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Identification and Evaluation of Nutrient and Bacterial Loadings to Maquoit Bay, Brunswick and Freeport, Maine

Horsley & Witten Inc.

Horsley & Witten, Inc.
Environmental Services

Final Report

IDENTIFICATION AND EVALUATION OF NUTRIENT AND BACTERIAL LOADINGS TO MAQUOIT BAY, BRUNSWICK, AND FREEPORT, MAINE

JANUARY 1996

Submitted to:

Casco Bay Estuary Project
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ACKNOWLEDGMENT

Horsley & Witten, Inc. acknowledges the subcontracting services of Wright-Pierce and the Woods Hole Oceanographic Institution. Wright-Pierce assisted in runoff measurements, conducted laboratory bacteriological analyses and provided technical review. The Woods Hole Oceanographic Institution conducted the nutrient analyses. Mr. George Heufelder of the Barnstable County Health and Environment Department also served as an advisor.

Horsley & Witten, Inc. also acknowledges the assistance of Ros Arienti of Gray, Maine, and Nathalie Forster of Freeport, Maine. We also wish to thank Mr. Tom Burns and Ms. Melissa Gormley of the Casco Bay Estuary Project for their valuable assistance.

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I. INTRODUCTION

This final report provides a description of the methods and results of watershed modeling and surface water data collection within the Maquoit Bay watershed system. The work was conducted in accordance with a contract between Horsley & Witten, Inc. (H&W) and the Casco Bay Estuary Project (CBEP) and U.S. Environmental Protection Agency (EPA) Region I, through the New England Interstate Water Pollution Control Commission (NEIWPCC). The results of the project are presented here.

A. Purpose and Scope

Nitrogen and fecal coliform have been identified as potential sources of contamination to Maquoit Bay. These contaminants are presumed to affect the Bay's water quality and shellfish resources. Stormwater runoff from land uses in the watershed surrounding the Bay has been suspected as one of the major potential pathways for contaminants to reach the Bay. Shellfish bed closures have resulted from excessive concentrations of fecal coliform bacteria in the upper Bay. A fish kill resulted from an algal bloom which, in part, may have been prompted by watershed-derived nutrients, including nitrogen.

The purpose of the project was to evaluate the water quality impacts associated with existing and future land uses in six subwatersheds of Maquoit Bay, and to develop water quality loading models of the Bay's watershed to predict present and future loadings of nitrogen and fecal coliform (as the indicator organism for other, more harmful pathogenic organisms) from these land uses.

Predicted pollution loadings from the model, in conjunction with the water quality monitoring data, is intended to be used as a basis for recommending measures to modify sources or pathways in order to reduce pollutant loading to Maquoit Bay. The watershed models have been designed such that they can be transferred to, and used by, other coastal communities in Maine.

B. Description of the Study Area

Casco Bay lies along the southern Maine coast in Cumberland County (Figure 1). It encompasses a 150-square mile area with 578 miles of shoreline and 763 islands. Along the coast of the Bay are numerous smaller embayments, many with year-round inhabitants along the shore. The principal rivers flowing into the Bay are the Fore River, Stroudwater River, Presumpscot River, and the Royal River. The area is characterized by a rocky coastline with moderate to heavy forest along some parts of the shore. Most of the Casco Bay watershed lies within Cumberland County.

Maquoit Bay is one of the smaller bays within Casco Bay. It has a surface area of approximately five square miles. It is approximately four miles long and approximately 1.25 miles wide at its widest point. The Bay narrows toward the head. Three fourths of the Bay lie within the Town of Brunswick with the remainder in the Town of Freeport. Maquoit Bay is relatively shallow with a mean depth of 10-12 feet and a tidal range of 10 feet. These characteristics make it a good location for shellfishing. They also render it susceptible to land-based pollution.

Marine fish resources of the Bay are classified into three categories: shellfish (mollusks); crabs and lobsters; and finfish. Of these categories, only shellfish found within the intertidal zone are within the jurisdiction of the Towns of Brunswick and Freeport. The two other categories are jointly controlled by U.S. National Marine Fisheries Service, and the Maine Department of Marine Resources. Maquoit Bay has been historically recognized as one of the most significant shellfish areas along the Maine coast as well as "one of the most studied bays in the State of Maine." (Wallace, D. 14 April 1993). The Bay typically produces a shellfish harvest in excess of $1 million per year, with some reports indicating harvests upwards of $2 million per year.

Clam flats are routinely closed due to bacterial pollution, as indicated by fecal coliform counts in waters over the beds. Over a third of the 11,112 acres of clam flats in Casco Bay were closed. It is suspected that the pathway for much of this pollution is stormwater runoff from the watershed.

