versus Flow from the Control Area in the Stewardship Period. The Envelope of Coliform Concentrations is Delineated.

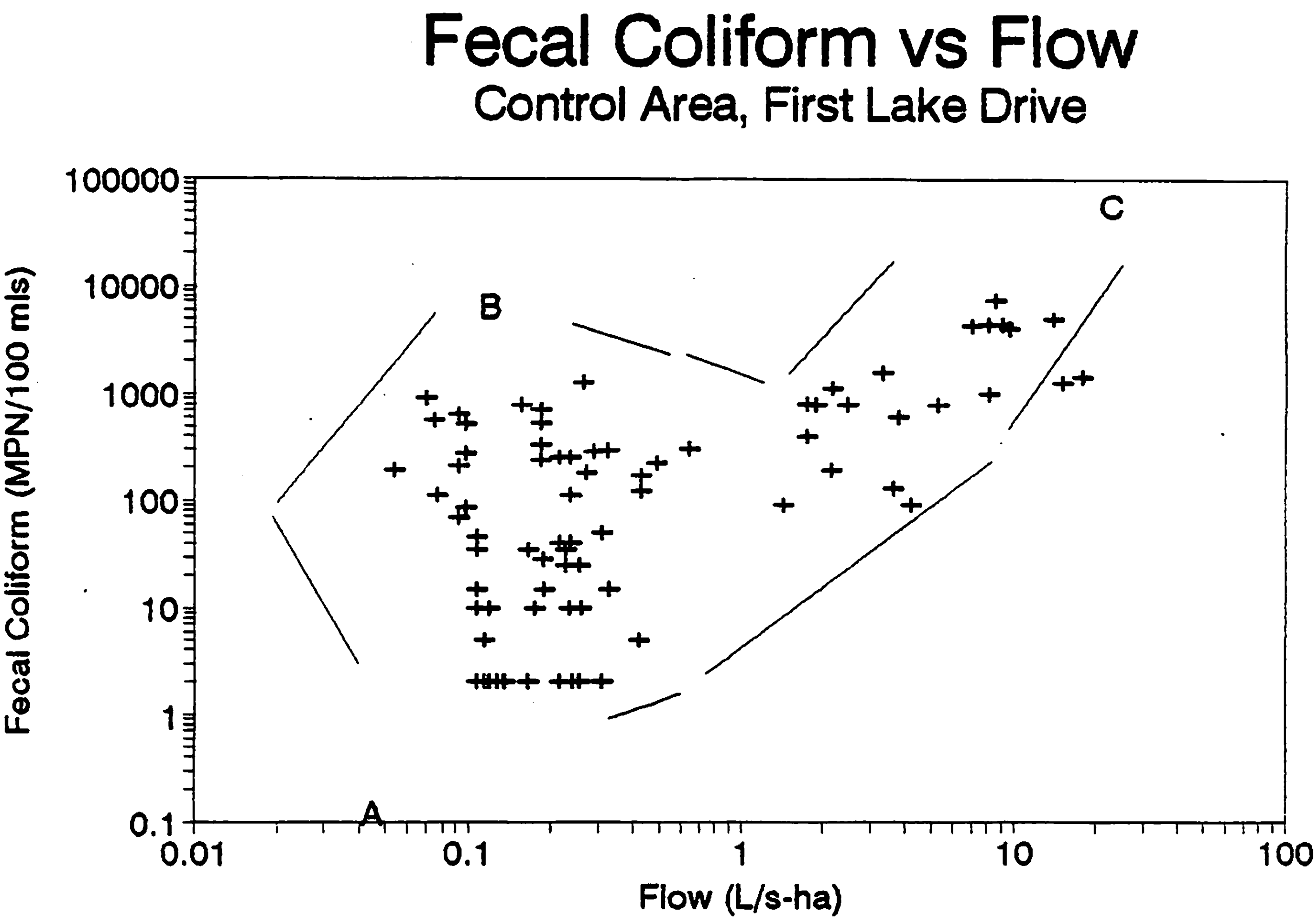


Figure 3.17
Fecal Coliform Versus Flow from the Test Area in the Stewardship Period. The Envelope of Coliform Concentrations is Delineated.

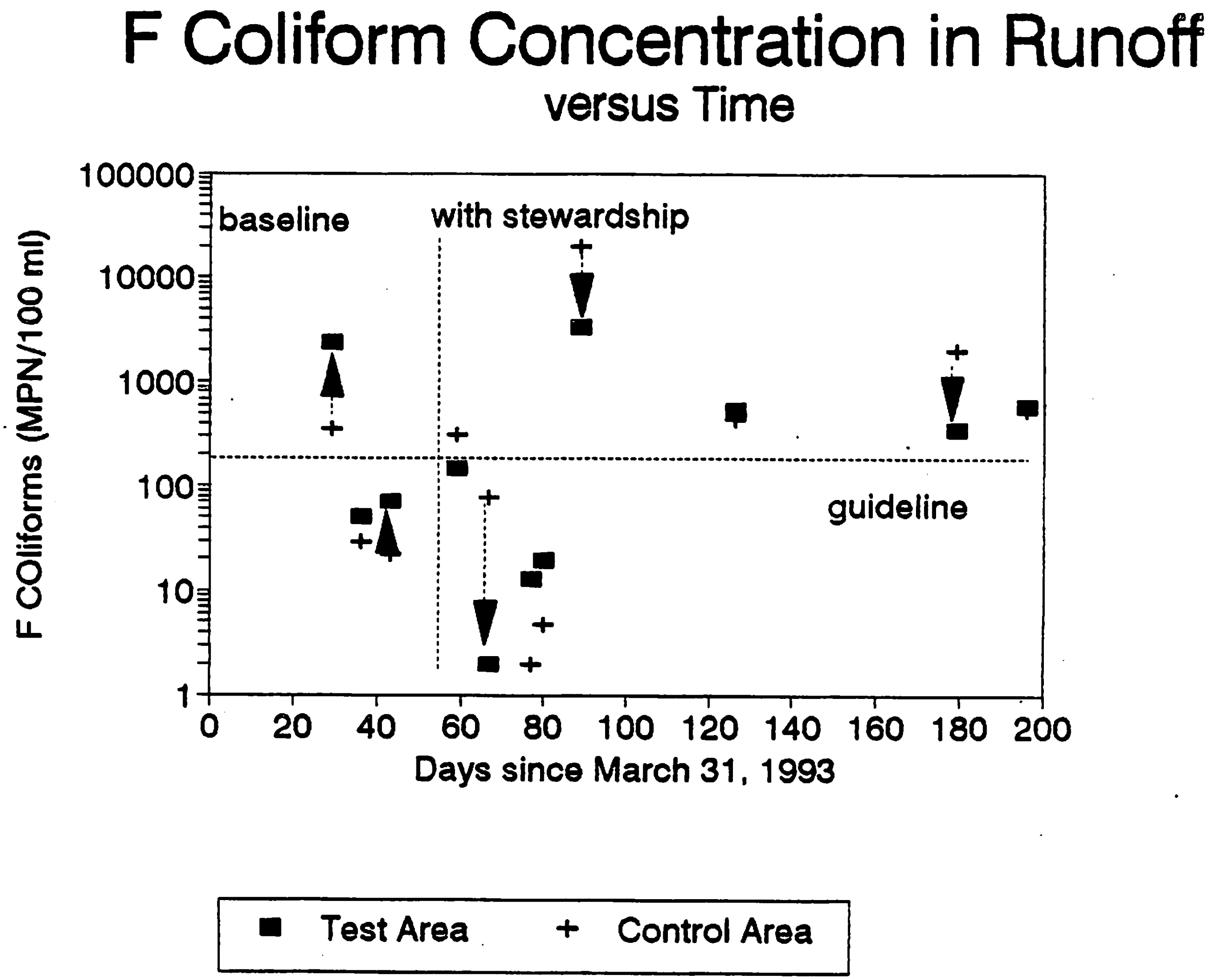


Figure 3.18
Time Series of Storm-mean Fecal Coliform Concentrations, with Arrows Identifying th Larger Differences Between Test and Control, and with a Lake Guideline.

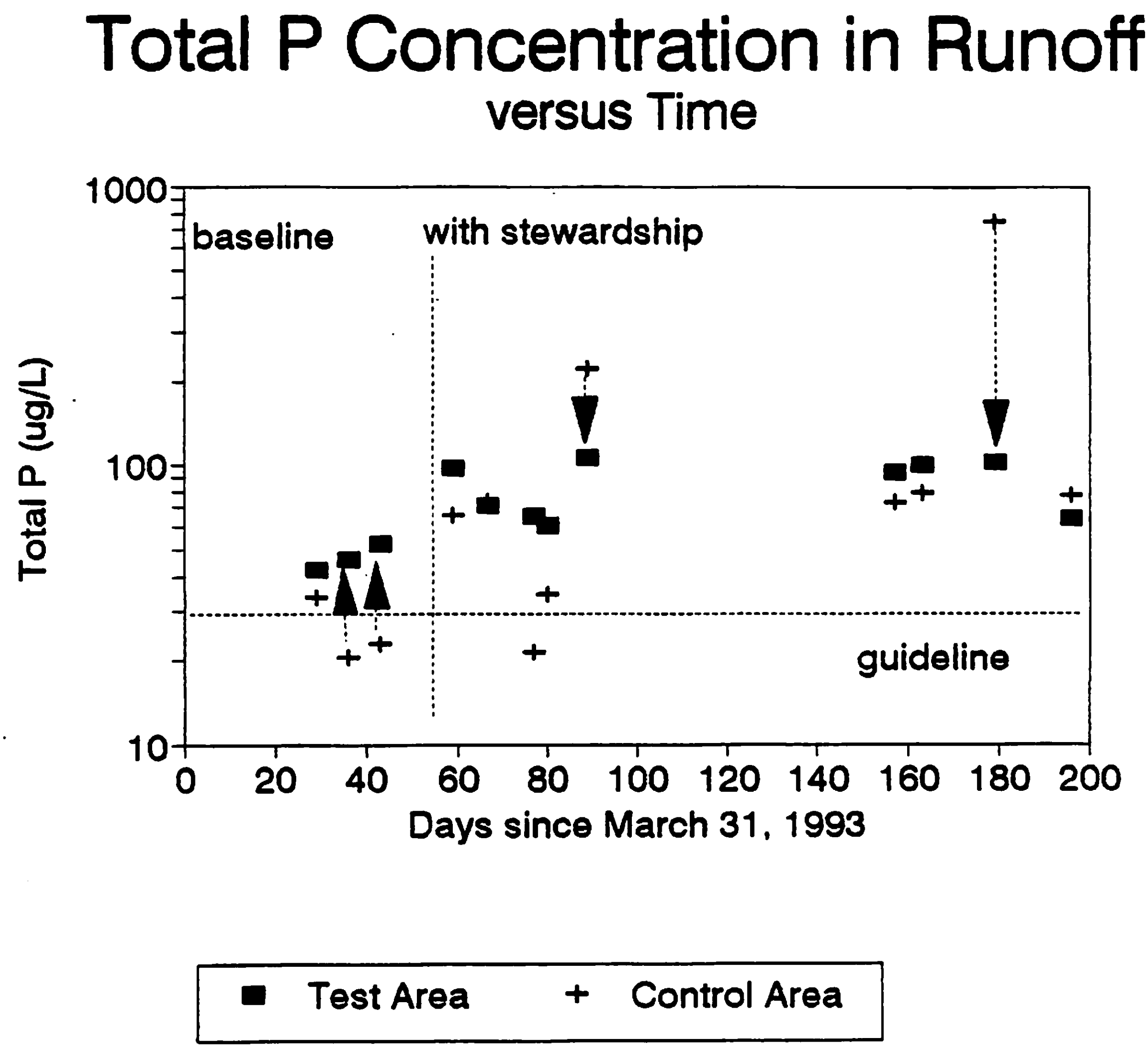


Figure 3.19
Time Series of Storm-mean Total Phosphorus Concentrations, with Arrows Identifying the Larger Differences Between Test and Control, and with a Lake Guideline.

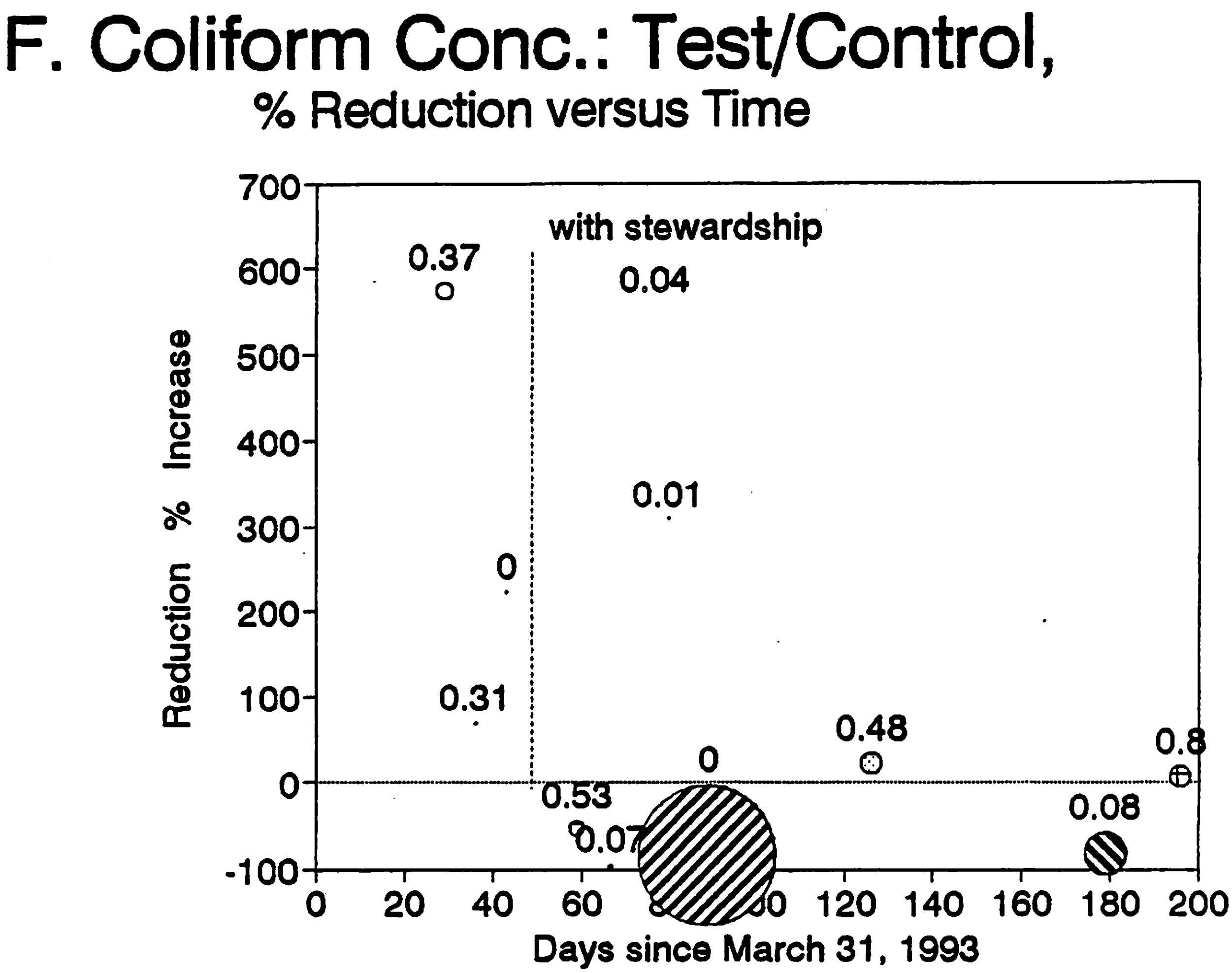


Figure `3.20
Time Series of the Percentage Reduction of Concentration of Fecal Coliforms in the Test Area Compared to the Control Area.

Total P Conc.: Test/Control,

% Reduction versus Time

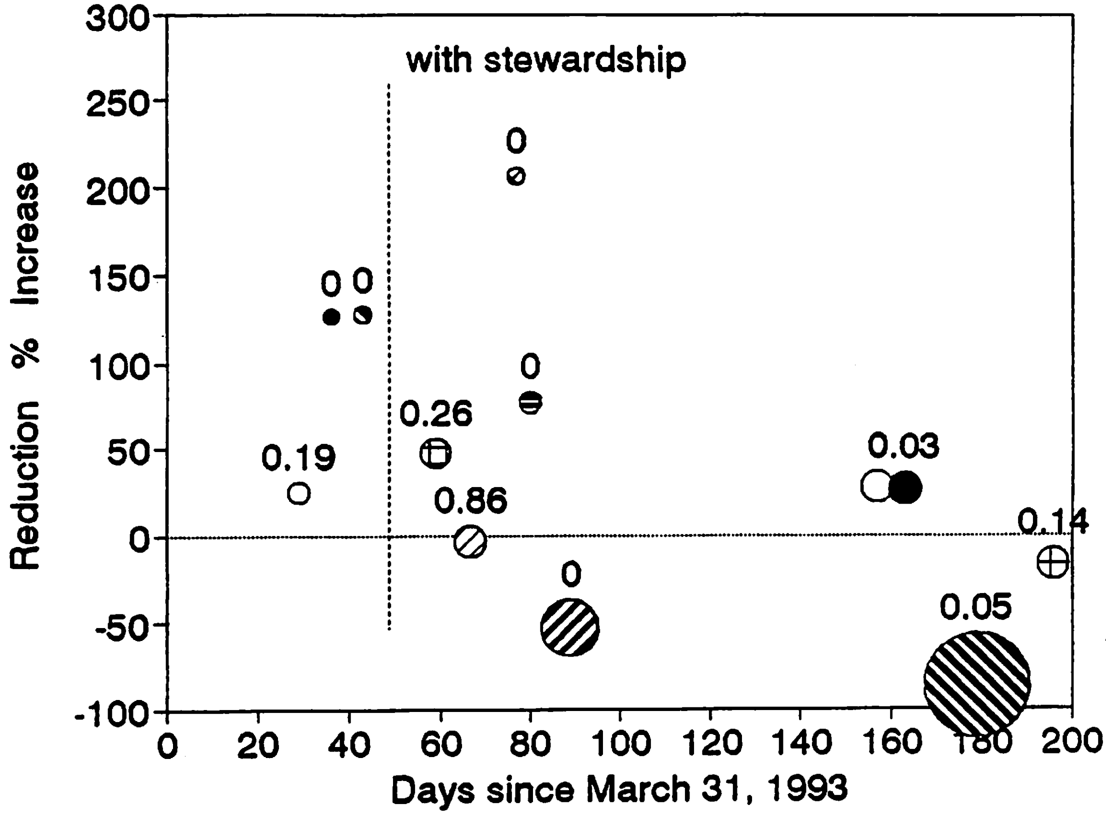


Figure 3.21
Time Series of the Percentage Reduction of Concentration of Fecal Coliforms in the Test Area Compared to the Control Area.