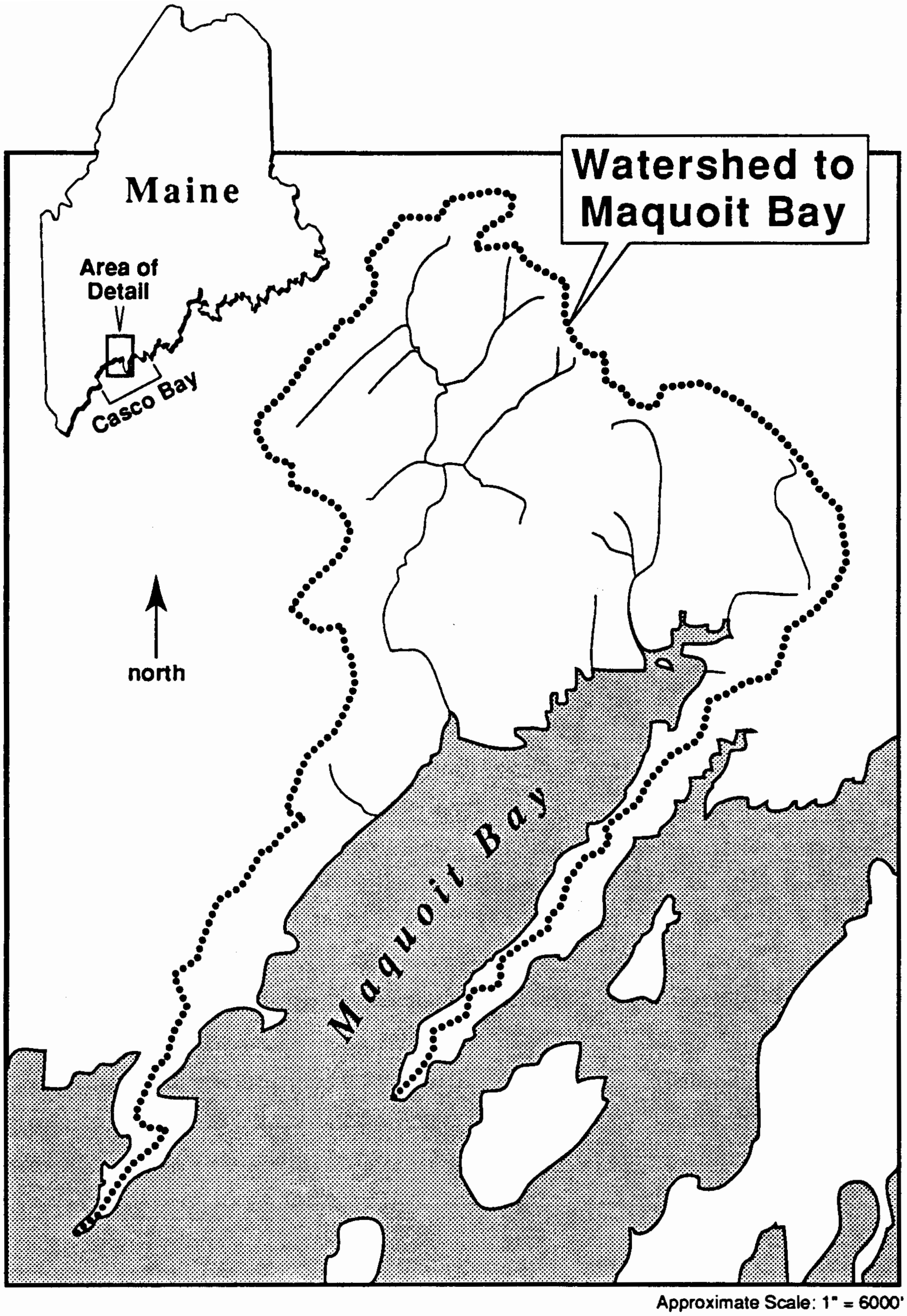


FIGURE 1.
Locus Map

II. DESCRIPTION OF WATERSHED

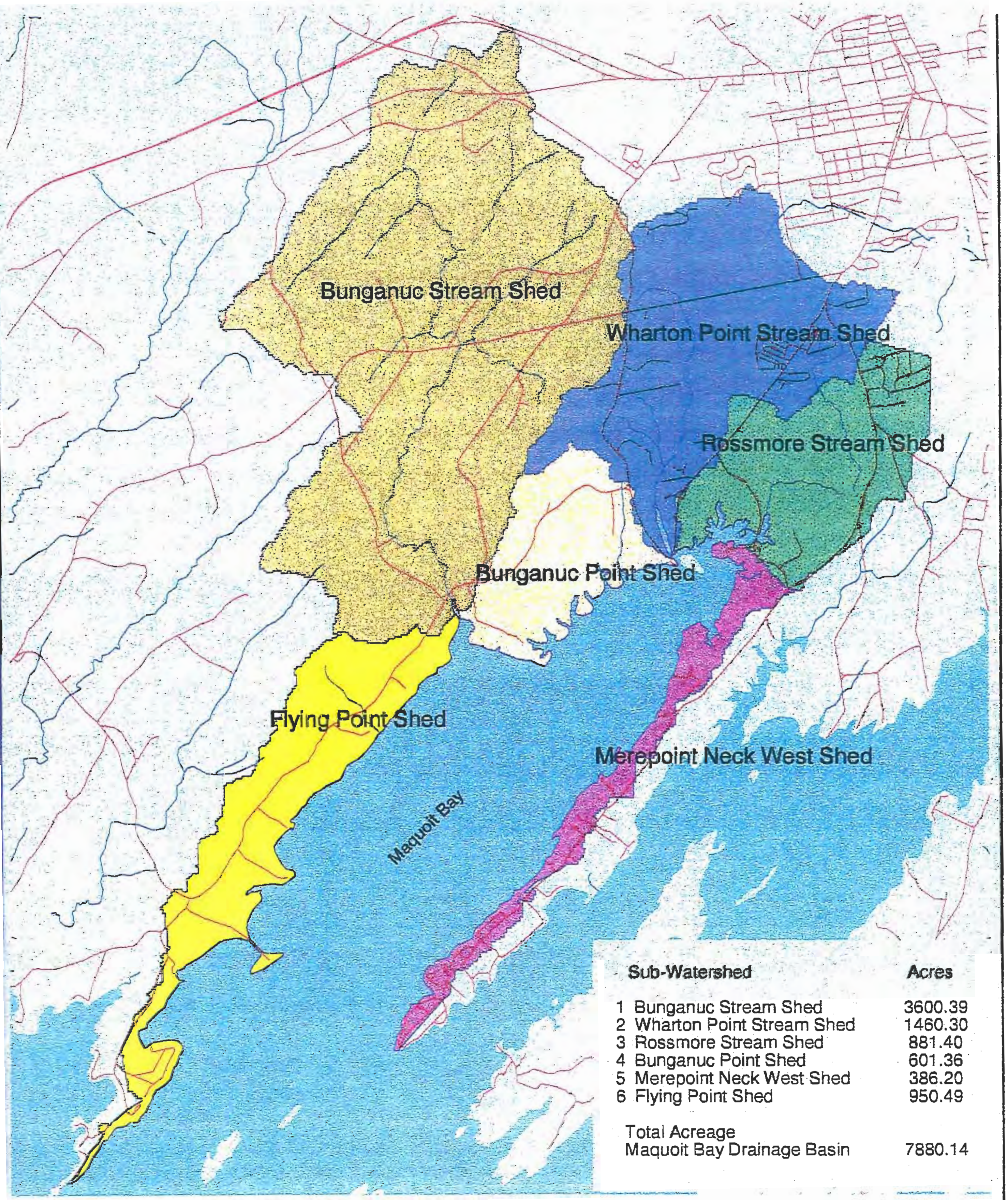
A. Watershed Delineation

The Maquoit Bay watershed drains 7,878 acres. The surface watershed boundaries of Maquoit Bay were delineated through the use of topographic maps and field checking of Geographic Information System (GIS) maps generated by the Casco Bay Estuary Project (CBEP).