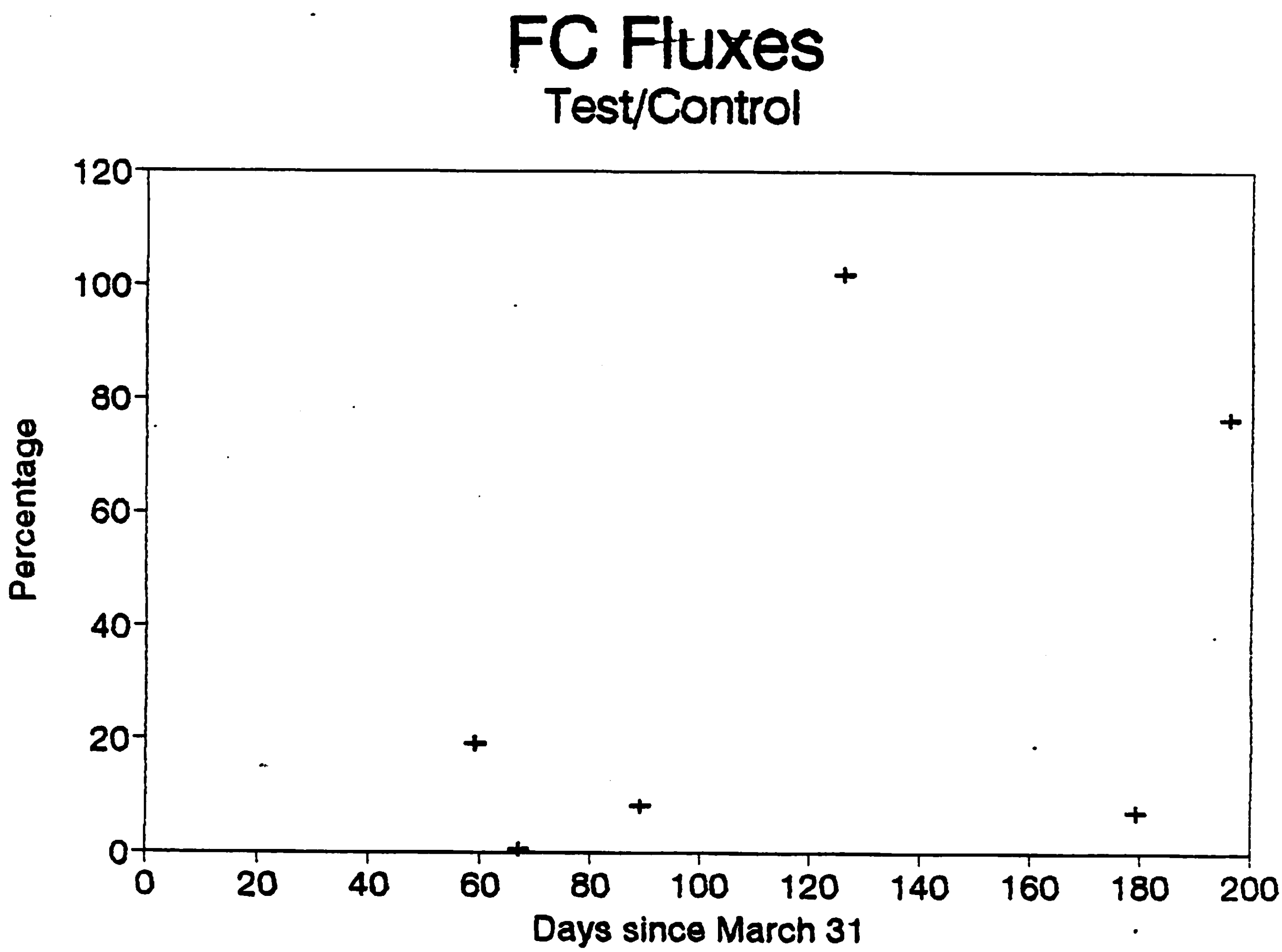


Figure 3.22
Time Series of the Ratio of the Fecal Coliform Fluxes.
Test/Control, Corrected for Outdoor Canine Density.

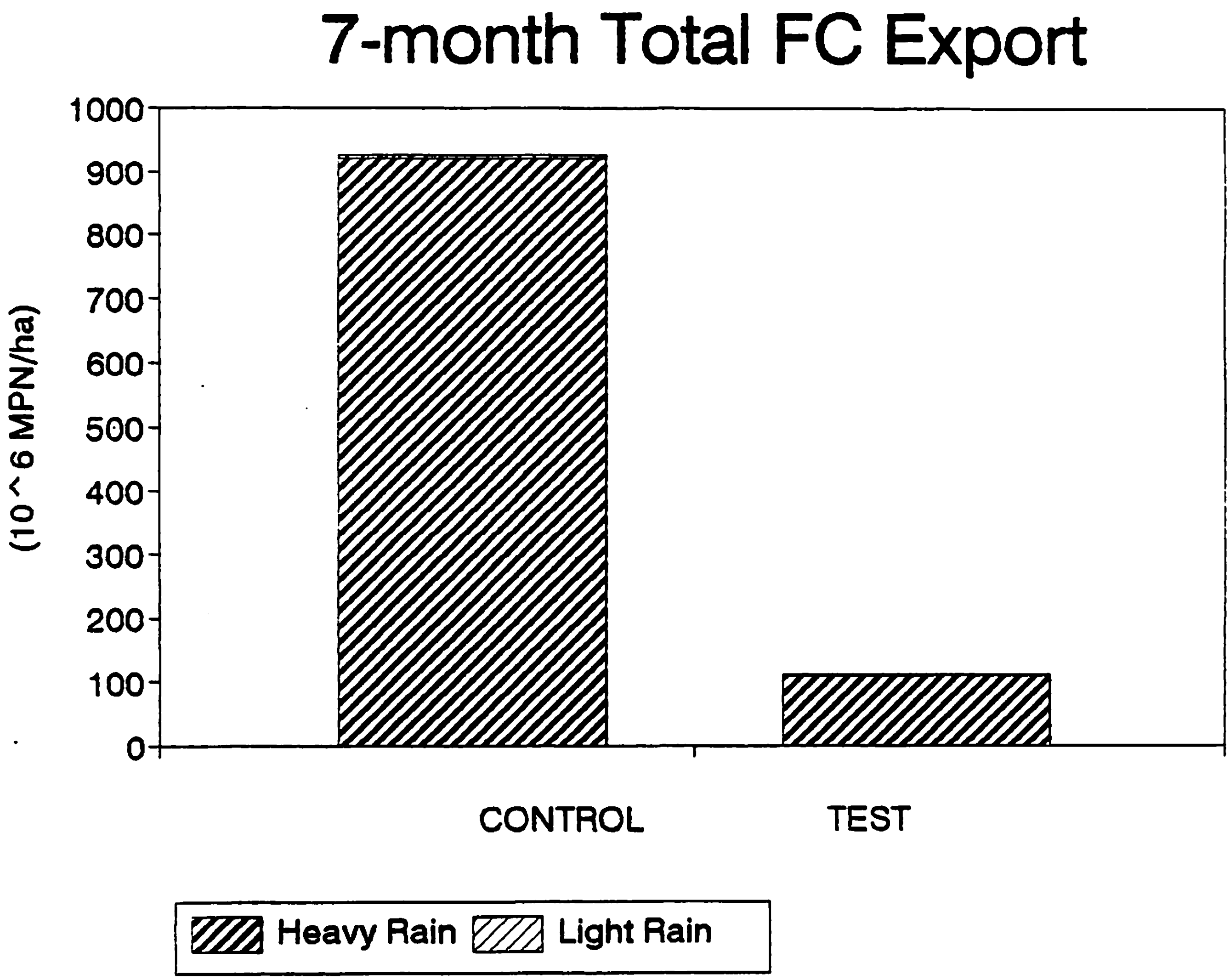


Figure 3.23
Bar graph of total 7-month export of FC
from Control and Test Areas.

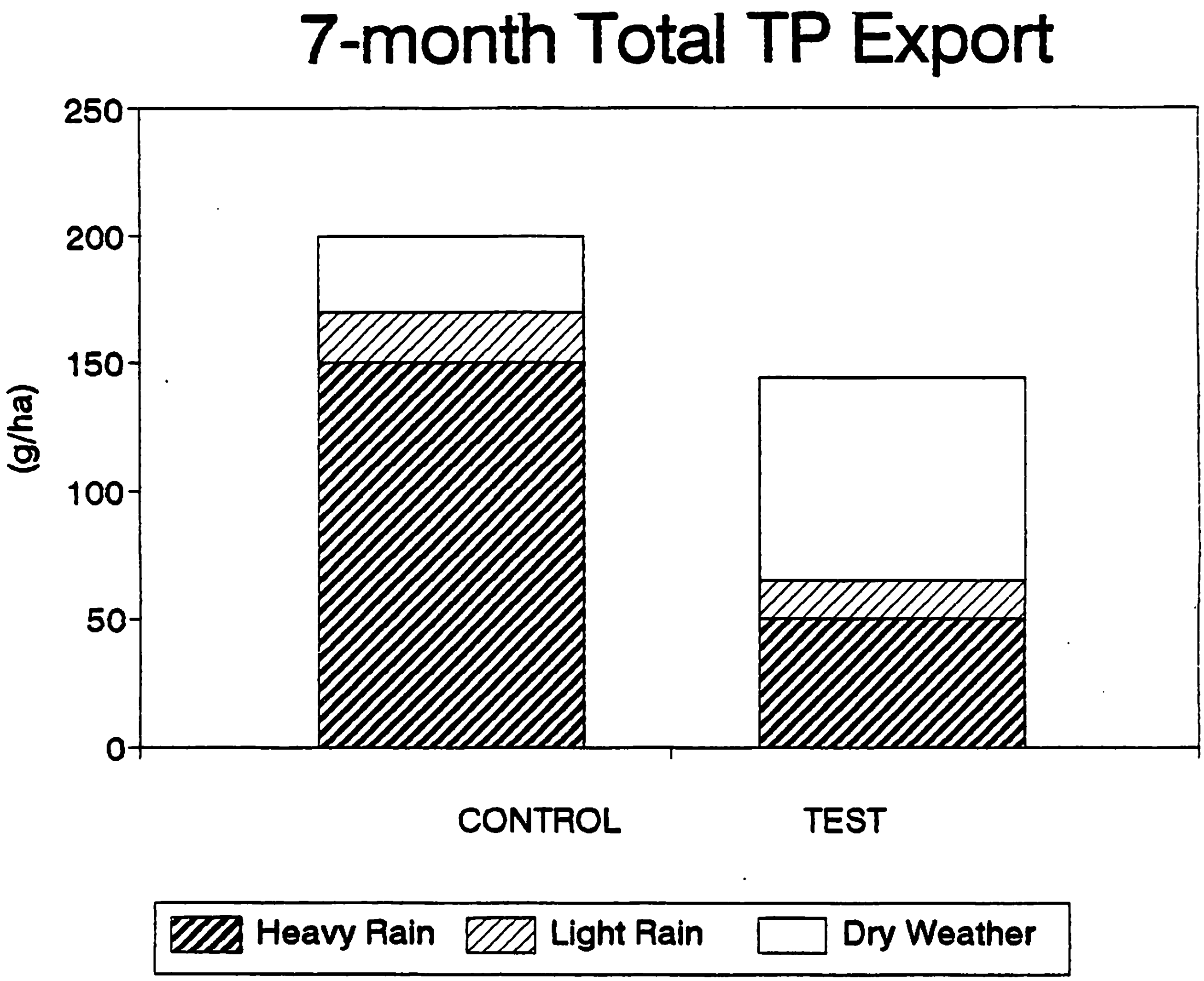


Figure 3.24
Bar graph of total 7-month export of TP from Control and Test Areas.

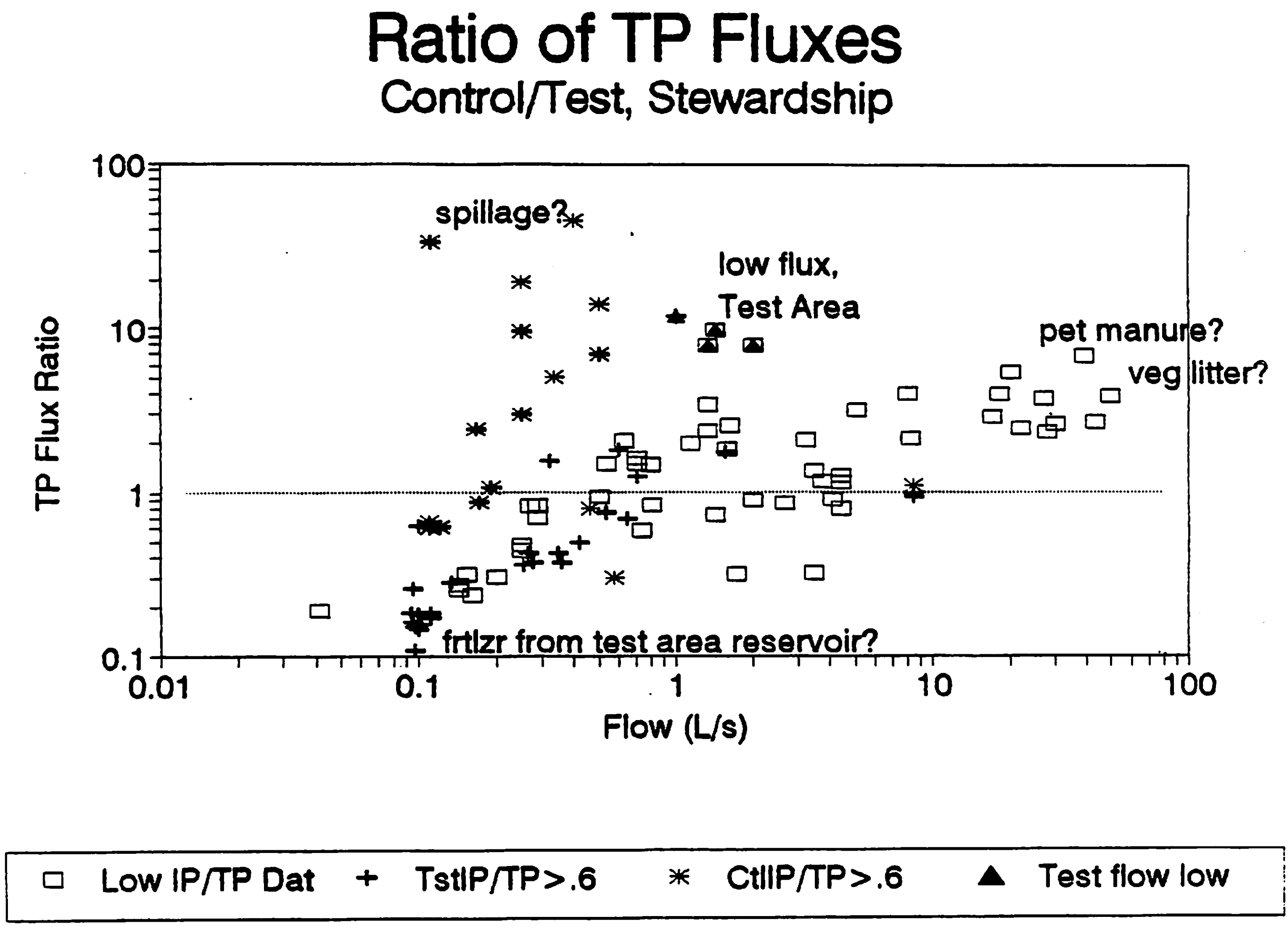


Figure 3.25
Ratio of Control Area TP Flux/Test Area TP Flux versus
Control Area Flow - Stewardship Period

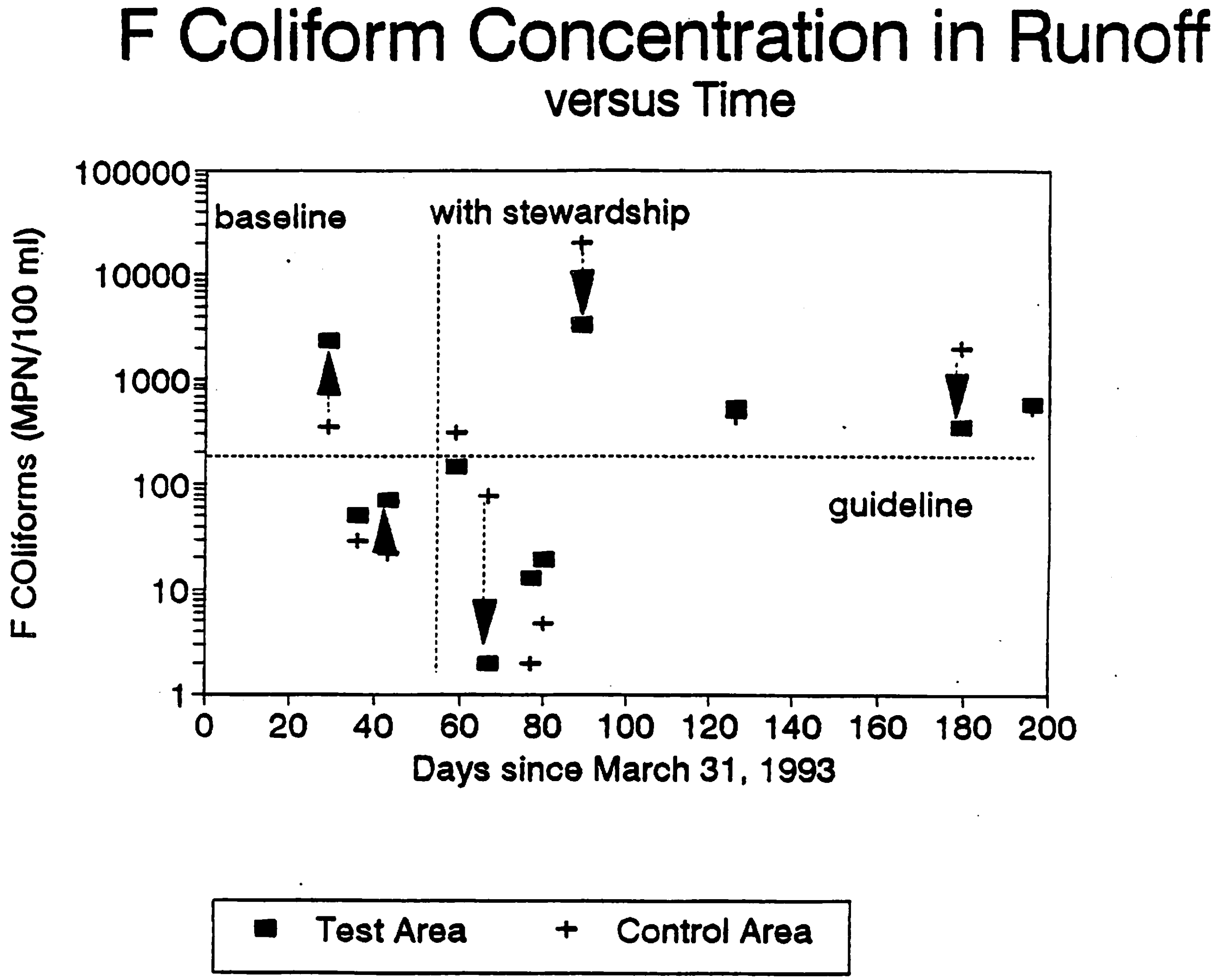


Figure 3.26
Time Series of Storm-mean Fecal Coliform Concentrations, with Arrows Identifying th Larger Differences Between Test and Control, and with a Lake Guideline.

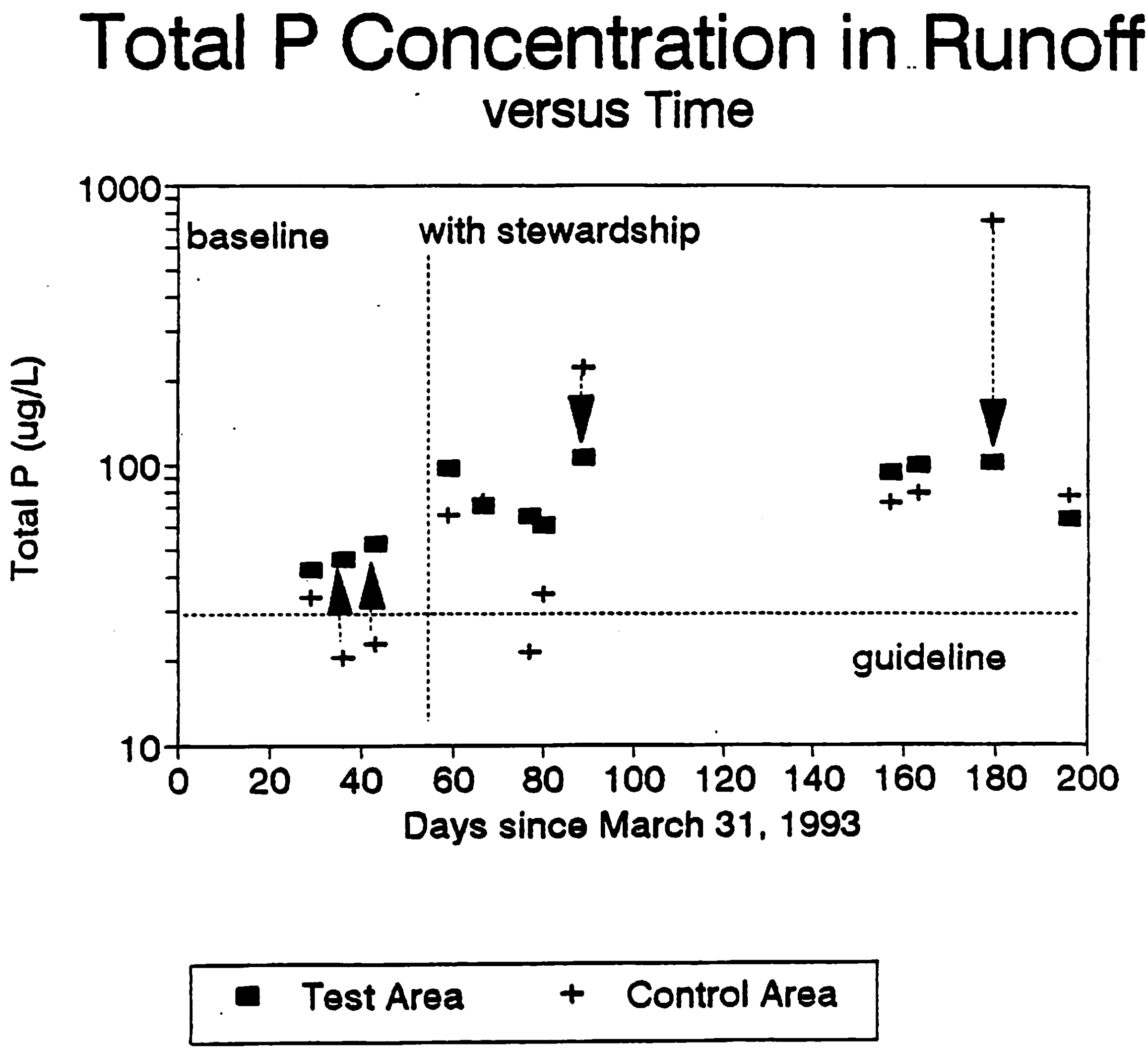


Figure 3.27
Time Series of Storm-mean Total Phosphorus Concentrations, with Arrows Identifying the Larger Differences Between Test and Control, and with a Lake Guideline.

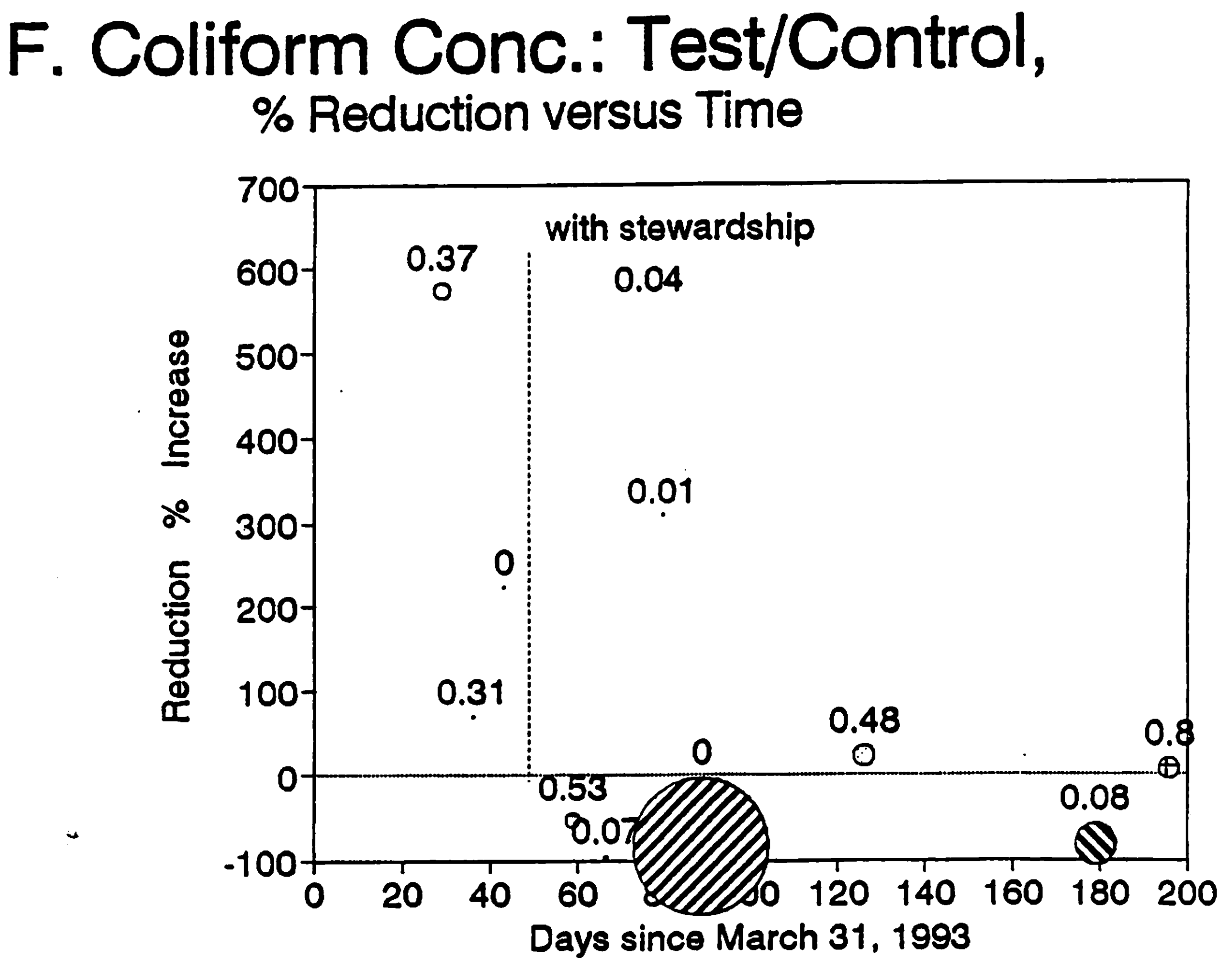


Figure 3.28
Time Series of the Percentage Reduction of Concentration of Fecal Coliforms in the Test Area Compared to the Control Area.

Total P Conc.: Test/Control,
% Reduction versus Time

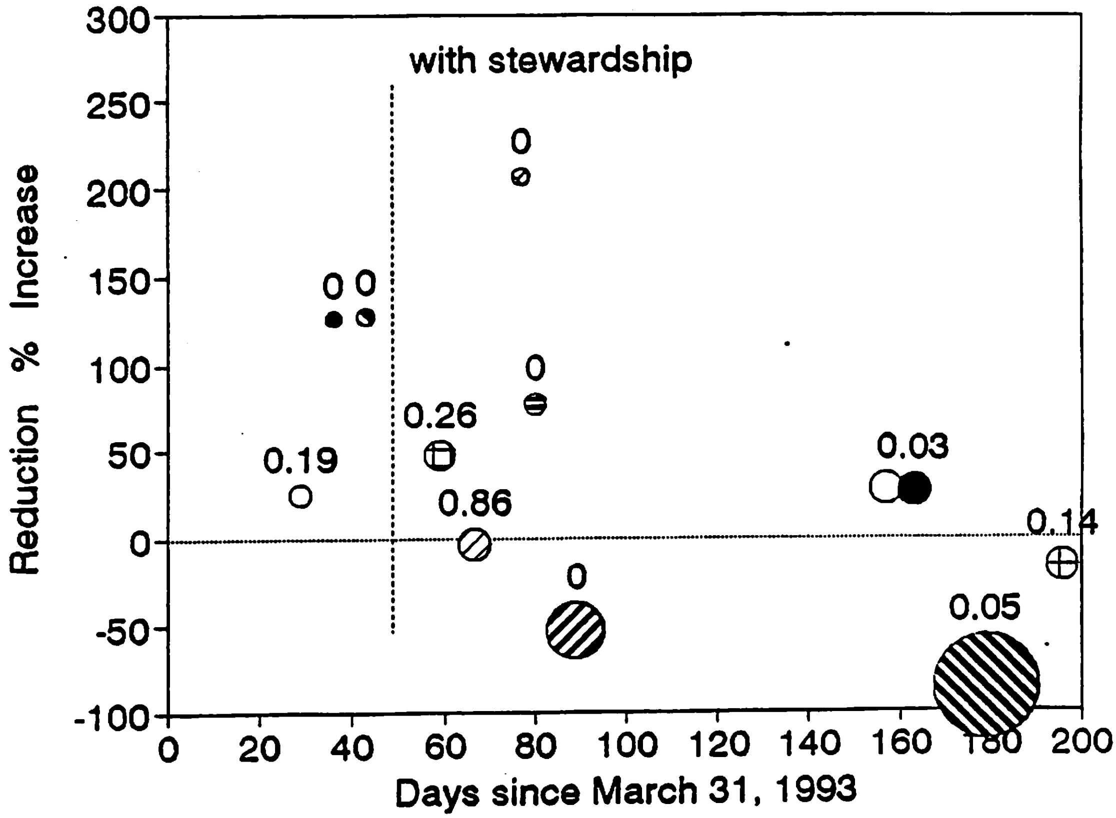


Figure 3.29
Time Series of the Percentage Reduction of Concentration of Fecal Coliforms in the Test Area Compared to the Control Area.

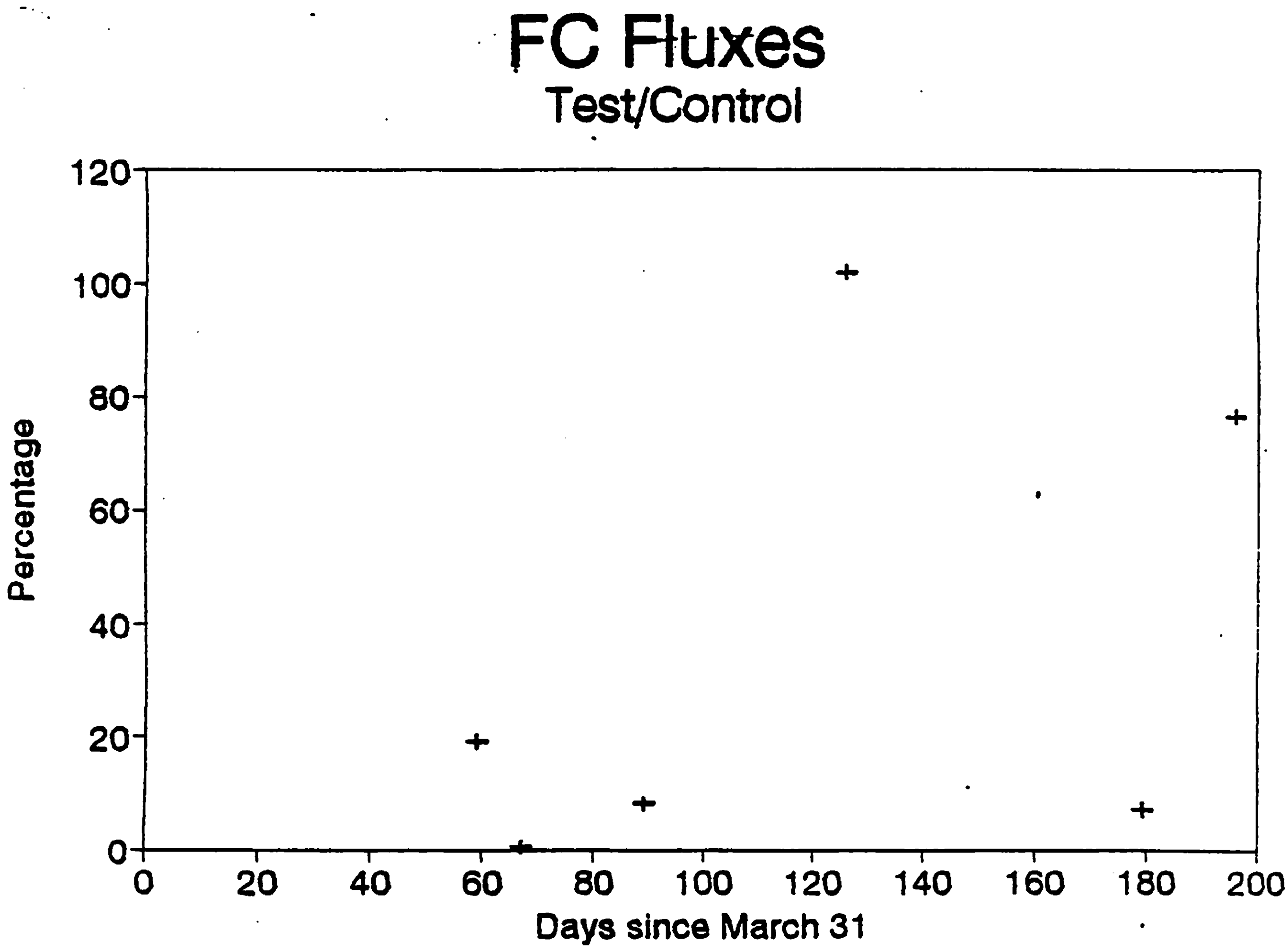


Figure 3.30
Time Series of the Ratio of the Fecal Coliform Fluxes.
Test/Control, Corrected for Outdoor Canine Density.

APPENDIX A

EXAMINATION OF FOUNDATION DRAINS

Halifax County Municipality provides a number of services to property owners relative to storm drainage. One such service is the investigation and analysis of drainage and flooding problems. During the years 1985 to 1993 inclusive, the Engineering and Works Department of the Municipality has responded to an average of approximately 300 new drainage complaints per year. A proportion of this total are complaints of basement flooding which are related to malfunctioning foundation drains.

The National Building Code provides for construction techniques which are intended to prevent flooding of building basements. In accordance with Code requirements, most building in Halifax County are provided with foundation drains which are constructed around the perimeter of the building foundation, (Figure A-1 on Page A-5).

The foundation drain material most commonly used in Halifax County is Big "O" pipe - a corrugated, flexible perforated pipe. Also, as provided for by the Code, crushed rock is typically provided beside and above the pipe itself, (Figure A-2 on Page A-6).

The primary function of the foundation drain is to intercept groundwater which could otherwise enter the building basement. This groundwater flows through the foundation drain (and/or the crushed rock), and is discharged (usually, but not always) to a ditch, storm sewer or some other acceptable system, (Figure A-3 on Page A-7).

There are a number of possible deficiencies related to the grading and drainage in the vicinity of the building which could contribute to basement flooding. One such deficiency which appears to be fairly common in Halifax County is the accumulation of fine soil material - silt and clay - in the foundation drain pipe and crushed rock. This fine material is carried into the pipe and crushed rock by water percolating through the soil and into the pipe and rock. It has been the experience of Halifax County that this accumulation of soil can be such that the foundation drain cannot function as intended, and basement flooding is a common result.

We also suspect that there is a carry-over of silt and clay into the storm sewer system and eventually into the area watercourse, carried by the water which flows through the foundation drain.

Our experience in this regard has come to us in a number of ways, as follows:

1) We receive from time-to-time complaints of water in their basement from people who have owned a property for some time and who have never flooded before. As a result of further investigation, we have found in some of these cases that the foundation drain has become filled with soil material, and consequently does not function as intended.

2) We have received similar information from contractors especially, in the Lower Sackville area. They have confirmed to us that it is not unusual to find foundation drains in the area which are plugged with soil material, resulting in flooded basements.

It is our experience that foundation drains in the First Lake watershed are generally constructed in conformance with the requirements of the National Building Code, which is the standard which governs the construction of such foundation drains. It is our view that the Code is not adequate to prevent against the eventual failure of the foundation drain system, at least when the native soil is fine and therefore mobile in the presence of water.

The purpose of our investigations relative to foundation drains in this project was to confirm the extent of failure (i.e. the build-up of silt in foundation drains), related particularly to the age of the system and other possible factors.

In order to determine if this theory was correct, the foundation drains of five houses in the watershed were partially exposed, opened, examined, and re-covered. The exposed portion was approximately one meter of the total length around the foundation. Before being re-covered, the drain, where cut to be examined, was repaired and new gravel was used around the exposed pipe.

House A is approximately 22 years old and the foundation drain was totally filled with silt and sand (Plate 1 on Page A-8). Little water would be able to travel through this pipe. The gravel surrounding the pipe was also completely full of silt and sand so that drainage through the gravel is equally unlikely. The homeowners indicated that they have recently (in the last 5 years) been experiencing water leakage into the basement in the approximate area where the drain was found to be blocked.

The drain at House B was exposed and found to be approximately 1/4 full of silt/sand. The gravel was relatively clean. The residence here is approximately four years old. In the past, more than one house on this street has had drainage problems.

House C had its foundation drains exposed and the drains were found to be approximately 1/2 full of sand/silt. This residence is approximately nine years old.

The foundation drain at House D was found to be over 1/2 full of material (Plate 2 on Page A-8). This house was approximately eight years old.

The last drain exposed, at House E was slightly different from the others. The drain had only 1 - 1.25 cm of silt in the pipe. This house is approximately eleven years old.

There are factors other than age which likely determine the extent of silt build-up in foundation drains, as follows:

1) Infiltrated Water - The amount of surface water which infiltrates into the ground and into the foundation drain is likely a highly significant factor. This in turn is determined by a variety of factors - the proximity of roof downspouts and how the discharge of these is controlled or directed, the grading of the land in the vicinity of the building (which will determine whether surface water is directed to or away from the area), the type of ground cover (lawn, asphalt, gravel, crushed rock, patio stones, etc., all of which permit varying rates of infiltration), the type of soil, the area of roof or ground area which drains or discharges water to the area, and others.

2) Soil Type - The grain size distribution of a soil will influence the mobility of the grains in water flowing through it.

3) Drain Filter - The grading of the material surrounding the foundation drain will affect its ability to screen out silt particles.

4) Others.

None of these listed factors was quantified for the foundation drains which were sampled. The purpose of this exercise was simply to determine through a limited sample size the extent of silt build-up in foundation drains. Our findings confirm what we had hypothesized: that even when constructed in accordance with the Code, foundation drains in certain soil types are likely to fail.