Six subwatersheds, within the overall Maquoit Bay watershed, drain to the Bay (see Figure 2). Three of these subwatersheds are stream basins, the remainder have direct runoff to the Bay over the land surface. For the purposes of the watershed analysis project, H&W assigned the following subwatershed names based on prominent geographical features:

- Flying Point Neck subwatershed (950 acres)
- Bunganuc Stream subwatershed (3600 acres)
- Bunganuc Point subwatershed (601 acres)
- Wharton Point Stream subwatershed (1460 acres)
- Rossmore Stream subwatershed (881 acres)
- Merepoint Neck subwatershed (386 acres)

The three major streams account for much of the watershed drainage. Bunganuc Stream drains the northwestern portion of the watershed and empties just north of the Freeport boundary along Flying Point Neck. Wharton Point Stream and Rossmore Stream drain the northeastern portion of the watershed and empty into the head of the Bay. However, surface runoff and subsurface flow not hydrologically connected to the streams also occurs. This was observed on Merepoint Neck and Flying Point Neck during a shoreline survey conducted to evaluate sources of direct contamination to the Bay. Drainage from the Bunganuc Point subwatershed occurs via sheet and swale flow in the open areas, and through ephemeral stream flow in other areas.



Sub-Watershed	Acres
1 Bunganuc Stream Shed	3600.39
2 Wharton Point Stream Shed	1460.30
3 Rossmore Stream Shed	881.40
4 Bunganuc Point Shed	601.36
5 Merepoint Neck West Shed	386.20
6 Flying Point Shed	950.49
Total Acreage Maquoit Bay Drainage Basin	7880.14

Casco Bay Estuary Project

FIGURE 2.
Six Subwatersheds

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B. Geologic Framework

An understanding of the site specific hydrology and geology is necessary to determine the pollutant pathways from land-based sources to the Bay. The bedrock of the Maquoit Bay watershed is primarily of volcanic origin which has been metamorphosed several times over the last 200 million years. Much of it is fractured, providing pathways for water movement. Foliation (folding) of the bedrock and sediments has occurred in the Casco Bay region such that the lineation of ridges and troughs run from northeast to southwest, and are inclined gently downward toward the southwest. These ridges are locally called "necks." Troughs between the ridges were flooded by the ocean in the geologic past and make up the present bays and inlets oriented to the northeast, Maquoit Bay among them.

Surficial unconsolidated materials, most originating from the last glaciation, lie on top of the bedrock mantle. These include glacial till, outwash and a clay-rich formation known as the "Presumpscot". For the purposes of this report, the surficial soils of the watershed are generally classified into two types: 1) those with a predominance of sand, and 2) those with a predominance of clay. Sandy soils (glacial outwash) encourage infiltration of precipitation at the land's surface. Clayey soils include the Presumpscot Formation clays and glacial till. Precipitation on the these "clayey-type" soils results in mostly overland flow due to their low infiltration capacity.

C. Hydrologic Framework

1. Precipitation

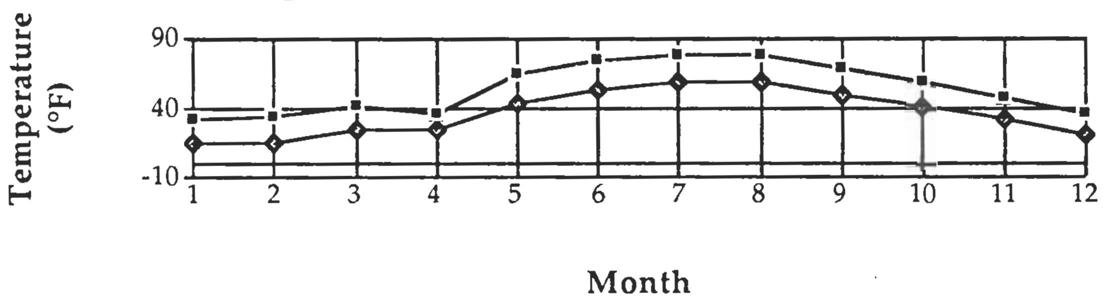
Precipitation in the Maquoit Bay region is monitored by the U.S. Naval Air Station (N.A.S.) at Brunswick, Maine. The N.A.S. measures rainfall and snowfall (converted to liquid precipitation) to one hundredth of an inch on a daily basis. Any precipitation less than this is considered a "Trace (T)" amount and is so recorded. The data are then transferred to the National Weather Service in Raleigh, North Carolina and subsequently to the State of Maine. Historical precipitation data used in this modeling effort were compiled with the assistance of the State climatologist. A total of 40 years of data have been reviewed.

Based on annual totals of precipitation, the 40-year period exhibited an annual mean of 40.11 inches, a median of 41.18 inches and a standard deviation of 13.53. The monthly mean for this period is 3.34 inches with a median value of 3.43 inches and a standard deviation of 1.13. Temperature on average fluctuates between 10°F and 80°F in the study area (Figure 3). The region commonly experiences snowfall from November through March, and a typical spring thaw beginning in March although frozen ground has been observed by H&W as late as mid April.

Groundwater from seasonally high water tables resulting from the snow melt will generally saturate the soils before discharging to Bunganuc Stream, Rossmore Stream and Wharton Point Stream, the three primary streams draining the Maquoit Bay watershed. Seasonal groundwater and soil saturation conditions are of concern because they can be problematic for septic system effluent percolation through soils depending on the level of saturation.

Figure 3

Average Monthly Maximum and Minimum Temperatures for Brunswick, Maine for 1990 - 1992



Other factors which affect the rate at which precipitation becomes stream flow include the shape of the watershed: A round or bowl-shaped watershed will concentrate runoff more quickly at its drainage point than an elongate watershed (all other factors being equal). Additional factors include drainage density--the sum of all stream channel lengths divided by the watershed area (this correlates to stream ordering); antecedent moisture conditions of the soil; vegetation type and density; percent basin coverage of surface water bodies; and urbanization with its associated impervious surfaces.