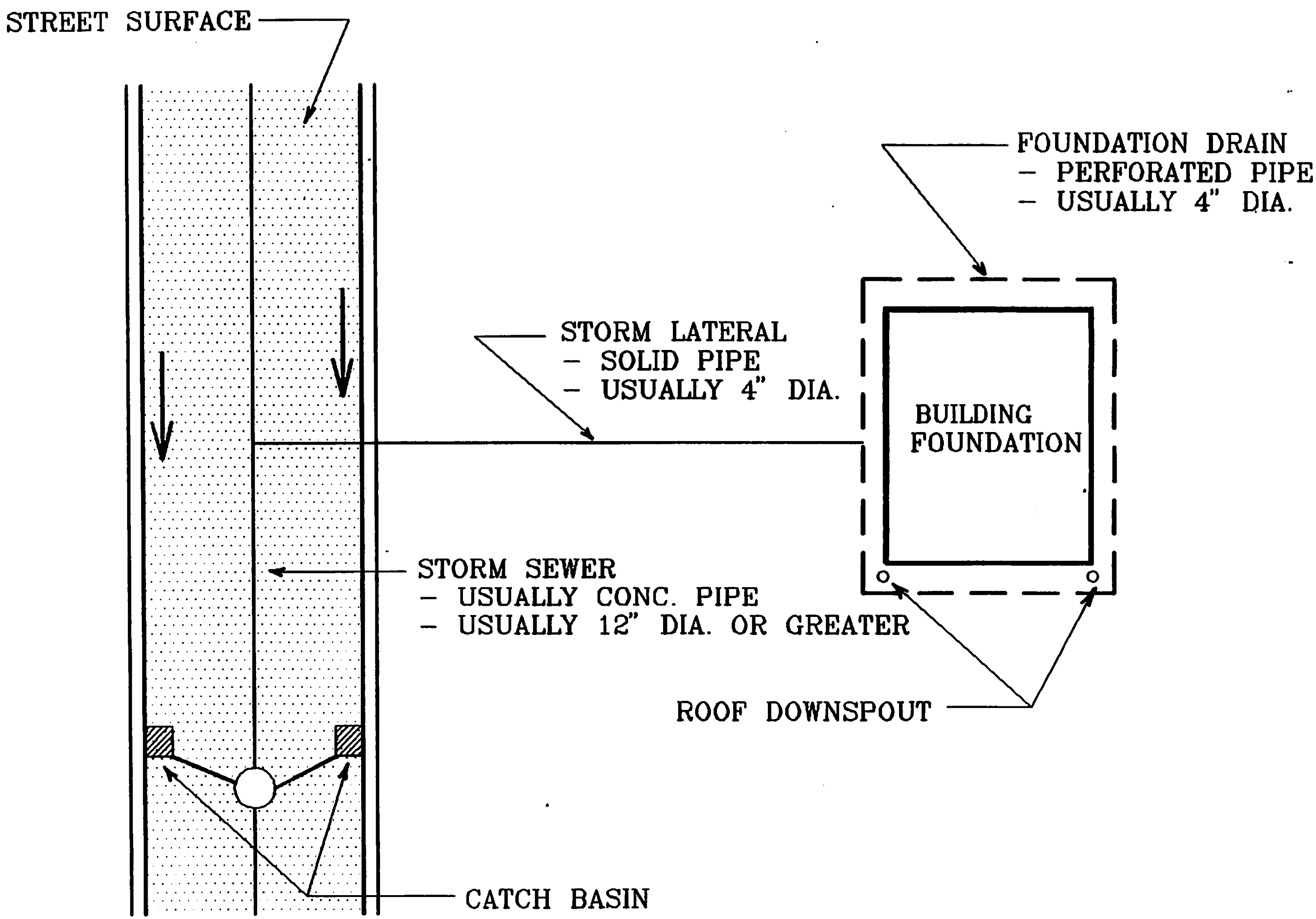

STREET SURFACE
FOUNDATION DRAIN
- PERFORATED PIPE
- USUALLY 4" DIA.
STORM LATERAL
- SOLID PIPE
- USUALLY 4" DIA.
BUILDING FOUNDATION
STORM SEWER
- USUALLY CONC. PIPE
- USUALLY 12" DIA. OR GREATER
ROOF DOWNSPOUT
CATCH BASIN

Figure A-1

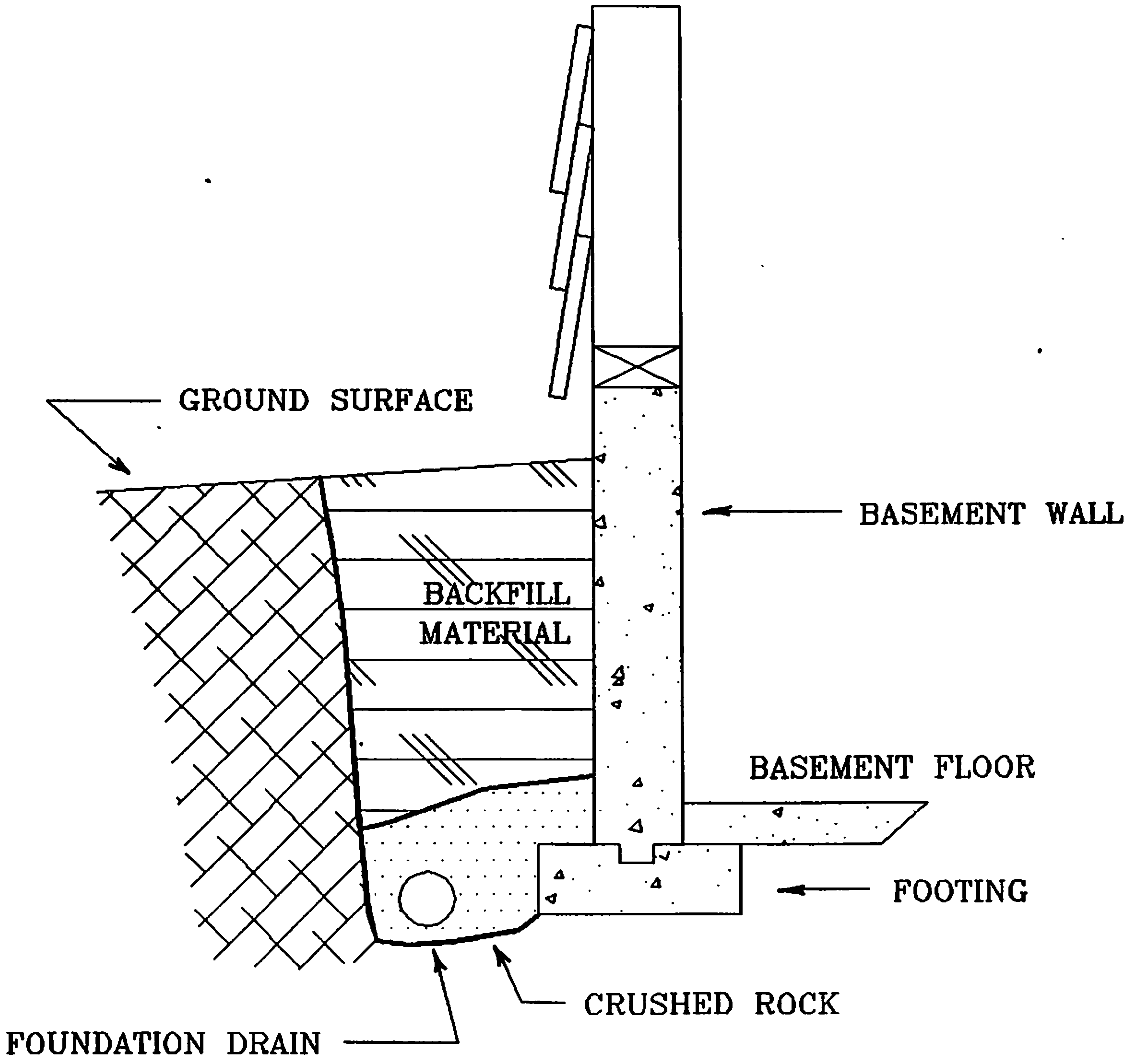

GROUND SURFACE
BASEMENT WALL
BACKFILL
MATERIAL
BASEMENT FLOOR
FOOTING
CRUSHED ROCK
FOUNDATION DRAIN

Figure A-2

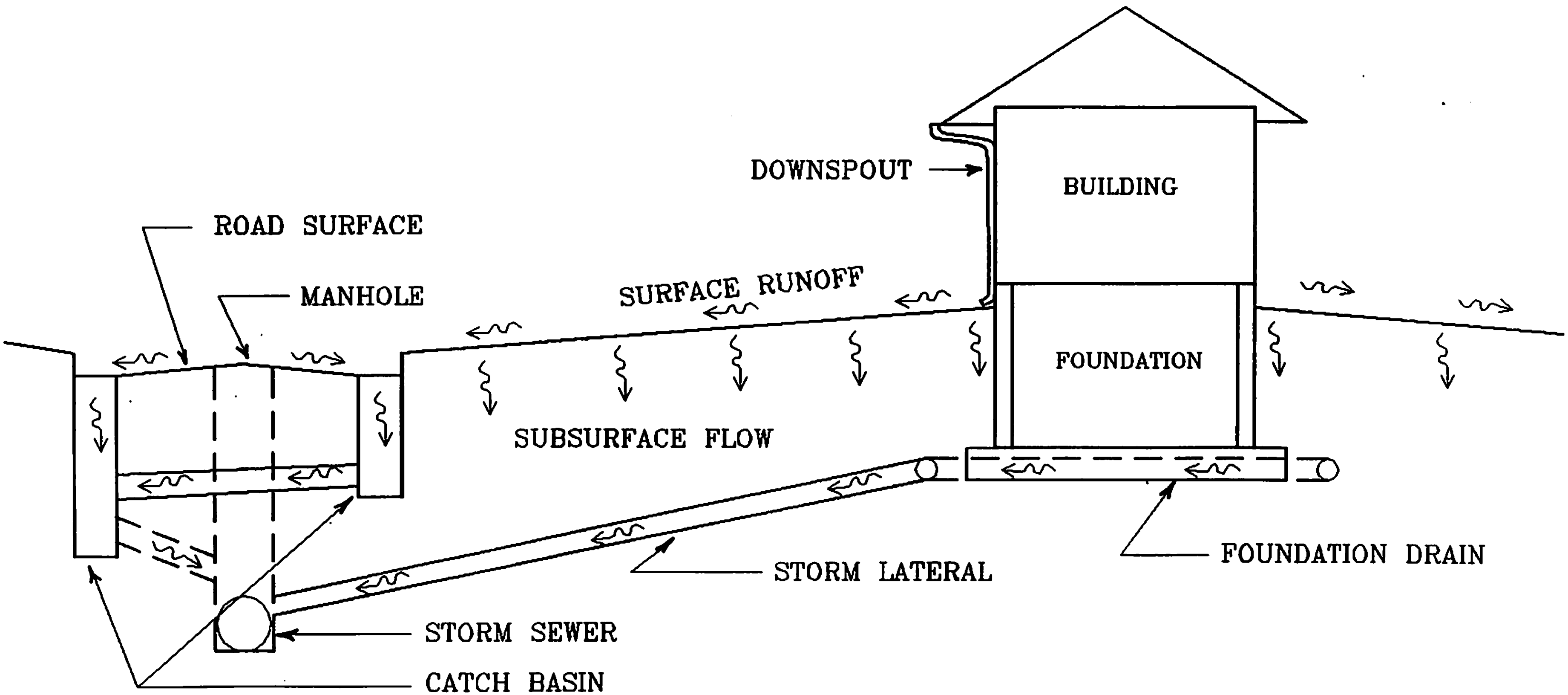

ROAD SURFACE
MANHOLE
SURFACE RUNOFF
DOWNSPOUT
BUILDING
FOUNDATION
SUBSURFACE FLOW
STORM LATERAL
FOUNDATION DRAIN
STORM SEWER
CATCH BASIN

Figure A-3

Plate 1

Foundation Drain - Filled with Silt - House A

Plate 2

Foundation Drain - 1/2 Filled with Silt - House D

APPENDIX B

SOIL AND TURF AUDITS FOR CRIMSON DRIVE

TABLE OF CONTENTS - APPENDIX B

Appendix B - 1 formed the overview of basic practice theory, in terms of soil fertility, and applied it to the results gained from the laboratory soil analysis of the test area soils. Each element of the soil analysis is explained with particular attention paid to the practice application of this information in a watershed based landscape.

Appendix B-1 was one of the major vehicles used by the research team to educate the residents of the watershed about land stewardship and in particular about unwarranted and unnecessary applications of Phosphorus to the soil in the form of surface fertilizer applications.

Appendix B - 2 is a compilation of information obtained about our test area from questionnaires, individual interviews, site observations and physical analysis. This information was also delivered to the individual residents to raise awareness about what was happening in their neighbourhood, as well as on their own properties. Appendix B-2 speaks to topics of turf, soils, cultural practices and individual stewardship.

Appendix B-2 also includes samples of individual reports given to the residents of the test area, specific to their own properties. It is preceded by a legend which will assist in identifying and defining abbreviations used in the information.

Appendix B - 3 is specific to a set of soil based experiments run at the municipal Fire Hall located in the First Lake watershed and adjacent to the test and control areas. The experiments were set up to test the impact of soil amendments and fertilizers on overall turf quality grown on typical local soils. These experiments were run simultaneously with test and control area experiments. Ten different applications were made based on assumptions about soil type, quality, chemistry and structure. The highlights of these experiments will be found in test groups numbers 6 to 9 which provided the best results and mirrored the recommendations made to the residents later in the experiment, for their own properties. The results are followed by statistical information compiled during the experiment.

SOIL AND TURF AUDITS FOR CRIMSON DRIVE (THE LOW P TREATMENT GROUP)*

Each family is being given a detailed soil and turf audit based on soil samples taken on May 20,21, and observations on turf over the ensuing period. These will help you manage your turf for good quality, while participating in the experiment in the in the low P treatment group. Below, the data and recommendations for the whole neighborhood are summarized and discussed.

1. SOIL FERTILITY (LAB) AUDITS, & RECOMMENDATIONS

Very detailed soil fertility audits were conducted. The primary objective is to determine the requirements for P for each property, so that P is applied only when it is really needed. Restrictions on the quantities and types of P fertilizer used on Crimson Drive are essential for the duration of the experiment. This restricts, in turn, the range of material inputs that can be used. Thus the recommendations are more limited in scope or possibilities than would be the case if we were not so concerned about drastically reducing the possibility of runoff of P for the duration of this experiment. Once we have a better understanding of the dynamics of P movement in this system, we will be able to recommend a wider range of options for material inputs. Alternative recommendations that involve minimal use of P fertilizers might be offered by Professional Lawn Care companies working in the area; these have been discussed with us and are acceptable. For the sake of documentation, we are asking Lawn Care Companies to tell us what fertilizer inputs they are making.

Timing of fertilizer applications: If you do not water your lawn regularly. we suggest holding off fertilization until September. (With heat and drought. many grasses go into mid-summer dormancy; applying fertilizer would keep them from doing that, making them more susceptible to drought-kill; also salt effects will be more severe). If you water regularly on the other hand, and the grass is looking somewhat beat out, then an early July application is appropriate (but not in later July/early August when it is hottest). See page 5 for a fertilizer application schedule.

Units: Rates of fertilizer application for turfs, even in Canada, are commonly expressed in "pounds per 1000 square feet". To convert lbs/1000 sq feet to kilograms per 10 x 10 m, multiply by 0.5

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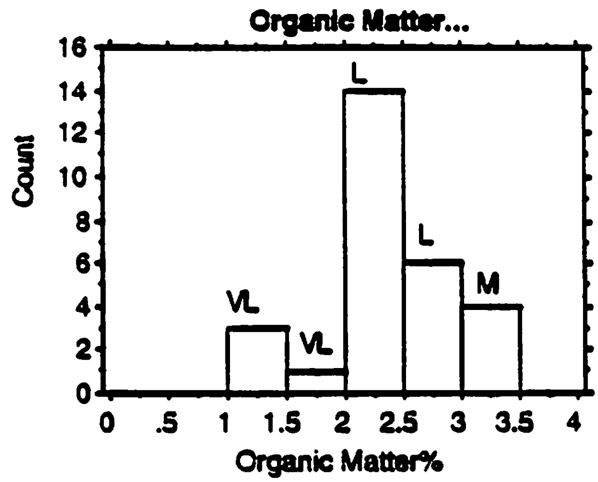
*The interpretations and recommendations are those of David Patriquin (Dalhousie University), David Reid and John Edmonds (Edmonds Environmental Services), July 7, 1993. Many individuals have contributed to the audit process in various ways, including Greg MacAskill. Margaret Hope-Simpson, Eric O'Brien, Chengzhi Yang, David Morse, Greg Sharam, Richard Van Ingen, Perry Lambourne.

Comments on the neighborhood data

Organic Matter: All soil organic matter values are low compared to what is desirable in turf soils, which is >4% OM; values below 2% are very low. Applications of about 1/2 inch compost in spring and fall will help to increase soil organic matter.



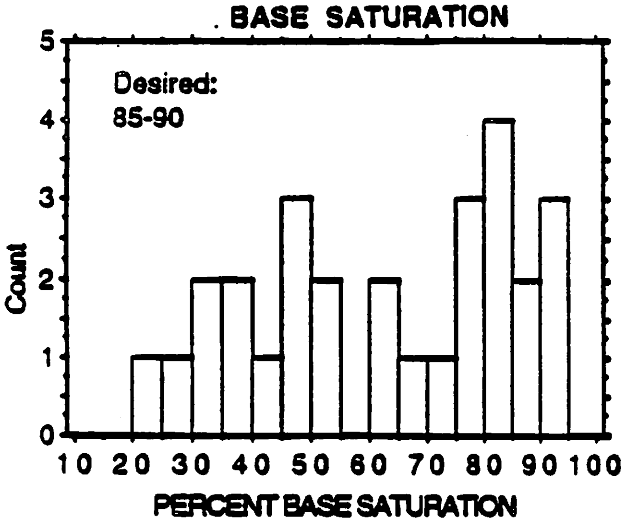
(Letters denote ratings: VL=very low, L=low, M=medium, H=high, VH=very high. "Count" refers to the number of properties in each category. Twenty eight properties were sampled)

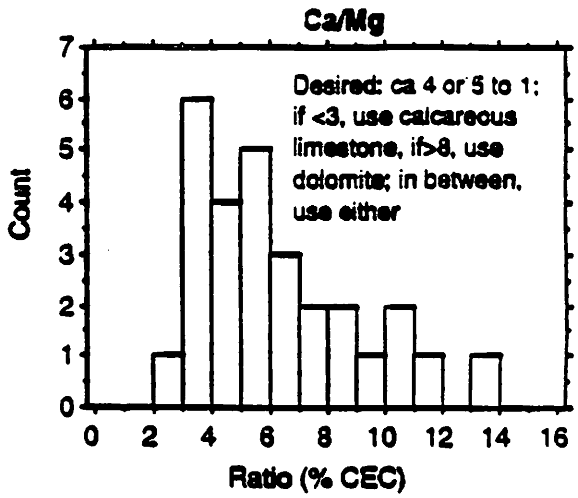
pH; lime requirement; Base Saturation

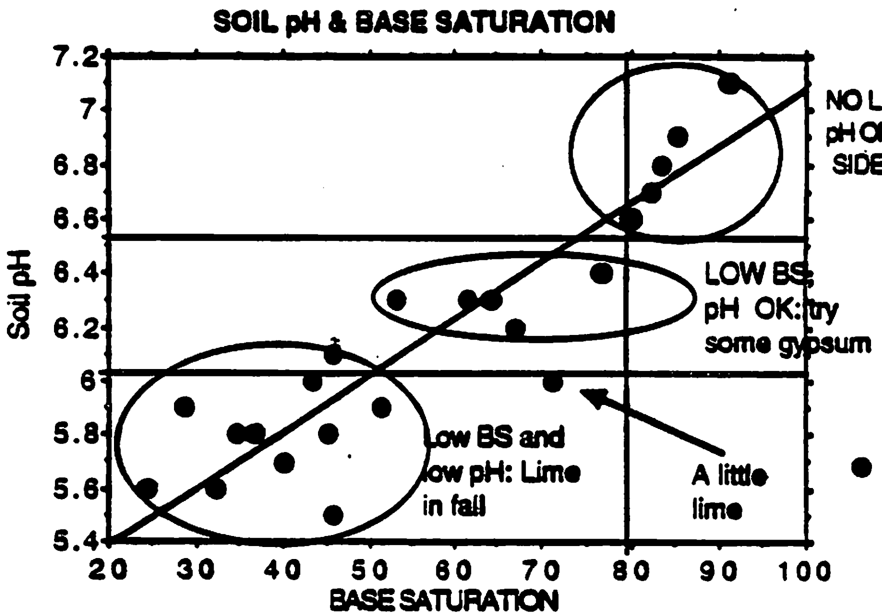
Nine of the soils had pH in the range 6-6.5 which is ideal; ten were >6.5 but not seriously; and nine were between 5.4 and 6 which is in the suboptimal range. Liming is indicated for the low pH soils. (A rule of thumb application of lime to turfs is 50 lbs/1000 sq feet every 3 years). For the soils with pH values of 6.6 and above, we recommend no more application of lime this year, and then retesting the soil next spring.

For the soils "in between", the story is a little more complicated. For good structure or "tilth", about 85-90% of the negative charges (the "Cation Exchange Capacity") on the soil colloids (clay and humus), should be occupied by basic cations such as Ca, Mg and K, particularly Ca. Higher Base Saturation (100%) is good for tilth, but in other regards it is best for the soil to be slightly acid which means that 10-15% of the cation exchange capacity should be occupied by acidic cations (mainly H^+). Generally, if the pH is in the desirable range, the soil will be 80% or more saturated with basic cations. However, for eight of the Crimson

Drive samples, base saturation was low while the pH (6.2-6.4) was well within the desired range. In these cases, we are suggesting that you experiment with adding



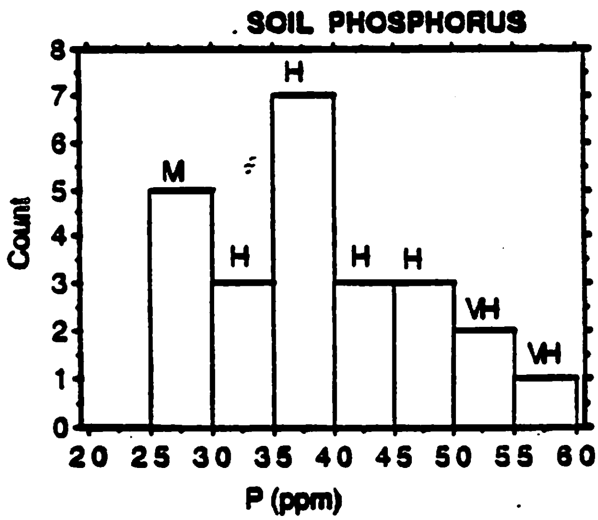




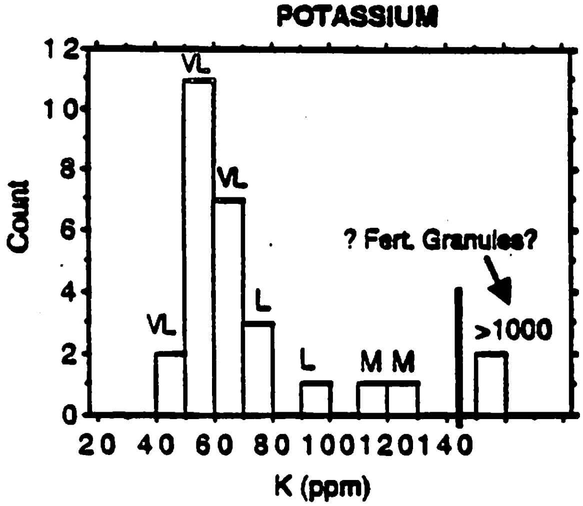
some pelleted gypsum (20-40 lbs/1000 sq ft) to raise the Ca quickly. The gypsum is highly soluble, and will work its way down the soil profile more readily than would lime, especially where earthworm populations are low. (Use of gypsum is also a good way to ameliorate deterioration in areas that have been affected by road salts, and burned patches caused by dog urine). The gypsum will have no effect or a very slight acidifying effect on soil pH (it's not recommended for soils with suboptimal pH). There is no risk in applying gypsum if the pH is OK now, but we are not yet confirmed its benefits locally, thus the homeowners might want to try this on only a part of the lawn -or wait to see the results from the Fire Hall turf experimnent (p.6).

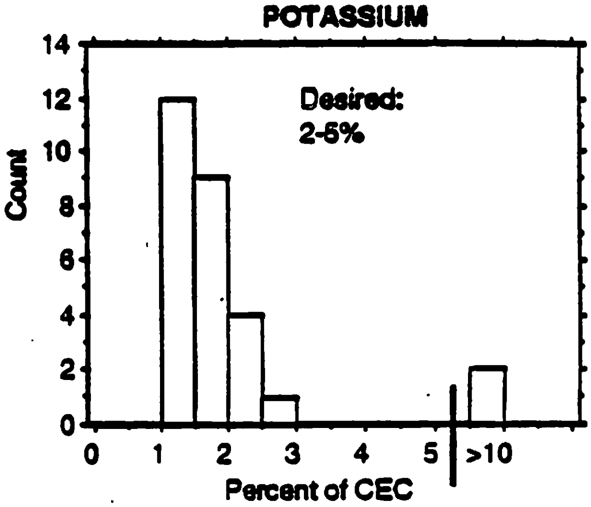
Another consideration in liming is the ratio of calcium to magnesium on the cation exchange complex . Ideally, 60-70% of the CEC (cation exchange capacity) is occupied by calcium, 10-20% by magnesium, and 2 to 5% by potassium. If the ratio of Ca/Mg is less than 3, it is suggested to use calcareous limestone, which is very low in Mg. If it is greater than 7-8, be sure to use dolomitic limestone (the most common type locally). In between, use either.

Phosphorus (P): P is the nutrient of particular interest in the project. According to the soil analyses, all soils have medium to very high levels of P. This is not surprising, as most the soils have been regularly fertilized with mixed fertilizers, and most of the P is retained in the soil. For the M level soils, we are recommending application of "Rock-P", a relatively coarse, mostly insoluble P mineral. The natural acidifying reaction of the soil will gradually make this available. For soils with high and very high levels of available P, we are asking that no P fertilizer be applied this year.



Potassium (K): Most soils had low potassium, judged either by the rating of the total amount, or by its percentage of the Cation Exchange Capacity. This is not surprising as K is very mobile, and soils are thin. Use of highly soluble N fertilizers also causes leaching of the basic cations (potassium, calcium, magnesium). We are recommending use of potassium sulfate rather than muriate of potash (potassium chloride), as the sulfate salt is more gentle on plants and soil microbes. If K is very high relative to magnesium (>5:1 on a weight basis), magnesium uptake can be inhibited. This was the case, possibly, for two properties that had exceptionally high K. However, these exceptionally high values would have to be confirmed. They could have been due to recently deposited fertilizer granules in the soil samples and not reflective of the average condition in the soil.





Nitrogen (N): Nitrogen status of soils is not estimated in standard soil analyses, as it exists mostly in the form of humus (soil organic matter), which is only slowly available, and it is difficult to estimate precisely how much N will be supplied from this source. There is little residual N from soluble N applied in previous years. Thus usual recommendations for N are based primarily on the crop, (in this case turf grass), allowing for a minimal supply from the humus. The recommendation that would be given on this basis for Crimson Drive soils is 4 lbs N/1000 sq ft per season, usually in the form of urea or ammonium or nitrate salts. As these soils are all quite low in soil organic matter and will not supply a lot of N naturally, levels in the region of 3-4 lb N per season may be needed currently to keep the grass at the desired level of greenness. We have suggested use of feathermeal which for natural materials has a high N content (10%), and should be almost as effective in the short term as synthetic fertilizers applied at the same rate. Do not use urea in summer; you could use ammonium nitrate, but be careful to avoid burning.

For N fertilizers, the rate of application, and timing, should be assessed on the basis of how green the grass is. how green you want it, and the time of year. Most important is a late fall or "dormant" application; in our area this is typically in the latter half of October/early November after there have been one or two good frosts, but before solid freezing sets in. Then you can apply 1 lbs N per 1000 sq feet (10 lbs feathermeal). If you do that, then the grass will green up early in the spring, and the spring application can be delayed until end of May/early June. Whether you apply more in mid summer should be judged on greenness, and whether or not you irrigate regularly. If you do irrigate regularly, another 1 lb application could be made towards the end of June -- or into July if weather is cool as it is this year. But don't apply N towards the latter half of July, or in early August, when it is very hot. Apply N only modestly if at all in early fall - most turfs will green up well on their own during this period. The apply it again late October/early November.

As the soil organic matter is built up, you will find that the grass stays greener longer on its own, and you can cut back on the N. That helps the environment as nitrate leaching from turfs is a pollutant. Generally, N causes eutrophication in estuarine and coastal waters, and P in Lake waters; regardless, its safest to keep the leaching of both to a minimum.

SUMMARY SCHEDULE OF FERTILIZER APPLICATIONS:

Phosphorus (P): in mid September if low now; routinely, in spring.

Nitrogen (N) in mid summer (now) if needed and if turf is watered regularly; otherwise, wait until circa Nov. 1 for the dormant application. Do not apply it in the hot dry weather. Apply N again in spring, towards end of May, early June.

Potassium (K): this should be applied mid-September to help hardening off of the grass.

Lime: apply lime if needed in mid-to end of October, or in the spring.

As possible, aerate turf in October to facilitate incorporation of soil amendments in the profile.

2. Turf (Field) Audits

Soils :

1. Clay content, assessed by malleability of soil samples was high.

2.Topsoil depth and quality was consistently poorest within 3-5 ft. of home foundations and driveways.

3. Organic and clay horizons were consistently found at levels 6"- 9" deep in the soil in the rear of the properties and within 10 ft. of the natural tree line.

Turf :

4. Turfgrass covers range from 100% Bluegrass Sod to "Seed Blend" established properties. Many of the home owners have overseeded in the past which has resulted in some very diverse turf flora.

5. Overall, the average thatch level of the turf areas is medium to high in range, which bears attention.

6. The overall weed population of the turf on Crimson Drive is actually quite good(<5% weed cover overall). However, some individual properties do have high weed populations. These findings can be considered typical of most neighborhoods.

7. Most of the properties that have weeds have tolerable and manageable levels. There are many personal interpretations of tolerable, and many ways to deal with high weed levels.

8. Most lawn areas started off fairly well in the spring. A few properties fell back a bit but most progressed well and observations reflected a stable pattern of growth and development for a healthy turf system.

Cultural Practices :

9. Six properties were found to be aerated. (21% initially ; now >50%).
Four properties were found to have been fertilized this Spring. (14%).
Two properties were found to have been topdressed with composted material this Spring (9%).

Twenty-eight properties in total are in the Test Group. (100%)

10. Maintenance practices of the properties range from "well maintained" to a more "passive approach". Overall the entire area is well kept with all residents being "House Proud" with respect to the exterior maintenance.

11. Aeration is a good tool to help control thatch, and to help incorporate soil amendments like compost, lime gypsum, fertilizer into the soil profile.

Response to Questionnaire Data :

12. The existence of Pet Manure on the properties throughout the neighborhood was reported to be extensive (98% of properties). The handling and disposal of this material must be stressed.

13. The stewardship of the pet manure in the test area was very good. Your work and cooperation are very much appreciated. A job well done!

14. The potential problem of surface run-off resulting from weekly car washes needs to be addressed. In total; 234 cars get washed on Crimson Drive in one Season. Please remember to use a phosphate-free soap or cleaner when washing the car.

LEGEND :

H #	-	House Number
F/B	-	Front / Back of Property
Slope / Grade	-	Drainage Pattern
%Sn	-	Percentage of Direct Sunlight in 1 Day.
B	-	Kentucky Bluegrass
F	-	Fescue Grasses
R	-	Rye Grasses
Cl	-	Clover
Dd	-	Dandilion
Other	-	Other Ground Covers (grasses/weeds/wildflowers/perrenials)
Depth / Area	-	Average Depth & Range of Topsoil / Total sq/ft. of Turf Area
Th	-	Average Thatch Level
CW	-	Car Wash (number of times per year)
PM	-	Existence of Pet Manure on Property
Care- SM/PM	-	Property "Self Maintained " or "Professional Care"

Property: [redacted] Crimson Dr. [redacted]

Field Observations:

H #	F/B	Slope/Grade	%Sn	B	F	R	Cl	Dd	Other	Depth/Area	Th
1	F	Gradual to Street	90	30	40	20	5	5	5	3.8"(1-14)	1"
	B	Gradual to Forest	70	15	15	10	40	15	5	4500 sq/ft	3/4 "

Observations	CW	PM	Care
	2	Yes	SM

Soil Audit:

Soil organic matter (%)	P (ppm)	K (ppm)	Mg (ppm)	Ca (ppm)	Soil pH	Buffer pH	CEC
2.9	31.0	78.0	86.0	497.0	5.6	6.4	10.6
	High	Low	Low	Very Low			

Base Saturation %	% K	% Mg	% Ca	Ca/Mg
32.1	1.9	6.8	23.4	3.4

Fertilizer recommendations:

Lime	N	P	K
35 lbs/1000 sq ft	See Group Recs for N	None	5 lbs Pot. sulfate per 1000 sq ft

Comments:

Turf color and density are fairly good given your particular turf system. Clover population has increased substantially. Broad leafed and other weed populations seem in better control now. Cutting height is good.
The thatch level overall is high. Your turf would benefit from dethatching this fall to regain a healthy control level. Your stewardship of pet manure has been good - thank you for your efforts!
Follow your fertility recommendations.

Your cooperation in this community project is very much appreciated.

Property: [redacted] [redacted]

Field Observations:

H #	F/B	Slope/Grade	%Sn	B	F	R	Cl	Dd	Other	Depth/Area	Th
2	F	Gradual to Street	90	70	30	0	0	0	0	4.5"(1-11)	3/4"
	B	Gradual to Forest	50	60	40	0	0	0	0	3100 sq/ft	1/2"

Observations	CW	PM	Care
Strong Healthy Turf. Organic Soil layer at 8"& Clay horizon at 9" in Rear.	0	Yes	PC

Soil Audit:

Soil organic matter (%)	P (ppm)	K (ppm)	Mg (ppm)	Ca (ppm)	Soil pH	Buffer pH	CEC
3.4	31.0	59.0	147.0	711.0	5.8	6.5	10.9
	High	Very low	Medium	Very low			

Base Saturation %	% K	% Mg	% Ca	Ca/Mg
45.1	1.4	11.2	32.5	2.9

Fertilizer recommendations

Lime	N	P	K
35 lbs/1000 sq ft; use calcareous limestone if poss.	See Group Recs for N	None	6 lbs Pot. sulfate per 1000 sq ft

Comments:

Turf color and density are OK. Front turf area is patchy, slightly dry and yellow in comparison to the back. Recommend slightly more regular cutting practices and maybe a little irrigation for the front. Your thatch levels are getting high and your turf would benefit from dethatching in the next year or so.
The turf started the year in good shape but has faded somewhat in terms of quality and strength. This can be easily remedied.
Follow your fertility recommendations.

Your cooperation in this community project is very much appreciated.

Property: [redacted] [redacted]

Field Observations:

H #	F/B	Slope/Grade	%Sn	B	F	R	Cl	Dd	Other	Depth/Area	Th
8	F	Medium to Street	90	80	10	3	3	3	1	5.9"(2-10)	1/2"
	B	Gradual to House	30	25	40	0	5	0	30	2200 sq/ft	1/2"

Observations	CW	PM	Care
Rear is 50% Wooded. Mature Trees within 20' of rear of house.	2	Yes	SM

Soil Audit:

Soil organic matter (%)	P (ppm)	K (ppm)	Mg (ppm)	Ca (ppm)	Soil pH	Buffer pH	CEC
2.3	32.0	51.0	45.0	870.0	6.2	6.8	7.3
	High	Very low	Low	Medium			

Base Saturation %	% K	% Mg	% Ca	Ca/Mg
66.9	1.8	5.2	60.0	11.5

Fertilizer recommendations

Lime	N	P	K
None this year.	See Group Recs for N.	None.	6 lbs Pot. sulphate per 1000 sq ft.

Comments:

Turf color and density are fairly good. Weed population in back has doubled since the start of the test. Should you have inquiries with respect to control measures, we would be happy to advise. Clover population has nearly doubled as well, which we think is good.
Follow your fertility recommendations.

Your cooperation in this community project is very much appreciated.

Property: [redacted] [redacted]

Field Observations:

H #	F/B	Slope/Grade	%Sn	B	F	R	Cl	Dd	Other	Depth/Area	Th
9	F	Gradual to Street	85	65	25	0	1	1	6	5.2"(2-9)	1"
	B	Gradual to Forest	90	65	30	0	1	0	5	4200 sq/ft	3/4"

Observations	CW	PM	Care
Clay horizon at 7-8" at Side and Rear	24	Yes	SM

Soil Audit:

Soil organic matter (%)	P (ppm)	K (ppm)	Mg (ppm)	Ca (ppm)	Soil pH	Buffer pH	CEC
2.3	75.0	55.0	154.0	1080.0	6.6	6.9	8.5
	Very high	Very low	High	Medium			

Base Saturation %	% K	% Mg	% Ca	Ca/Mg
80.1	1.7	15.1	63.3	4.2

Fertilizer recommendations.

Lime	N	P	K
None	See Group Recs for N	None	6 lbs Pot. sulfate per 1000 sq ft

Comments:

Turf color and density are very good. Cutting height is also good. Property is well maintained.
Thatch levels are high overall. Your turf would benefit from dethatching this fall to establish healthy and manageable thatch levels.
Follow your fertility recommendations.

Your cooperation in this community project is very much appreciated.

Property: [redacted] [redacted]

Field Observations:

H #	F/B	Slope/Grade	%Sn	B	F	R	Cl	Dd	Other	Depth/Area	Th
16	F	Gradual to Street	90	100	0	0	0	0	0	4.1"(2-10)	1/2"
	B	Gradual to Forest	75	80	15	0	5	0	0	2100 sq/ft	1/2"

Observations	CW	PM	Care
Organic layer at 6" in Rear. Rear area is wet.	N/A	N/A	N/A

Soil Audit:

Soil organic matter (%)	P (ppm)	K (ppm)	Mg (ppm)	Ca (ppm)	Soil pH	Buffer pH	CEC
2.0	29.0	59.0	62.0	1075.0	6.7	6.9	7.3
	Medium	Very low	Low	Medium			

Base Saturation %	% K	% Mg	% Ca	Ca/Mg
82.3	2.1	7.0	73.2	10.4

Fertilizer recommendations

Lime	N	P	K
None	See Group Recs for N	25 lbs Rock-P per 1000 sq ft	6 lbs Pot. sulfate per 1000 sq ft

Comments:

Turf color and density are fairly good overall. Weed populations have remained in control.
Problem with amount of water/drainage in the back of the property. A drainage syster has been installed from the back yard to the street. Recommend raising cutting height : much as 1 inch higher to benefit the turf. The layout and appearance of your landscape attractive.
Property has remained stable throughout the test period.
Follow your fertility recommendations.

Your cooperation in this community project is very much appreciated.

Property: [redacted] [redacted]

Field Observations:

H #	F/B	Slope/Grade	%Sn	B	F	R	Cl	Dd	Other	Depth/Area	Th
21	F	Gradual to Street	95	70	5	5	0	3	10	4.7"(2-9)	1/2"
	B	TBC	60	20	60	0	0	0	20	3900 sq/ft	1/2"

Observations	CW	PM	Care
Home Owner has Over-seeded & Topdressed with mulch. Has also aerated. Well maintained.	4	Yes	N/A

Soil Audit:

Soil organic matter (%)	P (ppm)	K (ppm)	Mg (ppm)	Ca (ppm)	Soil pH	Buffer pH	CEC
1.7	36.0	51.0	86.0	974.0	6.3	6.7	9.3
	High	Very low	Low	Low			

Base Saturation %	% K	% Mg	% Ca	Ca/Mg
61.4	1.4	7.7	52.3	6.8

Fertilizer recommendations

Lime	N	P	K
None	See Group Recs for N	None	6 lbs Pot. sulfate per 1000 sq ft

Comments:

Turf density and color are fairly good, considering the flora mix. Weed population ha increased and so has the amount of clover (both up 5%). Selective weed control may b in order at this time.