2. Surface Water Flow

Surface water flows within the watershed occur as overland runoff and as stream flow. Overland flow, or stormwater as it is commonly called, is generated when the capacity of the soils and vegetation to absorb water from precipitation is exceeded. In clay-rich soils (which comprise the majority of the watershed) this capacity is low and is reached quickly. In sandy soils, a larger portion of the precipitation infiltrates the land surface and recharges the underlying groundwater system.

Three perennial streams carve through the watershed. They derive water from adjacent groundwater (baseflow) and from surface runoff during storms (storm flow). H&W undertook a 12-month field study to quantify stream flows. From 5 May 1994 through 19 May 1995, an H&W site inspector made daily stage measurements at Bunganuc Stream and Rossmore Stream (Figures 4 and 5, data in Appendix G). Additionally, stage and discharge measurements were made on a monthly basis for the purpose of constructing stage-discharge rating curves (Figures 6 and 7). The stage-discharge rating graphs were then used to estimate discharges in the streams for the dates where only stage measurements were made (See Figures 8 and 9).
Both streams exhibit low baseflows during the summer months when groundwater recharge is minimal due to elevated evapotranspiration. Higher baseflows were observed in the late fall, winter and spring months. The lower stage readings reflected in the Bunganuc Stream curve during the winter months reflect ice cover (Figure 8). The Rossmore Stream graph also exhibits a defined "plateau" in the winter months (Figure 9). H&W

Figure 4. BUNGANUC STREAM STAGE vs. RAINFALL MEASUREMENTS June 1994 - May 1995

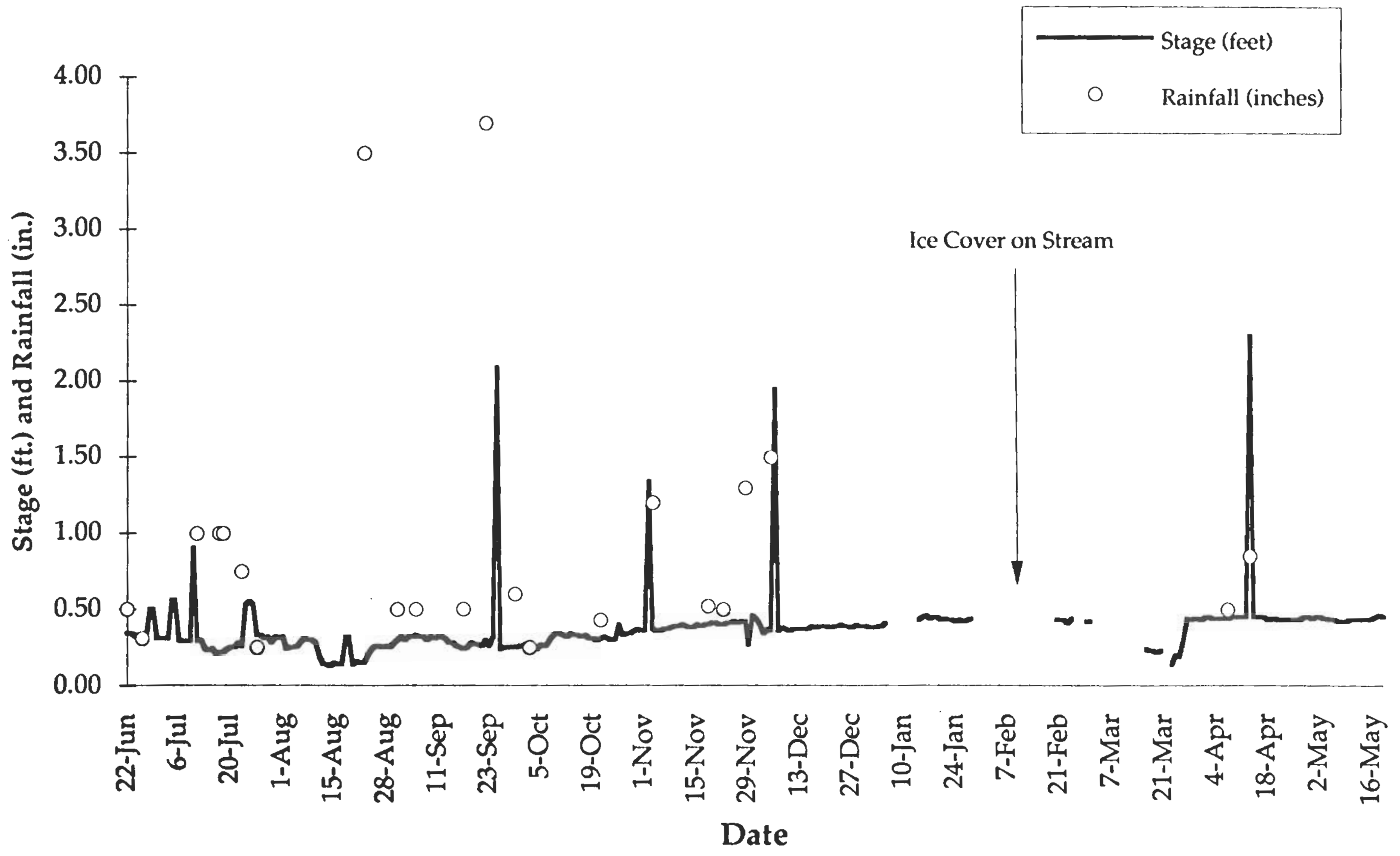


Figure 5. ROSSMORE STREAM STAGE vs. RAINFALL MEASUREMENTS May 1994 - May 1995

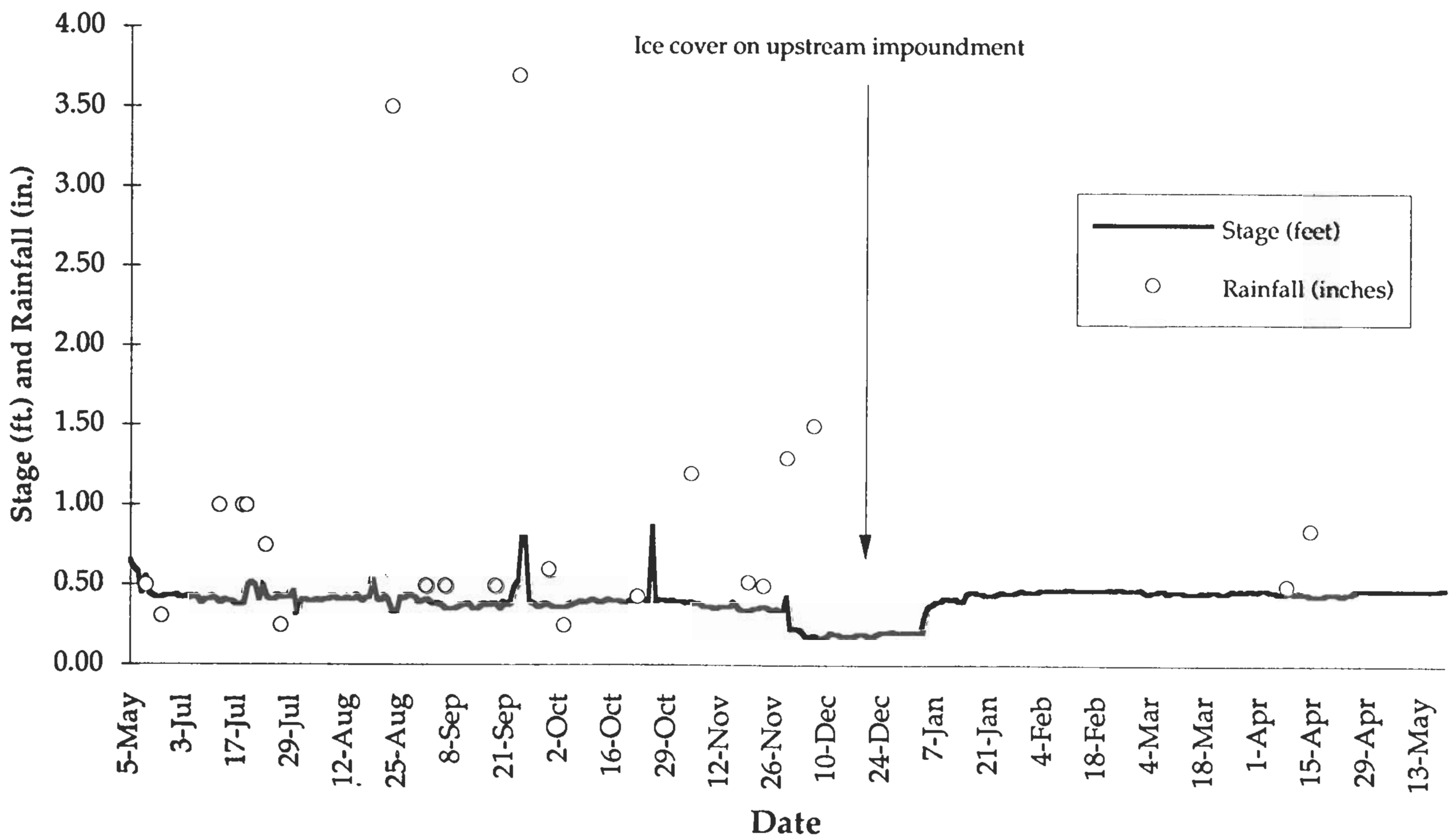


Figure 6. Bunganuc Stream Rating

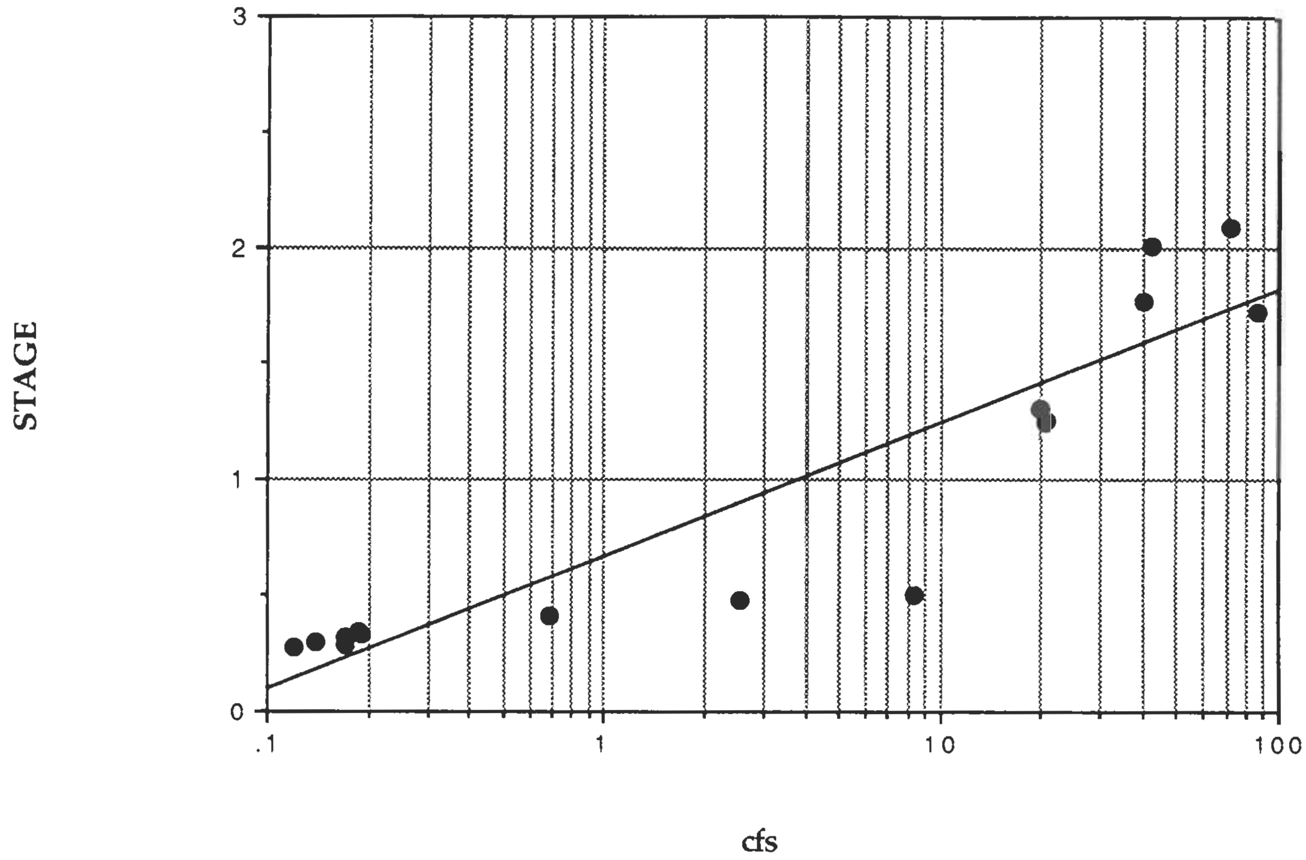


Figure 7. Rossmore Stream Rating

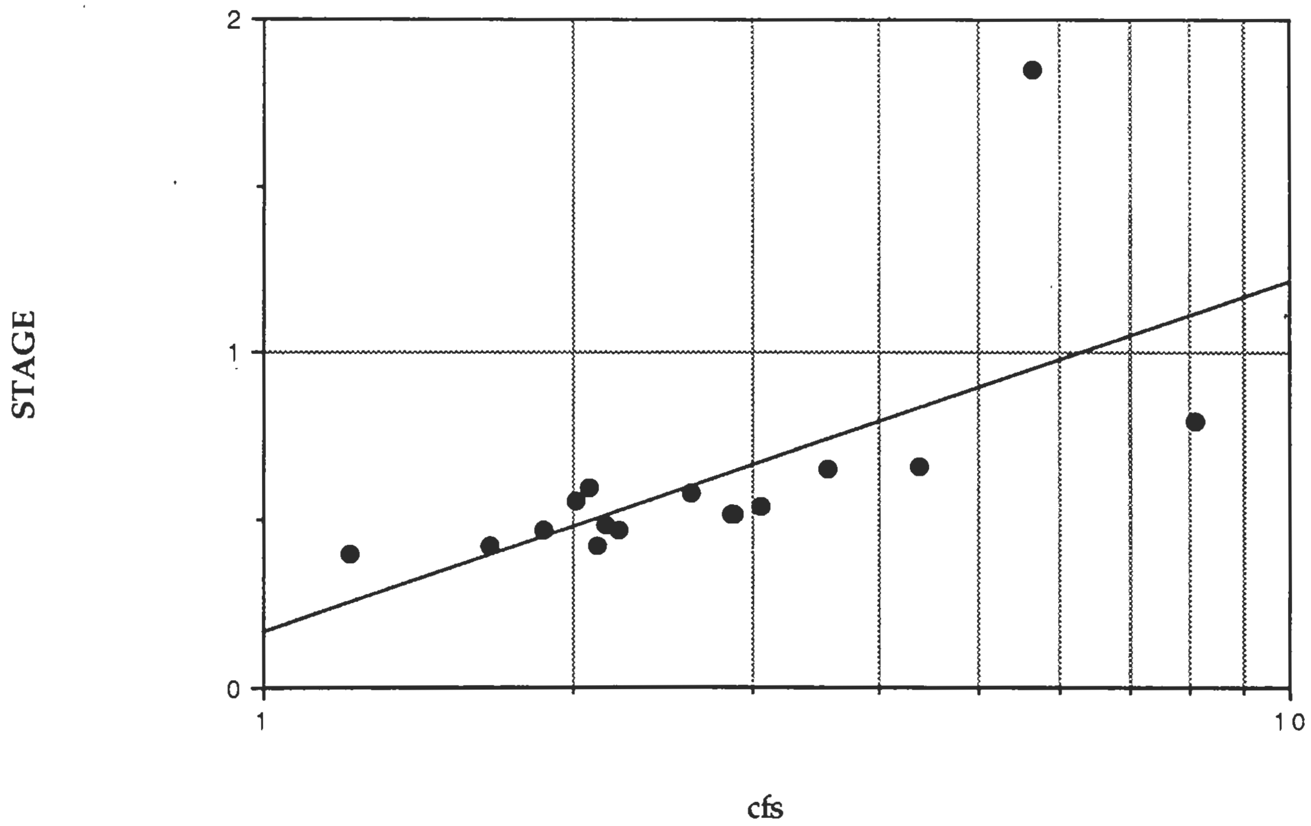


Figure 8. PREDICTED BUNGANUC STREAM DISCHARGE MEASUREMENTS 5/94 - 5/95

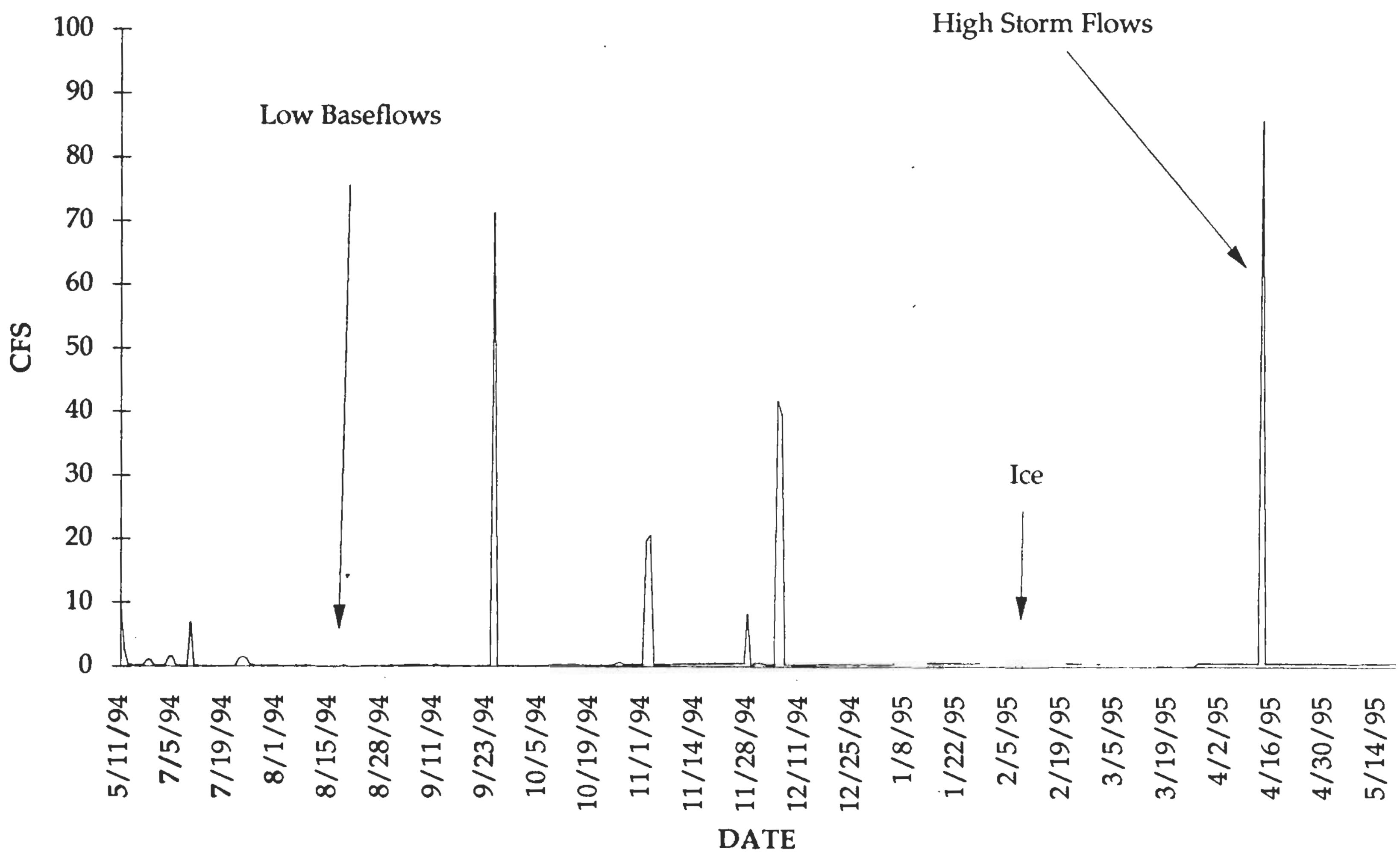