Turf area is a whimsical mix of wild and meadow flowers, clover and grass. This is a pleasant mix and complements your perennial landscape nicely. The mix of species in turf area will fluctuate over time.

Desirable quantities of each species is a matter of personal taste. Your home has a friendly and inviting appearance.

Follow your fertility recommendations.

Your cooperation in this community project is very much appreciated.

Property: [redacted] [redacted]

Field Observations:

H #	F/B	Slope/Grade	%Sn	B	F	R	Cl	Dd	Other	Depth/Area	Th
28	F	Gradual to Street	90	95	0	5	0	0	0	5.4"(2-10)	3/4"
	B	Gradual to Forest	80	90	10	0	0	0	0	3600 sq/ft	1/2"

Observations	CW	PM	Care
Aerated. Rear area is wet.	3	Yes	SM

Soil Audit:

Soil organic matter (%)	P (ppm)	K (ppm)	Mg (ppm)	Ca (ppm)	Soil pH	Buffer pH	CEC
2.3	38.0	62.0	105.0	1303.0	6.6	6.8	9.4
	High	Very low	Low	Medium			

Base Saturation %	% K	% Mg	% Ca	Ca/Mg
79.9	1.7	9.3	68.9	7.4

Fertilizer recommendations

Lime	N	P	K
None	See Group Recs for N	None	6 lbs Pot. sulfate per 1000 sq ft

Comments:

Turf quality, color, and density are good in the back and OK in the front. The front is patchy and dry and seems to be a high traffic/use lawn area. It is showing natural signs stress.
A little water now and again would still help, and immediate fertilizer application in the front area is recommended. Thatch levels are medium to high and the turf would bene from dethatching this fall or next spring.
Follow your fertility recommendations.

Your cooperation in this community project is very much appreciated.

Property: [redacted] [redacted]

Field Observations:

H #	F/B	Slope/Grade	%Sn	B	F	R	Cl	Dd	Other	Depth/Area	Th
29	F	Gradual to Street	90	90	10	0	0	1	0	5.0"(2-12)	1/2"
	B	TBC	80	45	50	0	1	2	2	3500 sq/ft	1/2"

Observations	CW	PM	Care
Aerated and well maintained.	10	Yes	SM

Soil Audit:

Soil organic matter (%)	P (ppm)	K (ppm)	Mg (ppm)	Ca (ppm)	Soil pH	Buffer pH	CEC
2.5	54.0	60.0	97.0	605.0	5.7	6.5	10
	Very high	Very low	Low	Very low			

Base Saturation %	% K	% Mg	% Ca	Ca/Mg
39.9	1.5	8.1	30.3	3.7

Fertilizer recommendations

Lime	N	P	K
35 lbs/1000 sq ft	See Group Recs for N	None	6 lbs Pot. sulfate per 1000 sq ft

Comments:

Turf color and density are fairly good. Both front and back lawns are high traffic/use areas which will naturally stress your turf. Cutting height could be a little higher, and this will help in trafficked areas and assist in weed control. Weed population has increased since the spring, and total population may require some form of control. Pleasant landscape; nice selection and layout of perennials in front and back. Follow your fertility recommendations.

Your cooperation in this community project is very much appreciated.

Property: [redacted] [redacted]

Field Observations:

H #	F/B	Slope/Grade	%Sn	B	F	R	Cl	Dd	Other	Depth/Area	Th
36	F	Gradual to Street	90	50	20	0	5	0	30	3.5"(1-11)	1/2"
	B	Gradual to Forest	50	50	15	0	2	0	35	3200 sq/ft	1/2"

Observations	CW	PM	Care
Home Owner had applied 20-6-4 in the spring prior to the start of the test. Very well Maintained Property.	5	Yes	SM

Soil Audit:

Soil organic matter (%)	P (ppm)	K (ppm)	Mg (ppm)	Ca (ppm)	Soil pH	Buffer pH	CEC
3.0	61.0	121.0	87.0	995.0	5.5	6.4	13.2
	Very high	Medium	Low	Very low			

Base Saturation %	% K	% Mg	% Ca	Ca/Mg
45.5	2.3	5.5	37.7	6.9

Fertilizer recommendations

Lime	N	P	K
35 lbs/1000 sq ft	See Group Recs for N	None	3 lbs Pot. sulfate per 1000 sq ft

Comments:

Turf color, density, quality and height are very good. Thatch levels are good. Mix of species is also good and in balance. Weeds are minimal. The property is very well landscaped. A job well done!
Follow your fertility recommendations.

Your cooperation in this community project is very much appreciated.

Property: [redacted] [redacted]

Field Observations:

H #	F/B	Slope/Grade	%Sn	B	F	R	Cl	Dd	Other	Depth/Area	Th
37	F	Steep to the Street	90	60	20	5	5	0	15	4.3"(2-12)	1/2"
	B	Gradual to Back & Side	80	60	20	0	0	0	20	4600 sq/ft	1/2'

Observations	CW	PM	Care
Aerated. Well Maintained.	5	Yes	SM

Soil Audit:

Soil organic matter (%)	P (ppm)	K (ppm)	Mg (ppm)	Ca (ppm)	Soil pH	Buffer pH	CEC
2.6	36.0	56.0	134.0	830.0	6.3	6.6	10.2
	High	Very low	Medium	Very low			

Base Saturation %	% K	% Mg	% Ca	Ca/Mg
53.0	1.4	10.9	40.6	3.7

Fertilizer recommendations

Lime	N	P	K
None	See Group Recs for N	None	6 lbs Pot. sulfate per 1000 sq ft

Comments:

Turf color and density are fine. Weed populations have increased slightly, but are still a tolerable and manageable level. The turf in the front yard is showing some signs of stress, probably due to the slope/grade of the lawn area and its inability to hold water. Thatch levels are in control. Property has remained fairly stable throughout the test. Follow your fertility recommendations.

Your cooperation in this community project is very much appreciated

Property: [redacted]

Field Observations:

H #	F/B	Slope/Grade	%Sn	B	F	R	Cl	Dd	Other	Depth/Area	Th
49	F	Gradual to Street	75	70	20	0	5	0	5	3.1"(2-7)	1/2"
	S	Level									
	B	Gradual to B/S	55	70	20	0	5	0	5	7500 sq/ft	1/2"

Observations	CW	PM	Care
Property has been Areated.(twice)	5	Yes	SM

Soil Audit:

Soil organic matter (%)	P (ppm)	K (ppm)	Mg (ppm)	Ca (ppm)	Soil pH	Buffer pH	CEC
3.3	63.0	111.0	216.0	1328.0	6.9	7.0	10.2
	Very high	Medium	High	Medium			

Base Saturation %	% K	% Mg	% Ca	Ca/Mg
85.3	2.8	17.6	64.9	3.7

Fertilizer recommendations

Lime	N	P	K
None	See Group recs	None	3 lbs Pot. sulfate per 1000 sq ft

Comments:

Turf color and density are good. Weed populations are up a few percentage points but they are tolerable and manageable now.
Large corner property and a heavy traffic/use lawn area. The turf is stressed a bit but that is to be expected.
Turf started well this spring, fell off a bit, but is now in fairly good shape.
Follow your fertility recommendations.

Your cooperation in this community project is very much appreciated.

Property: [redacted] [redacted]

Field Observations:

H #	F/B	Slope/Grade	%Sn	B	F	R	Cl	Dd	Other	Depth/Area	Th
40	F	Level	90	75	10	0	10	5	0	4.7"(1-15)	1/2"
	B	Level	60	85	15	0	0	0	0	2300 sq/ft	1/2"

Observations	CW	PM	Care
Some Die-Back & Bare Patches (dog). Well aerated.	3	Yes	SM

Soil Audit:

Soil organic matter (%)	P (ppm)	K (ppm)	Mg (ppm)	Ca (ppm)	Soil pH	Buffer pH	CEC
2.2	48.0	65.0	46.0	576.0	5.8	6.5	9.4
	High	Very low	Very low	Very low			

Base Saturation %	% K	% Mg	% Ca	Ca/Mg
36.4	1.8	4.1	30.5	7.4

Fertilizer recommendations

Lime	N	P	K
35 lbs/1000 sq ft	See Group Recs for N	None	6 lbs Pot. sulfate per 1000 sq ft

Comments:

Turf color and density are good in the back and OK in the front. The back is very wet and Mr. Gary has installed a drainage system from the back to the street. Weeds have increased slightly, but they remain tolerable and manageable now. Clover has also increased somewhat, but we consider this a beneficial part of the turf system. Your stewardship of pet manure has been very good. Thank you for your effort. Follow your fertility recommendations.

Your cooperation in this community project is very much appreciated.

The Fire Hall Turf Experiments: This experiment is being conducted by Greg Sharam (resident of Sackville and student at Dalhousie University) with assistance from Edmonds Environmental Services, and Dr. D. Patriquin (Dalhousie University), and the cooperation of the Sackville Fire Department.

The turf in front of the Fire Hall is typical of much of the turf in the Sackville region: soil is thin, tight, acid, and turfgrass is of poor quality. Thus when it rains, there is a lot of runoff, which carries fertilizers with it into the lake. The object of this experiment is to test various means of improving the infiltration of the soil, and turf grass growth with minimal disturbance, and minimal use of P. There are ten treatments, each replicated 3 times. Plots are 3 x 3 m, and were set up on July 1. We will be monitoring them for grass growth, and soil structure characteristics.

TREATMENTS:

1. **NONE: NO AERATION, NO LIME**

2. **AERATION ONLY**

3. **AERATION + LIME** (2.5 tonnes/ha)

4. **AERATION + GYPSUM** (1.7 tonnes/ha) **+LIME** (1.25 tonnes/ha)

5. **AERATION + GYPSUM** (1.7 tonnes/ha)

6. **AERATION + LIME** (1.25 tonnes/ha) **+ GYPSUM** (1.70 tonnes/ha) **+ COMPOST:** (Spread to 1/2 inch thick)

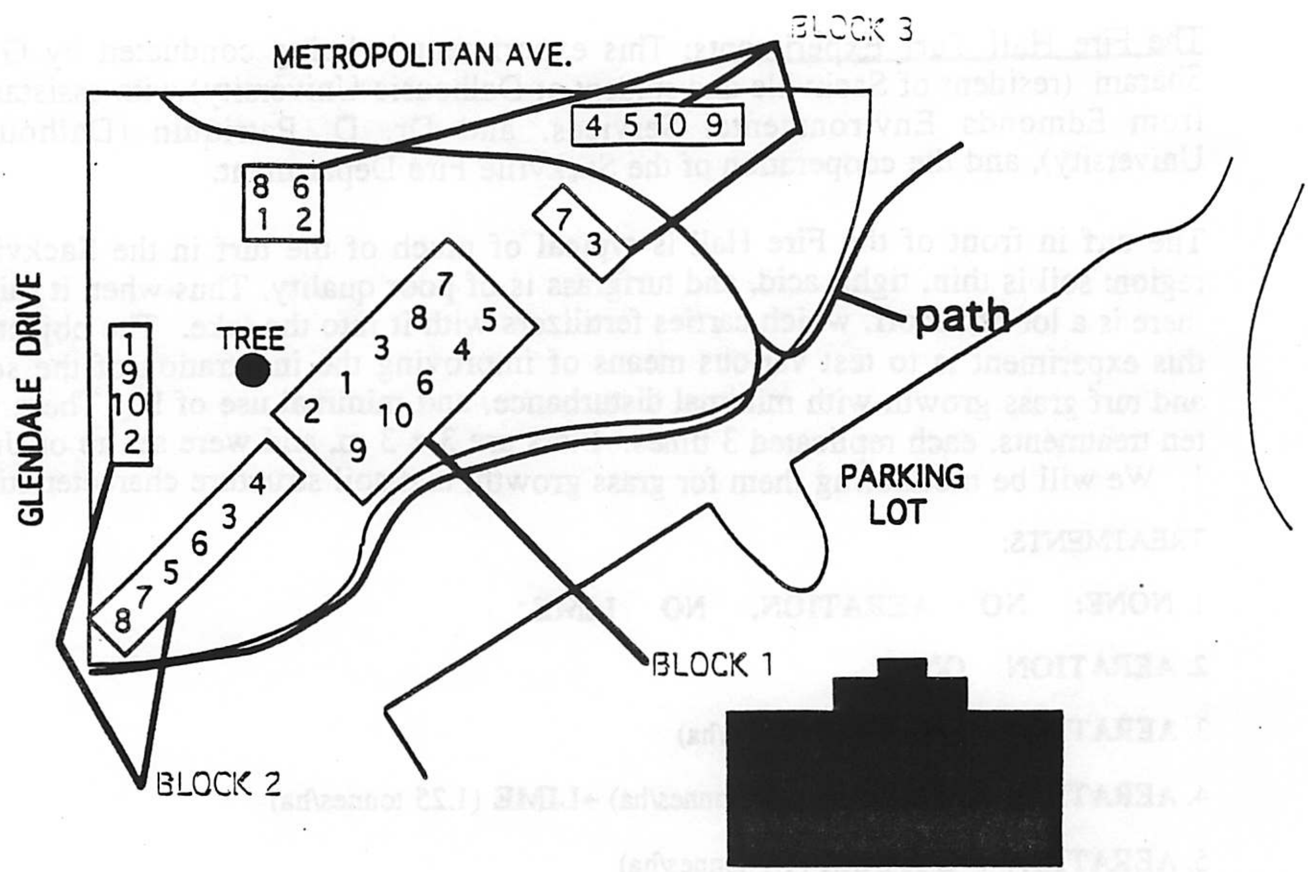
7. **AERATION + LIME + GYPSUM + COMPOST** (as in 6) **+ FEATHERMEAL** (25 kg N/ha) **+ROCK-P** (1 tonne/ha) **+POTASSIUM SULFATE** (50 kg/ha K_20)

8. **AERATION +LIME +GYPSUM +FEATHERMEAL +ROCK P + POT SULFATE**

9. **AERATION +LIME + GYPSUM + SEAGREEN** (Seagreen with 8-4-6 formulation: @25 kg N/ha)

10. **AERATION + LIME + GYPSUM +SLOW RELEASE N** (25-5-10) AT 25 kg N/ha)

SACKVILLE FIRE HALL TURF EXPERIMENTS



TREATMENTS:

1. **NONE: NO AERATION, NO LIME**

2. **AERATION ONLY**

3. **AERATION + LIME** (2.5 tonnes/ha)

4. **AERATION + GYPSUM** (1.7 tonnes/ha) **+LIME** (1.25 tonnes/ha)

5. **AERATION + GYPSUM** (1.7 tonnes/ha)

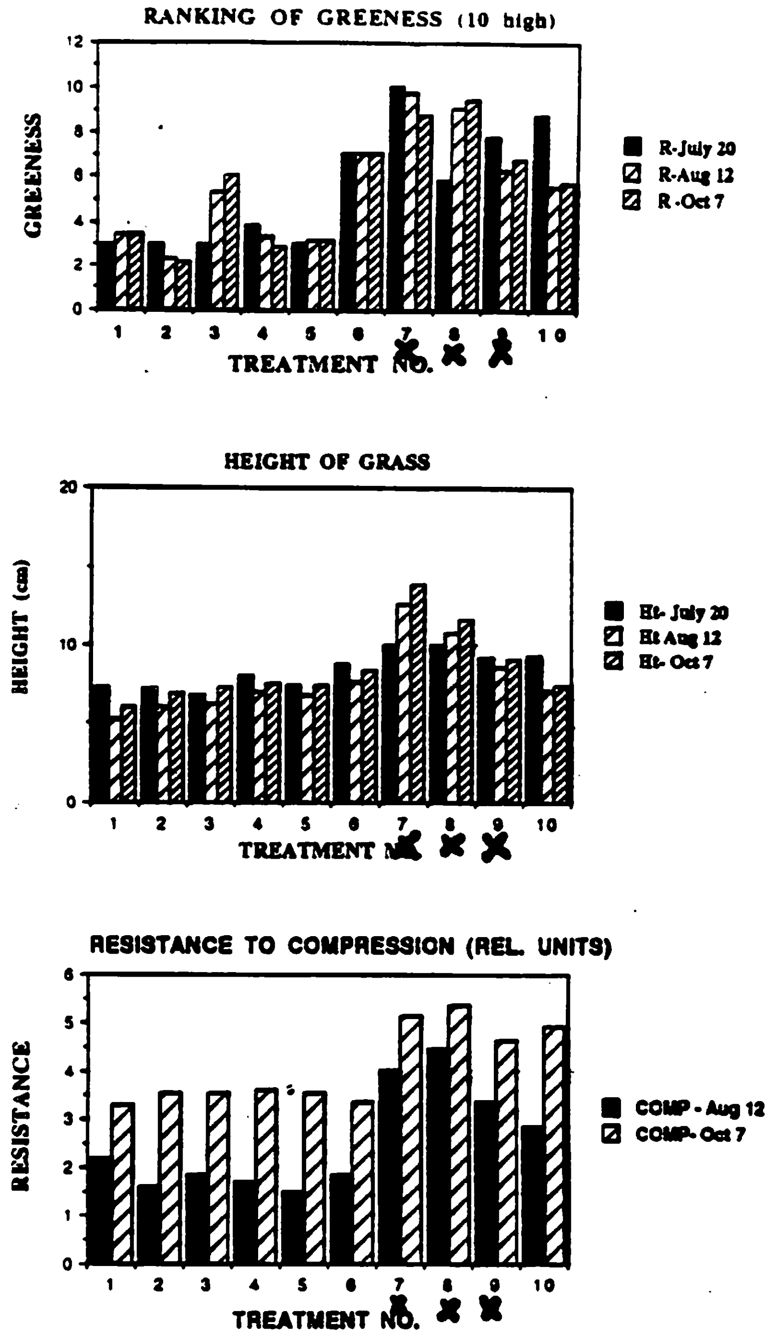
6. **AERATION + LIME** (1.25 tonnes/ha) **+ GYPSUM** (1.70 tonnes/ha) **+ COMPOST:** (Spread to 1/2 inch thick)

7. **AERATION + LIME + GYPSUM + COMPOST** (as in 6) **+ FEATHERMEAL** (25 kg N/ha) **+ROCK-P** (1 tonne/ha) **+POTASSIUM SULFATE** (50 kg/ha K_2O)

8. **AERATION +LIME +GYPSUM +FEATHERMEAL +ROCK P + POT SULFATE**

9. **AERATION +LIME + GYPSUM + SEAGREEN** (Seagreen with 8-4-6 formulation: @25 kg N/ha)

10. **AERATION + LIME + GYPSUM +SLOW RELEASE N** (25-5-10) AT 25 kg N/ha)



TREATMENTS:

1: NONE (NO AERATION, NO LIME)
2. AERATION ONLY
3. AERATION + LIME
4. AERATION + GYPSUM + LIME
5. AERATION + GYPSUM
6. AERATION + LIME + GYPSUM + COMPOST
7. AERATION + LIME + GYPSUM + COMPOST + FM+RP+K
8. AERATION + LIME + GYLSUM +FM + RP + K
9. AERATION + LIME + GYPSUM + SEAGREEN
10. AERATION + LIME + GYPSUM + SLOW RELEASE FERT'R

FIGURE Summary diagrams showing values of turf quality variables for the Fire Station Turf Amendment Experiment. FM + RP + K refers to feathermeal, rock phosphate and potassium sulfate.