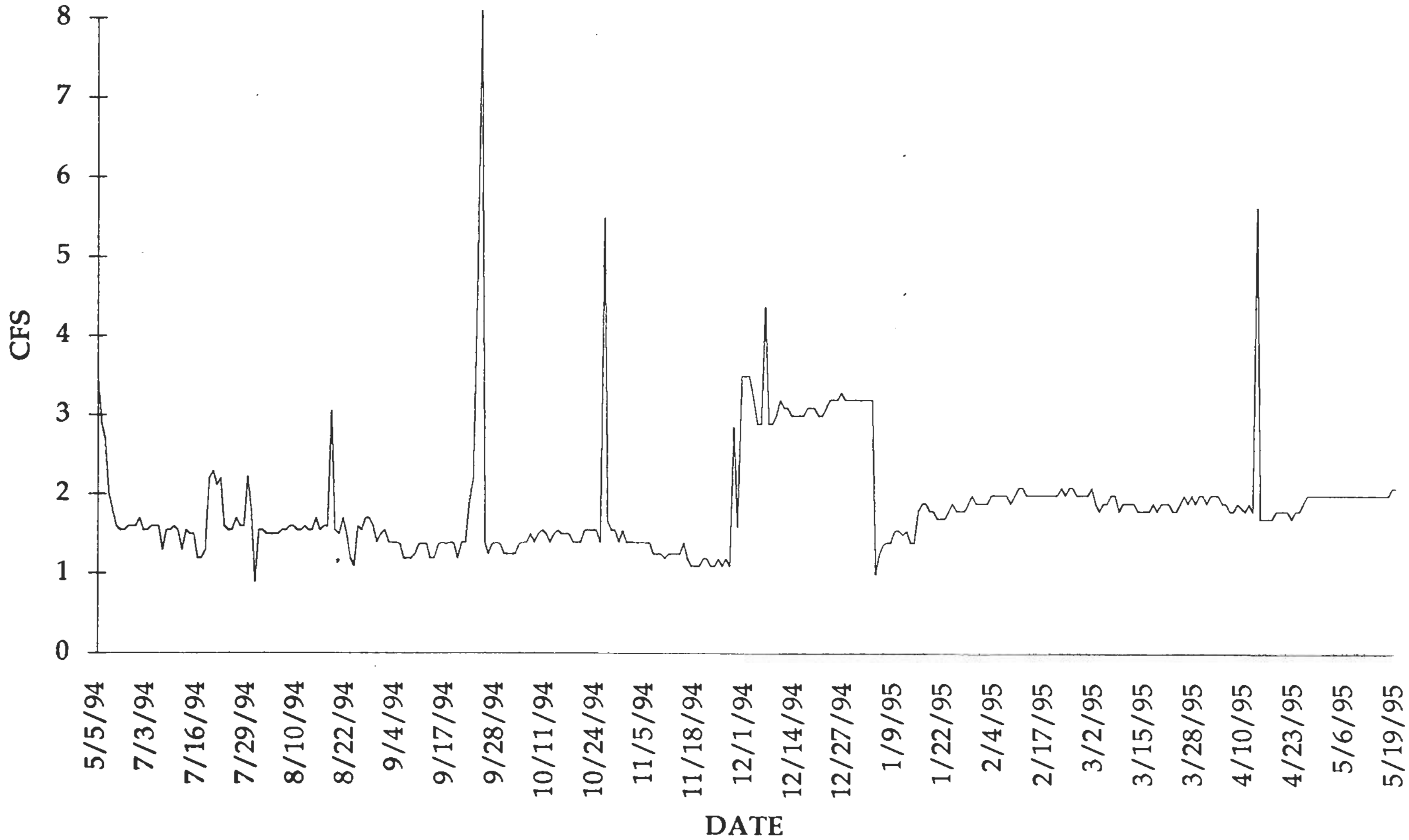


Figure 9. PREDICTED ROSSMORE STREAM DISCHARGE MEASUREMENTS 5/94 - 5/95



interprets the result of snow melt and rain recharging the impoundment via the watershed over the winter, resulting in a higher discharge for this period.

3. Groundwater Flow

Groundwater flows though the watershed from upland areas and discharges to the streams and to Maquoit Bay directly. Groundwater discharge rates were estimated utilizing groundwater recharge rates for the two major soil groups (3 inches/year for clay and 18 inches for sand) and multiplying by the acreage of these soil types in each subwatershed. Stormwater runoff rates were estimated utilizing runoff rates of 18 inches/year for clay and 3 inches/year for sand. Table 1 summarizes the results of this preliminary hydrologic budget analysis. It indicates that the Bunganuc Stream subwatershed is the most significant area within the Maquoit Bay watershed. The analysis also suggests that stormwater accounts for 71% of the total discharge from the Maquoit watershed.