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
BLOCK	2	36.744	18.372	5.155	.0170
TREATMENT	9	44.616	4.957	1.391	.2628
Residual	18	64.150	3.564		

Dependent: HEIGHT JY21

Means Table
Effect: TREATMENT
Dependent: HEIGHT JY21

LSD 0.05= 3.23; LSD 0.1= 2.67

	Count	Mean	Std. Dev.	Std. Error
Control	3	7.280	.892	.515
Aeration	3	7.213	.910	.526
Aer + L	3	6.760	.529	.306
Aer + L + G	3	8.060	.906	.523
Aer + G	3	7.387	1.925	1.112
Aer + L + G + C	3	8.760	1.677	.968
A+L+G+C+FM+RP+K	3	10.467	2.910	1.680
A+L+G+FM+RP+K	3	10.007	5.002	2.888
A+L+G+SG	3	9.160	2.115	1.221
A+L+G+SLOW NPK	3	9.313	1.801	1.040

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
BLOCK	2	3.022	1.511	1.778	.1973
TREATMENT	9	142.601	15.845	18.650	.0001
Residual	18	15.292	.850		

Dependent: HIEGHT A12

Means Table
Effect: TREATMENT
Dependent: HIEGHT A12

LSD 0.05=1.58; LSD 0.1= 1.31

	Count	Mean	Std. Dev.	Std. Error
Control	3	5.253	.694	.401
Aeration	3	5.940	.620	.358
Aer + L	3	6.160	.442	.255
Aer + L + G	3	6.960	1.403	.810
Aer + G	3	6.713	.685	.395
Aer + L + G + C	3	7.580	.072	.042
A+L+G+C+FM+RP+K	3	12.613	.133	.077
A+L+G+FM+RP+K	3	10.753	.991	.572
A+L+G+SG	3	8.567	1.911	1.103
A+L+G+SLOW NPK	3	7.093	1.000	.578

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
BLOCK	2	.452	.226	.453	.6427
TREATMENT	9	31.733	3.526	7.077	.0002
Residual	18	8.968	.498		

Dependent: COMPR A12

Means Table
Effect: TREATMENT
Dependent: COMPR A12

LSD 0.05= 1.00; LSD 0.1 = 1.21

	Count	Mean	Std. Dev.	Std. Error
Control	3	2.173	.401	.231
Aeration	3	1.598	.299	.172
Aer + L	3	1.843	.150	.087
Aer + L + G	3	1.697	.351	.203
Aer + G	3	1.487	.191	.111
Aer + L + G + C	3	1.850	.953	.550
A+L+G+C+FM+RP+K	3	4.053	.594	.343
A+L+G+FM+RP+K	3	4.463	.950	.549
A+L+G+SG	3	3.360	.529	.306
A+L+G+SLOW NPK	3	2.873	1.354	.782

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
BLOCK	2	2.764	1.382	1.077	.3615
TREATMENT	9	161.029	17.892	13.948	.0001
Residual	18	23.090	1.283		

Dependent: HEIGHT Oct 7

Means Table
Effect: TREATMENT
Dependent: HEIGHT Oct 7

LSD 0.05 = 1.94; LSD 0.1 = 1.60

	Count	Mean	Std. Dev.	Std. Error
Control	3	6.000	.762	.440
Aeration	3	6.840	1.048	.605
Aer + L	3	7.280	.507	.293
Aer + L + G	3	7.480	1.534	.886
Aer + G	3	7.400	.524	.302
Aer + L + G + C	3	8.297	.156	.090
A+L+G+C+FM+RP+K	3	13.913	.031	.018
A+L+G+FM+RP+K	3	11.677	.507	.293
A+L+G+SG	3	9.037	2.402	1.387
A+L+G+SLOW NPK	3	7.397	1.520	.878

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
BLOCK	2	16.289	8.145	17.120	.0001
TREATMENT	9	18.172	2.019	4.244	.0044
Residual	18	8.563	.476		

Dependent: COMPR O 7

Means Table
Effect: TREATMENT
Dependent: COMPR O 7

LSD 0.05 = 1.18; LSD 0.1 = 0.98

	Count	Mean	Std. Dev.	Std. Error
Control	3	3.277	.344	.198
Aeration	3	3.537	1.786	1.031
Aer + L	3	3.523	.746	.431
Aer + L + G	3	3.613	.543	.314
Aer + G	3	3.550	1.307	.754
Aer + L + G + C	3	3.367	1.446	.835
A+L+G+C+FM+RP+K	3	5.137	1.030	.595
A+L+G+FM+RP+K	3	5.357	1.116	.645
A+L+G+SG	3	4.647	1.363	.787
A+L+G+SLOW NPK	3	4.937	.551	.318

Oct 7: Friedman's Test For Rankings

Friedman 10 X variables

DF	9	
# Samples	10	
# Cases	3	
Chi_r-Squared	18.418	p = .0306
Chi corrected for ties	19.113	p = .0242
# tied groups	3	

Friedman 10 X variables

Name:	Σ Rank:	Mean Rank:
None	10.5	3.5
Aer	6.5	2.167
Aer+L	18	6
Aer+L+G	8.5	2.833
Aer+G	9.5	3.167

Friedman 10 X variables

Name:	Σ Rank:	Mean Rank:
Aer+L+G+C	21	7
Aer+L+G+C+FM+RP+K	26	8.667
Aer+L+G+FM+RP+K	28	9.333
Aer+L+G+SG	20	6.667
Aer+L+G+Slow NPK	17	5.667

Aug 12: Friedman's Test For Rankings

Friedman 10 X variables

DF	9	
# Samples	10	
# Cases	3	
Chi_r-Squared	18.491	p = .0299
Chi corrected for ties	19.433	p = .0218
# tied groups	3	

Friedman 10 X variables

Name:	Σ Rank:	Mean Rank:
None	10.5	3.5
Aer	7	2.333
Aer+L	16	5.333
Aer+L+G	10	3.333
Aer+G	9.5	3.167

Friedman 10 X variables

Name:	Σ Rank:	Mean Rank:
Aer+L+G+C	21	7
Aer+L+G+C+FM+RP+K	29	9.667
Aer+L+G+FM+RP+K	27	9
Aer+L+G+SG	18.5	6.167
Aer+L+G+Slow NPK	16.5	5.5

July 21: Friedman's Test For Rankings

Friedman 10 X variables

DF	9	
# Samples	10	
# Cases	3	
Chi_r-Squared	18.8	p = .0269
Chi corrected for ties	21.642	p = .0101
# tied groups	3	

Friedman 10 X variables

Name:	∑ Rank:	Mean Rank:
None	10	3.333
Aer	10	3.333
Aer+L	10	3.333
Aer+L+G	12.5	4.167
Aer+G	10	3.333

Friedman 10 X variables

Name:	∑ Rank:	Mean Rank:
Aer+L+G+C	15	5
Aer+L+G+C+FM+RP+K	30	10
Aer+L+G+FM+RP+K	17.5	5.833
Aer+L+G+SG	24	8
Aer+L+G+Slow NPK	26	8.667

APPENDIX C

RUNOFF AND LAKE DATA

APPENDIX C. RUNOFF and LAKE DATA

TABLE C.1 Data for Dry Weather Flow.

	TIME (h)	RAINFALL (mm/h)	FLOW (L/s)	FCOL (MPN/100	TP (ug/L)	IP (ug/L)	ECOND (mmhos/cm)	pH	NO3 (mg/L)	Susp.Solid (mg/L)
Control Area - First Lake Drive										
April 16, 1993						250				
May 16			0.1							
August 9			0.24							
August 17			0.07							
September 1			0.04							
October 29					29	3				
Feb 17/94	15.00			0	130	<1				
Feb 20	14.25	snowmelt	1.73		150	9				175
Feb 21	8.00	snowmelt	0.39							
Feb 22	8.25		0.73	76	49	9				9
Feb 23	8.33		0.16	2	20	2				1
Feb 23				0	30	3				
Feb 24	15.00			0 or 4	26	<1				
MEAN			0.43	15.60	62.00	34.50				61.67
STD.DEV.			0.53	30.21	50.30	81.52				80.21
Test Area - Crimson Drive										
April 16, 1993						60				
May 16			0.16							
August 9			0.25							
August 17			0.17							
September 1			0.1							
October 29					45	14				
Feb 17/94				38	46	<1				
Feb 20		snowmelt	6.23		140	40				84
Feb 21		snowmelt	0.57							
Feb 22	8.42		0.91	22	73	38				4
Feb 23	8.58		0.31	16	47	19				1
Feb 23				2	53	27				
Feb 24	15.25			0 or 4	44	<1				
MEAN			1.09	16.00	64.00					29.67
STD.DEV.			1.96	13.97	32.41					38.44

TABLE C.2 Data for Storm 1 of April 29, 1993.

Control Area - First Lake Drive

	TIME (h)	RAINFALL (mm/h)	FLOW (L/s)	FCOL (MPN/100	TP (ug/L)	IP (ug/L)	ECOND (mmhos/cm)	pH	NO3 (mg/L)
	6.10		0.40	0	12.00				
	6.32		0.40	0	13.00				
	6.58		0.40	0	13.00				
	6.83		0.40	3000	13.00				
	7.08		0.40	10	14.00				
	7.33		0.40						
	7.60		0.95	10	68.00				
	7.87		0.74	0	35.00				
	8.10		0.74	210	51.00				
	8.35		0.74	50	44.00				
	8.60		1.46	280	74.00				
MEAN			0.64	356	30.64				
STD.DEV.			0.32	886	24.09				

Test Area - Crimson Drive

	TIME (h)	RAINFALL (mm/h)	FLOW (L/s)	FCOL (MPN/100	TP (ug/L)	IP (ug/L)	ECOND (mmhos/cm)	pH	NO3 (mg/L)
	6.00		0.57	310	37.00				
	6.25		1.35	230	38.00				
	6.50		0.91	180	37.00				
	6.75		0.91	160	37.00				
	6.98		1.13	80	38.00				
	7.23		1.13						
	7.50		1.35	190	42.00				
	7.80		1.13	250	43.00				
	8.02		1.35	170	47.00				
	8.25		1.35	1020	45.00				
	8.50		1.35	21500	59.00				
MEAN			1.14	2409	38.45				
STD. DEV.			0.24	6369	13.67				

NOTES:

Rainfall was not measured.

Inorganic P, etc. were not measured.

TABLE C.3 Data for Storm 2 of May 6, 1993.

Control Area - First Lake Drive

	TIME (h)	RAINFALL (mm/h)	FLOW (L/s)	FCOL (MPN/100	TP (ug/L)	IP (ug/L)	ECOND (mmhos/cm)	pH	NO3 (mg/L)
	21.17		1.00	0	17.00				
	21.38		0.80	0	22.00				
	21.63		0.59	128	21.00				
	21.85		0.41	0	20.00				
	22.08		0.29	0	23.00				
	22.32		0.20	0	21.00				
	22.57		0.15	0	20.00				
	22.85		0.11	160	20.00				
	23.08		0.09	0	21.00				
	23.32		0.07	0	20.00				
MEAN			0.37	29	20.50				
STD.DEV.			0.31	58	1.50				

Test Area - Crimson Drive

	TIME (h)	RAINFALL (mm/h)	FLOW (L/s)	FCOL (MPN/100	TP (ug/L)	IP (ug/L)	ECOND (mmhos/cm)	pH	NO3 (mg/L)
	21.00		0.33	0	45.00				
	21.28		0.50	0	49.00				
	21.52		0.43	140	45.00				
	21.78		0.37	0	48.00				
	21.98		0.34	0	46.00				
	22.25		0.30	0	50.00				
	22.50		0.28	0	46.00				
	22.75		0.26	356	46.00				
	23.00		0.24	0	44.00				
	23.25		0.23	0	45.00				
MEAN			0.33	50	46.40				
STD.DEV.			0.08	110	1.85				

NOTES:

Stopwatch failed after second sample. Flows were then simulated using SWMM and rainfall observations on site and at AES Bedford.

Table C.4 Data for Storm 3 of May 13, 1993.

Control Area - First Lake Drive

	TIME (h)	RAINFALL (mm/h)	FLOW (L/s)	FCOL (MPN/100	TP (ug/L)	IP (ug/L)	ECOND (mmhos/cm)	PH	NO3 (mg/L)
	13.00		0.38	42	26.00				
	13.25		0.44	48	25.00		430.00		
	13.50		0.50	22	27.00		375.00		5.00
	13.75		0.40	22	27.00		300.00		
	14.00		0.44	16	18.00		300.00		5.00
	14.25		0.33	24	25.00		250.00		
	14.50		0.40	16	26.00				
	14.75		0.33	10	21.00		360.00		5.00
	15.00		0.29	6	18.00		160.00		
	15.25		0.29	10	16.00		375.00		5.00
MEAN			0.38	22	22.80		318.75		5.00
STD.DEV.			0.07	13	4.01		79.87		0.00

Test Area - Crimson Drive

	TIME (h)	RAINFALL (mm/h)	FLOW (L/s)	FCOL (MPN/100	TP (ug/L)	IP (ug/L)	ECOND (mmhos/cm)	PH	NO3 (mg/L)
	13.10		0.29	104	53.00				
	13.33		0.20	98	56.00		450.00		
	13.58		0.25	52	48.00		440.00		5.00
	13.83		0.20	84	54.00		340.00		
	14.07		0.17	72	54.00		450.00		5.00
	14.33		0.17	46	53.00				
	14.57		0.20	80	45.00		350.00		
	14.80		0.22	80	49.00		370.00		4.00
	15.07		0.20	40	52.00		370.00		
w	15.32		0.20	58	57.00		380.00		5.00
MEAN			0.21	71	52.10		393.75		4.75
STD.DEV.			0.04	21	3.53		42.70		0.43

TABLE C.5 Data for Storm 4 of May 29, 1993

Control Area - First Lake Drive

	TIME	RAINFALL	FLOW	FCOL	TP	IP	ECOND	PH	NO3
	(h)	(mm/h)	(L/s)	(MPN/100	(ug/L)	(ug/L)	(mmhos/cm)		(mg/L)
			0.63	140	100.00	25.00	160.00	6.50	
	18.37		0.54	110	69.00	23.00	200.00	6.40	5.00
	18.57		0.50	180	56.00	12.00	270.00	6.30	
	18.82		2.00	10	130.00	62.00	200.00	6.30	5.00
	19.07		1.14	2500	96.00	30.00	180.00	6.35	
	19.30		0.57	60	15.00	13.00	210.00	6.20	5.00
	19.57		0.71	0	50.00	11.00	300.00	6.25	
	19.82		0.71	50	54.00	12.00	300.00	6.10	5.00
	20.07		0.71	60	50.00	9.00	275.00	6.20	
	20.28		0.53	20	39.00	7.00	250.00	6.20	5.00
MEAN	20.53		0.80	313	65.90	20.40	234.50	6.28	5.00
STD.DEV.			0.43	731	32.01	15.63	48.19	0.11	0.00

Test Area - Crimson Drive

	TIME	RAINFALL	FLOW	FCOL	TP	IP	ECOND	PH	NO3
			0.40	251	82.00	8.00	325.00	6.25	
	18.25		0.44	251	61.00	26.00	350.00	6.30	10.00
	18.50		0.44	110	72.00	32.00	375.00	6.30	
	18.75		0.80	170	390.00	10.00	190.00	6.35	10.00
	19.00		0.80	120	74.00	11.00	220.00	6.25	
	19.25		0.50	180	61.00	33.00	300.00	6.30	10.00
	19.50		0.40	40	59.00	32.00	380.00	6.30	
	19.75		0.44	40	63.00	35.00	350.00	6.35	10.00
	20.00		0.57	50	54.00	35.00	360.00	6.30	
	20.25		0.53	280	55.00	36.00	400.00	6.40	10.00
MEAN	20.50		0.53	149	97.10	25.80	325.00	6.31	10.00
STD.DEV.			0.14	87	98.00	10.90	65.95	0.04	0.00

TABLE C.6 Data for Storm 5 of June 6, 1993

Control Area - First Lake Drive

	TIME (h)	RAINFALL (mm/h)	FLOW (L/s)	FCOL (MPN/100	TP (ug/L)	IP (ug/L)	ECOND (mmhos/cm)	PH	NO3 (mg/L)
	20.60		0.13	0	26.00	3.00	420.00	6.70	
	20.85		0.14	0	27.00	5.00	380.00	6.70	10.00
	21.10		0.14	0	25.00	2.00	450.00	6.70	
	21.35		0.15	0	30.00	2.00	450.00	6.80	10.00
	21.60		1.00	240	170.00	13.00	320.00	6.80	10.00
	21.85		1.33	270	130.00	10.00	200.00	6.80	
	22.10		2.00	40	120.00	10.00	150.00	6.70	5.00
	22.35		1.33	220	79.00	12.00	145.00	6.75	
	22.60		0.80	0	59.00	8.00	175.00	6.70	5.00
	22.85		1.33	0	74.00	13.00	170.00	6.70	5.00
MEAN			0.84	77	74.00	7.80	286.00	6.74	7.50
STD.DEV.			0.64	110	48.55	4.24	123.81	0.04	2.50

Test Area - Crimson Drive

	TIME (h)	RAINFALL (mm/h)	FLOW (L/s)	FCOL (MPN/100	TP (ug/L)	IP (ug/L)	ECOND (mmhos/cm)	PH	NO3 (mg/L)
			0.21	0	62.00	38.00	560.00	6.70	
	20.50		0.22	0	68.00	39.00	575.00	6.70	10.00
	20.75		0.22	0	68.00	40.00	600.00	6.50	
	21.00		0.25	0	63.00	37.00	600.00	6.50	10.00
	21.25		0.24	0	65.00	40.00	570.00	6.65	
	21.50		0.31	0	77.00	25.00	500.00	6.70	10.00
	21.75		0.40	0	82.00	33.00	375.00	6.70	10.00
	22.00		0.57	0	84.00	35.00	325.00	6.70	
	22.25		0.47	0	73.00	39.00	400.00	6.65	10.00
	22.50		0.44	0	70.00	39.00	400.00	6.70	
MEAN	22.75		0.33	0.00	71.20	36.50	490.50	6.65	10.00
STD.DEV.			0.12	0.00	7.28	4.39	99.74	0.08	0.00

TABLE C.7 Data for Storm 6 of June 16, 1993?

	TIME (h)	RAINFALL (mm/h)	FLOW (L/s)	FCOL (MPN/100	TP (ug/L)	IP (ug/L)	ECOND (mmhos/cm)	PH	NO3 (mg/L)
Control Area - First Lake Drive									
	22.17		0.10	20	22.00	9.00			
	22.42		0.09	0	24.00	8.00	340.00		
	22.67		0.10	0	20.00	11.00	525.00		5.00
	22.92		0.10	20	30.00	11.00	560.00		
	23.17		0.10	10	20.00	4.00	575.00		5.00
	23.42		0.10	0	15.00	3.00	560.00		
	23.67		0.10	0	19.00	2.00	550.00		10.00
	24.00		0.10	0	20.00	3.00	510.00		
	24.17		0.11	0	21.00	6.00	550.00		10.00
	24.42		0.11	0	22.00	2.00	550.00		
MEAN			0.10	5.00	21.30	5.90	524.44		7.50
STD.DEV.			0.01	8.06	3.66	3.42	67.72		2.50
Test Area - Crimson Drive									
	22.08		0.20	0	66.00	55.00	610.00		5.00
	22.33		0.20	35	66.00	54.00	440.00		
	22.58		0.20	15	64.00	56.00	560.00		5.00
	22.83		0.20	10	59.00	55.00	545.00		
	23.17		0.20	45	68.00	55.00	500.00		5.00
	23.58		0.21	0	68.00	53.00	600.00		
	23.83		0.21	5	66.00	51.00	640.00		5.00
	24.08		0.21	5	66.00	49.00	575.00		10.00
	24.33		0.22	0	66.00	54.00	625.00		
	24.58		0.22	10	65.00	48.00	575.00		5.00
MEAN			0.21	13	65.40	53.00	567.00		5.83
STD.DEV.			0.01	15	2.42	2.61	57.37		1.86

TABLE C.8 Data for Storm 7 of June 19, 1993

	TIME	RAINFALL	FLOW	FCOL	TP	IP	ECOND	PH	NO3
Control Area - First Lake Drive									
	(h)	(mm/h)	(L/s)	(MPN/100	(ug/L)	(ug/L)	(mmhos/cm)		(mg/L)
	6.88		1.64	15	44.00	9.00	175.00		0.00
	7.10		1.60	5	41.00	5.00	185.00		10.00
	7.37		0.65	0	33.00	5.00	250.00		0.00
	7.63		0.42	0	27.00	5.00	350.00		10.00
	7.88		0.36	0	27.00	5.00	410.00		0.00
	8.12		0.34	0	27.00	5.00	400.00		10.00
	8.38		0.27	0	27.00	8.00	425.00		0.00
	8.63		0.27	0	27.00	7.00	480.00		10.00
	8.88		0.25	0	28.00	10.00	500.00		10.00
	9.10		0.60	0	49.00	10.00	325.00		0.00
	9.37		1.56	25	47.00	5.00	180.00		0.00
MEAN			0.72	4	34.27	6.73	334.55		4.55
STD.DEV.			0.55	8	8.66	2.05	115.16		4.98
Test Area - Crimson Drive									
	6.75		0.47	25	64.00	36.00	420.00		10.00
	7.00		0.61	15	63.00	35.00	325.00		0.00
	7.25		0.48	10	70.00	43.00	400.00		10.00
	7.53		0.43	10	56.00	43.00	460.00		0.00
	7.78		0.42	25	67.00	45.00	450.00		15.00
	8.00		0.42	35	56.00	44.00	500.00		5.00
	8.27		0.34	28	62.00	44.00	500.00		0.00
	8.53		0.31	35	59.00	44.00	525.00		5.00
	8.78		0.35	15	60.00	43.00	500.00		0.00
	9.02		0.33	10	54.00	43.00	550.00		5.00
	9.25		0.78	5	57.00	28.00	350.00		5.00
MEAN			0.45	19	60.73	40.73	452.73		5.00
STD.DEV.			0.13	10	4.77	5.12	68.87		4.77

TABLE C.9 Data for Storm 8 of June 28. 1993

Control Area - First Lake Drive

	TIME (h)	RAINFALL (mm/h)	FLOW (L/s)	FCOL (MPN/100m	TP (ug/L)	IP (ug/L)	ECOND (mmhos/cm)	PH	NO3 (mg/L)
	10.50		8.00	21000	210.00	47.00	60.00	6.00	0.00
	10.75		20.00	21000	200.00	42.00	65.00	6.00	
	11.00		39.00	21000	300.00	45.00	55.00	6.00	0.00
	11.25		49.00	21000	190.00	71.00	79.00	5.90	
	11.50		43.00	21000	230.00	85.00	135.00	6.00	5.00
	11.75		30.00	21000	220.00	81.00	184.00	6.00	
	12.00		28.00	21000	150.00	72.00	182.00	6.00	10.00
	12.25		27.00	21000	210.00	100.00	190.00	6.00	
	12.50		22.00	21000	220.00	130.00	240.00	6.00	10.00
	12.75		17.00	11200	280.00	120.00	250.00	6.10	10.00
MEAN			28.30	20020	222.00	79.30	144.00	6.00	5.83
STD.DEV.			11.88	2940	42.14	29.02	71.51	0.04	4.49

Test Area - Crimson Drive

	TIME (h)	RAINFALL (mm/h)	FLOW (L/s)	FCOL (MPN/100m	TP (ug/L)	IP (ug/L)	ECOND (mmhos/cm)	PH	NO3 (mg/L)
	10.50		7.00	600	65.00	18.00	37.00	4.50	0.00
	10.75	10.00	15.00	1000	53.00	15.00	52.00	4.60	
	11.00	17.00	28.00	1250	68.00	21.00	53.00	4.70	0.00
	11.25	16.00	33.00	1400	78.00	29.00	60.00	4.80	
	11.50	10.00	26.00	5000	150.00	68.00	142.00	5.10	5.00
	11.75	3.00	18.00	4000	150.00	76.00	180.00	5.50	
	12.00	3.00	16.00	7200	120.00	51.00	174.00	5.70	5.00
	12.25	4.00	17.00	4400	95.00	50.00	145.00	5.80	
	12.50	2.00	15.00	4350	140.00	62.00	190.00	5.90	5.00
	12.75	1.00	13.00	4300	140.00	60.00	195.00	5.90	
MEAN		7.33	18.80	3350	105.70	45.00	122.80	5.25	3.00
STD.DEV.		5.77	7.43	2056	38.57	21.27	61.38	0.54	2.45

NOTES:

Flows were simulated using SWMM based on rainfall measured at Crimson Dr.

Bacteria counts higher than 20,000 MPN/100 mls were not resolved.

TABLE C.10 Data for Storm 9 of August 4, 1993

Control Area - First Lake Drive

	TIME (h)	RAINFALL (mm/h)	FLOW (L/s)	FCOL (MPN/100	TP (ug/L)	IP (ug/L)	ECOND (mmhos/cm)	PH	NO3 (mg/L)
	9.75		1.59	1365					
	10.00	0.58	1.99	27					
	10.25	0.00	1.82	240					
	10.50	0.06	1.60	143					
	10.75	1.49	2.22	115					
	11.00	0.00	2.00	780					
	11.25	2.50	1.66	741					
	11.50	0.52	2.21	807					
	11.75	0.00	2.50	203					
	12.00	0.00	1.67	1					
MEAN		0.57	1.93	442					
STD.DEV.		0.83	0.30	430					

Test Area - Crimson Drive

	TIME (h)	RAINFALL (mm/h)	FLOW (L/s)	FCOL (MPN/100	TP (ug/L)	IP (ug/L)	ECOND (mmhos/cm)	PH	NO3 (mg/L)
	9.85		2.00	780					
	10.10	0.00	1.18	780					
	10.35	0.00	1.00	297					
	10.60	0.81	1.05	220					
	10.85	0.45	1.11	287					
	11.10	0.03	1.18	233					
	11.35	4.81	5.82	702					
	11.60	0.00	1.43	1248					
	11.85	0.00	1.54	533					
	12.10	0.00	1.43	323					
MEAN		0.68	1.77	540					
STD.DEV.		1.48	1.38	318					

NOTE:
Phosphorus samples were discarded in a misguided economy move.

TABLE C.11 Data for Storm 10 of September 4, 1993

Control Area - First Lake Drive

	TIME (h)	RAINFALL (mm/h)	FLOW (L/s)	FCOL (MPN/100	TP (ug/L)	IP (ug/L)	ECOND (mmhos/cm)	PH	NO3 (mg/L)
	17.60		0.29		65.00	24.00	275.00	6.52	15.00
	17.85	3.90	3.46		70.00	23.00	120.00	6.28	10.00
	18.10	5.91	3.21		50.00	23.00	75.00	6.39	3.00
	18.35	0.19	0.81		79.00	37.00	164.00	6.67	6.00
	18.60	0.00	0.46		94.00	58.00	240.00	6.81	10.00
	18.85	0.00	0.27		97.00	47.00	325.00	6.89	6.00
	19.10	0.00	0.29		100.00	44.00	360.00	6.95	7.00
	19.35	0.00	0.25		75.00	23.00	455.00	6.98	8.00
	19.60	0.00	0.25		57.00	18.00	460.00	6.95	7.00
	19.85	0.00	0.20		48.00	19.00	490.00	6.95	8.00
		1.11	0.95		73.50	31.60	296.40	6.74	8.00
		2.08	1.21		18.07	13.19	139.85	0.25	3.03

Test Area - Crimson Drive

	TIME (h)	RAINFALL (mm/h)	FLOW (L/s)	FCOL (MPN/100	TP (ug/L)	IP (ug/L)	ECOND (mmhos/cm)	PH	NO3 (mg/L)
	17.75		0.29		100.00	49.00	450.00	6.95	8.00
	18.05	7.80	9.84		82.00	17.00	80.00	6.40	4.00
	18.28	1.43	1.19		69.00	20.00	180.00	6.87	6.00
	18.53	0.06	0.91		90.00	48.00	290.00	7.07	6.00
	18.82	0.00	0.60		98.00	53.00	350.00	7.22	10.00
	19.03	0.00	0.34		100.00	53.00	350.00	7.25	12.00
	19.28	0.00	0.34		110.00	46.00	400.00	7.33	18.00
	19.53	0.00	0.49		93.00	43.00	450.00	7.33	12.00
	19.78	0.00	0.34		95.00	47.00	490.00	7.35	18.00
	20.03	0.00	0.34		100.00	47.00	400.00	7.31	14.00
MEAN		1.03	1.47		93.70	42.30	344.00	7.11	10.80
STD.DEV.		2.43	2.80		10.80	12.26	122.33	0.29	4.66

NOTE:
Mistakenly, analysis for total coliform count was requested. Samples were then not available for

TABLE C.12 Data for Storm 11 of September 10, 1993

	TIME	RAINFALL	FLOW	FCOL	TP	IP	ECOND	PH	NO3
	(h)	(mm/h)	(L/s)	(MPN/100	(ug/L)	(ug/L)	(mmhos/cm)		(mg/L)
Control Area - First Lake Drive									
	22.00		1.43		160.00	14.00			
	22.25	0.52	1.43		130.00	22.00			
	22.50	0.00	0.32		74.00	44.00			
	22.75	0.00	0.19		72.00	45.00			
	23.00	0.00	0.17		62.00	38.00			
	23.15	0.00	0.12		60.00	39.00			
	23.50	0.00	0.11		57.00	38.00			
	23.75	0.00	0.11		62.00	38.00			
	24.00	0.00	0.11		56.00	34.00			
	24.25	0.00	0.10		58.00	34.00			
MEAN		0.06	0.41		79.10	34.60			
STD.DEV.		0.16	0.51		34.10	9.13			
Test Area - Crimson Drive									
	22.00		2.00		170.00	10.00			
	22.25	0.00	0.24		85.00	38.00			
	22.50	0.00	0.19		86.00	57.00			
	22.75	0.00	0.16		86.00	64.00			
	23.00	0.00	0.14		93.00	64.00			
	23.15	0.00	0.13		96.00	65.00			
	23.50	0.00	0.12		91.00	64.00			
	23.75	0.00	0.12		93.00	66.00			
	24.00	0.00	0.11		100.00	66.00			
	24.25	0.00	0.10		100.00	70.00			
MEAN		0.00	0.33		100.00	56.40			
STD.DEV.		0.00	0.56		23.90	17.63			

Note:
Fecal coliform samples were not analysed because the time limit had expired.

TABLE C.13 Data for Storm 12 of September 26. 1993

Control Area - First Lake Drive

	TIME (h)	RAINFALL (mm/h)	FLOW (L/s)	FCOL (MPN/100	TP (ug/L)	IP (ug/L)	ECOND (mmhos/cm)	PH	NO3 (mg/L)
	19.57		0.04	80	73.00	33.00	625.00	6.75	8.00
	19.93	1.10	0.11	240	2770.00	2400.00	475.00	7.00	0.00
qq	20.22	1.36	0.40	56	1860.00	1500.00	350.00	6.80	0.00
	20.47	0.32	0.25	66	600.00	400.00	225.00	6.55	0.00
	20.72	0.52	0.50	220	400.00	300.00	225.00	6.70	0.00
	20.97	1.10	0.25	640	930.00	810.00	225.00	6.80	0.00
	21.22	0.26	0.33	3200	290.00	230.00	200.00	6.60	0.00
	21.47	0.06	0.50	4800	210.00	160.00	240.00	6.70	0.00
	21.72	0.06	0.25	3800	180.00	120.00	325.00	7.00	0.00
	21.97	0.00	0.17	6550	210.00	135.00			
MEAN		0.53	0.28	1965	752.30	608.80	321.11	6.77	0.89
STD.DEV.		0.49	0.15	2292	840.71	729.52	135.74	0.15	2.51

Test Area - Crimson Drive

	TIME (h)	RAINFALL (mm/h)	FLOW (L/s)	FCOL (MPN/100	TP (ug/L)	IP (ug/L)	ECOND (mmhos/cm)	PH	NO3 (mg/L)
	19.77		0.14	110	120.00	63.00	600.00	7.50	0.00
	20.07	0.65	0.10	190	100.00	73.00	570.00	7.55	0.00
	20.32	0.91	0.18	510	100.00	52.00	370.00	7.40	0.00
	20.57	0.32	0.17	630	100.00	62.00	510.00	7.50	0.00
	20.83	1.04	0.14	560	110.00	64.00	525.00	7.55	0.00
	21.08	0.58	0.13	890	100.00	57.00	360.00	7.20	0.00
	21.33	0.13	0.17	208	120.00	63.00	400.00	7.30	0.00
	21.58	0.06	0.18	270	90.00	66.00	420.00	7.45	0.00
	21.85	0.00	0.18	86	90.00	67.00	430.00	7.40	0.00
	22.13	0.00	0.17	68	91.00	66.00	500.00	7.10	4.00
MEAN		0.41	0.16	352	102.10	63.30	468.50	7.40	0.40
STD.DEV.		0.38	0.03	264	10.66	5.40	79.69	0.14	1.20

TABLE C.14 Data for Storm 13 of October 13, 1993

Control Area - First Lake Drive

	TIME	RAINFALL	FLOW	FCOL	TP	IP	ECOND	PH	NO3
	(h)	(mm/h)	(L/s)	(MPN/100	(ug/L)	(ug/L)	(mmhos/cm)		(mg/L)
	0.67		3.46	120	60.00	15.00	50.00		0.00
	0.92	5.91	4.38	90	60.00	16.00	40.00		
	1.17	9.09	8.23	170	75.00	23.00	27.00		0.00
	1.42	11.89	18.15	330	82.00	13.00	20.00		
	1.67	4.81	5.10	1160	150.00	32.00	105.00		
	1.92	2.40	3.73	840	84.00	33.00	125.00		
	2.17	1.23	2.65	1200	77.00	24.00	150.00		
	2.42	2.92	4.38	530	58.00	18.00	110.00		0.00
	2.67	3.25	4.38	380	64.00	20.00			
	2.92	3.38	4.10	670	66.00	21.00			
MEAN		4.99	5.86	549	77.60	21.50	78.38		0.00
STD.DEV.		3.27	4.33	389	25.75	6.41	46.55		0.00

Test Area - Crimson Drive

	TIME	RAINFALL	FLOW	FCOL	TP	IP	ECOND	PH	NO3
	0.78		2.67	90	62.00	16.00	80.00		
	1.03	6.37	4.00	190	56.00	17.00	64.00		0.00
	1.28	10.52	6.73	130	46.00	17.00	35.00		
	1.53	13.45	7.81	90	51.00	14.00	55.00		
	1.78	1.75	3.27	390	79.00	35.00	160.00		5.00
	2.03	1.62	3.50	770	82.00	39.00	170.00		
	2.28	2.40	3.27	800	78.00	39.00	170.00		
	2.53	3.57	4.54	770	75.00	33.00	130.00		0.00
	2.78	2.73	4.04	1110	65.00	35.00			
	3.03	5.39	6.12	1550	52.00	28.00			
MEAN		5.31	4.60	589	64.60	27.30	108.00		1.67
STD.DEV.		3.93	1.62	470	12.52	9.71	52.12		

TABLE C.15 Data for Storm 14 of March 4, 1994

Control Area - First Lake Drive

	TIME (h)	RAINFALL (mm/h)	FLOW (L/s)	FCOL (MPN/100	TP (ug/L)	IP (ug/L)	ECOND (mmhos/cm)	PH	NO3 (mg/L)
	6.00	rain &	8.34		78				
	6.28	snowmelt	8.34		75				
	6.50		8.34		78				
MEAN			8.34	ERR	77.00				
STD.DEV.			0.00	ERR	1.41				

Test Area - Crimson Drive

	TIME (h)	RAINFALL (mm/h)	FLOW (L/s)	FCOL (MPN/100	TP (ug/L)	IP (ug/L)	ECOND (mmhos/cm)	PH	NO3 (mg/L)
	6.10	rain &	6.44		100				
	6.40	snowmelt	6.44		110				
	6.58		6.44		110				
MEAN			6.44	ERR	106.67				
STD.DEV.			0.00	ERR	4.71				

TABLE C.16 Lake Data - First Lake

Year	Date	Location	FCOL (MPN/100	TP (ug/L)	IP (ug/L)	Reference
1989			2000			CWRS (1990)
1990	June 25	Kinsmen's Beach	100			N.S. Dept. of Health
	July 3		28			
	July 11		10			
	July 23		90			
	July 30		20			
	August 13		44			
	August 20		26			
	August 27		20			
1991	June 27		800			
	July 3		80			
	July 9		140			
	July 17		180			
	July 23		340			
	July 30		12			
	August 7		1400			
	August 13		52			
	August 20		230			
	August 27		460			
1992	June 30		48			
	July 7		6			
	July 14		64			
	July 23		42			
	July 28		840			
	August 6		240			
	August 11		72			
	August 18		1460			
	August 25		100			
1993	July 2		94			
	July 8		96			
	July 15		20			
	July 22		194			
	July 29		>200			
	August 6		>200			
	August 12		48			
	Oct. 7	Sucker Brook		9	<1	TSWM Project - Phase I
	Oct. 13	Sucker Brook		12	<1	TSWM Project - Phase I

APPENDIX D

SURVEY QUESTIONNAIRES

FIRST LAKE TOTAL SYSTEM WATERSHED MANAGEMENT PROJECT

Handout #4 **May 24, 1993**

TO: RESIDENTS OF FIRST LAKE DRIVE (civic #'s 216 to 283) and CAVENDISH DRIVE (14 to 72, even #'s)

Thank you for your patience and cooperation! Our initial sampling of the storm drain runoff is complete. As the `control area', we ask you to please proceed with your usual lawn care practices beginning Monday, May 24. Please record on this sheet your fertilizer applications. We will collect this sheet later. A community meeting is planned for the near future. We will keep you informed as the project proceeds.

Date	Fertilizer type	Amount applied

If you have questions, please call our coordinator, Richard Van Ingen, 865-9238, or one of the following people.

Thank you for your cooperation,

John P. Sheppard, P. Eng.
Halifax County Municipality
Project Manager, 453-7526

John E. Edmonds
Edmonds Environmental Services
Turf Management, 423-8174

Ronald H. Loucks, Ph.D.
R.H. Loucks Oceanology Limited
Science, 433-1113

FIRST LAKE TOTAL SYSTEM WATERSHED MANAGEMENT PROJECT

Handout #4 May 24, 1993

TO: RESIDENTS OF CRIMSON DRIVE and FIRST LAKE DRIVE (civic #'s 367 & 373)

Thank you for your patience and cooperation! Our initial sampling of the storm drain runoff is complete. As the 'test area', please proceed with the check list of preventative measures to minimize runoff of bacteria and phosphorus.

As a check list, the immediate measures are as follows:

What?	When?	Who?
Soil profiles of lawns	May 20,21	Project staff
10-0-0 fertilizer supplied	Late May	Project staff
This fertilizer spread	**Late May/ Early June**	**Resident or Lawn Care Co.**
Curbsides cleaned of leaves & debris	**May-Nov**	**Resident**
Catchbasins cleaned	May-Nov	County of Hfx
Yardwastes gathered into covered pile	**May-Nov**	**Resident**
Consult, install composter	June	Project Staff
Pet manure removed (scooped up)	**May-Nov**	**Resident**
Crews suggested for sampling runoff	May-	Project Coord

As part of the record please note your fertilizer applications on this sheet. We will collect this sheet later.

Date	Fertilizer type	Amount applied

Thank you for your cooperation.
If you have questions, please call the project coordinator, Richard Van Ingen, 865-9238. (This phone number serves both our project and the Sackville Rivers Association)