Table 1. Estimated Average Groundwater and Stormwater Discharge Rates (cubic feet/day)

Watershed	Groundwater	Stormwater	Total
Bunganuc Stream	2.5	8.7	11.2
Rossmore Stream	1.6	2.1	3.7
Wharton Point Stream	2.3	3.5	5.8
Bunganuc Point	0.4	1.5	1.9
Merepoint Neck	0.3	0.9	1.2
Flying Point	0.6	2.3	2.9
TOTAL	7.7	19	26.7

4. Maquoit Bay Water Quality

H&W reviewed surface water quality data (June 1992-November 1994) from the Maine Department of Marine Resources (DMR) to assess the spatial and temporal variability of fecal coliform bacteria in Maquoit Bay. The DMR uses a fecal coliform concentration of 14 colonies/100 ml to trigger a regulatory action on shellfishing.

The shellfish beds at the head of the Bay (known as DMR site C-17B) are presently closed and have been closed for decades. This is also the location of the mouths of Rossmore Stream, Wharton Point Stream and Bunganuc Stream. Data collected under the supervision of the Town of Brunswick's Shellfish Warden, Alan Houston, from 1992 through the present, show surface water fecal coliform levels frequently in excess of the 14/100 ml level in this area. These exceedences do not appear to closely correspond with the tidal changes.

H&W evaluated the potential of using this bay sampling data as a tool to relate our storm water sampling data to Bay water quality. This could not be done because the marine data collection program did not correspond to the same rain events. Therefore, it is difficult to relate a stream loading from a particular monitoring event to a marine water quality sample on a different day, particularly since much of the marine sampling data reviewed by H&W was collected during dry weather.

III. LAND USES

A. Existing Land Uses

Through literature reviews, site visits and detailed GIS analyses, H&W has identified and compiled data regarding several land uses which can be considered potential sources of pollution within the Maquoit Bay's watershed. The watershed is predominantly forest (4,870 acres or 60%), agricultural (1,046 acres or 13%) and residential (945 acres or 12%). The remainder of the watershed is roads, wetlands and a limited amount of commercial land in the northeast corner of the watershed near the center of Brunswick.

The majority of residential land in Brunswick is within the Coastal Protection Zoning district (CPZ) with a minimum lot size of five acres (Figure 10). The descriptions of the remaining zoning districts are provided in Table 2.

Table 2. Summary of Zoning Districts in Maquoit Bay Watershed

Brunswick		
Zoning District	**Use**	**Minimum Lot Size**
CPZ	Residential	217,800 square feet (ft^2) (5.0 acres)
CR1D	Residential	80,000 ft^2 (1.8 acres)
MUZ11	Res./Comm.	15,000 ft^2 (w/sewer) (0.3 acres) 40,000 ft^2 (w/o sewer) (0.9 acres)
MDIZ	Industrial	80,000 ft^2 (1.8 acres)
SRD	Residential	15,000 ft^2 (0.3 acres)
IR11D	Residential	7,500 ft^2 (0.2 acres)
TRANS	Residential	40,000 ft^2 (0.9 acres)
Freeport		
Zoning District	**Use**	**Minimum Lot Size**
MDR-1	Residential	108,900 ft^2 (2.5 acres)
RR-1	Residential	108,900 ft^2 (2.5 acres)
ID	Residential	Max. 1 dwelling/island or lot of record
RP-1	Open	108,900 ft^2 (2.5 acres)
Shoreland	250 ft. Zone	Underlying zoning applies

While the zoning information doesn't itself specify existing land uses, the majority of the developed properties conform to today's zoning requirements. Further details on existing uses are provided in the following buildout section.

Based on existing land uses, septic systems, lawns, agricultural practices, road runoff, and atmospheric deposition were identified as the greatest potential contributors of nutrients and pathogens to the Bay. Other identified sources, with lesser potential for contamination, include forests and agricultural lands no longer in production. An estimated 591 residential units rely upon on-site septic systems for sewage disposal. Approximately 50% of the systems are constructed in soils rated as having severe limitations for septic drain field by the USDA Natural Resources Conservation Service. This soil rating is based upon shallow depth to bedrock, shallow depth to water table and low permeability. These factors contribute to the probability for failure of septic systems resulting in pollution to downstream surface waters. The majority of these residential units maintain lawns, presumably with fertilizers, which represents a source of nitrogen to the Bay.

There are 1,046 acres of agricultural land within the watershed. Pollutant sources include fertilizer spreading, livestock grazing areas and feedlots. Road drainage also represents a significant source of pollutants to coastal waters. Stormwater runoff from road surfaces and adjacent lands includes pollutants from domestic animal waste, drippings from automobiles and roadside accumulation of debris. A sanitary landfill and a sewage sludge disposal area were also identified in the Bunganuc Stream subwatershed.

1. Buildout Analysis

With the assistance of the CBEP Geographic Information System (GIS), H&W has completed a GIS buildout analysis for the Maquoit Bay watershed. The methodology used to conduct the buildout required the development of a series of assumptions about the conditions that affect future development. Overall, the analysis is based upon the assumption that future land development will be controlled by the combined influence of the local land use policies and regulations, environmental factors attributable to the land, and the requirements of the Maine Subsurface Wastewater Disposal Rules.

H&W's approach utilized the available GIS map coverages provided by the CBEP to approximate on-the-ground constraints which are likely to inhibit or preclude future development in the Maquoit Bay watershed (see Figures 10-13). A review of the existing zoning, subdivision, and state plumbing code regulations in conjunction with identified environmental databases provided the necessary criteria by which to assess the "suitability" for development within each of the five subwatersheds that drain into Maquoit Bay.

H&W used the following steps to generate the buildout results:

- a review and analysis of applicable zoning, subdivision, and sanitary code regulations;
- a review of available GIS map coverages to determine development constraints due to environmental or other (non-regulatory) factors;
- selection of development criteria derived from regulatory and environmental analysis;
- translation of development criteria into a series of processing steps or statements for application to GIS map coverages;
- application of the processing statements to the inventory of available GIS map coverages;
- analysis of processing results and calculation of net potential for future land development.

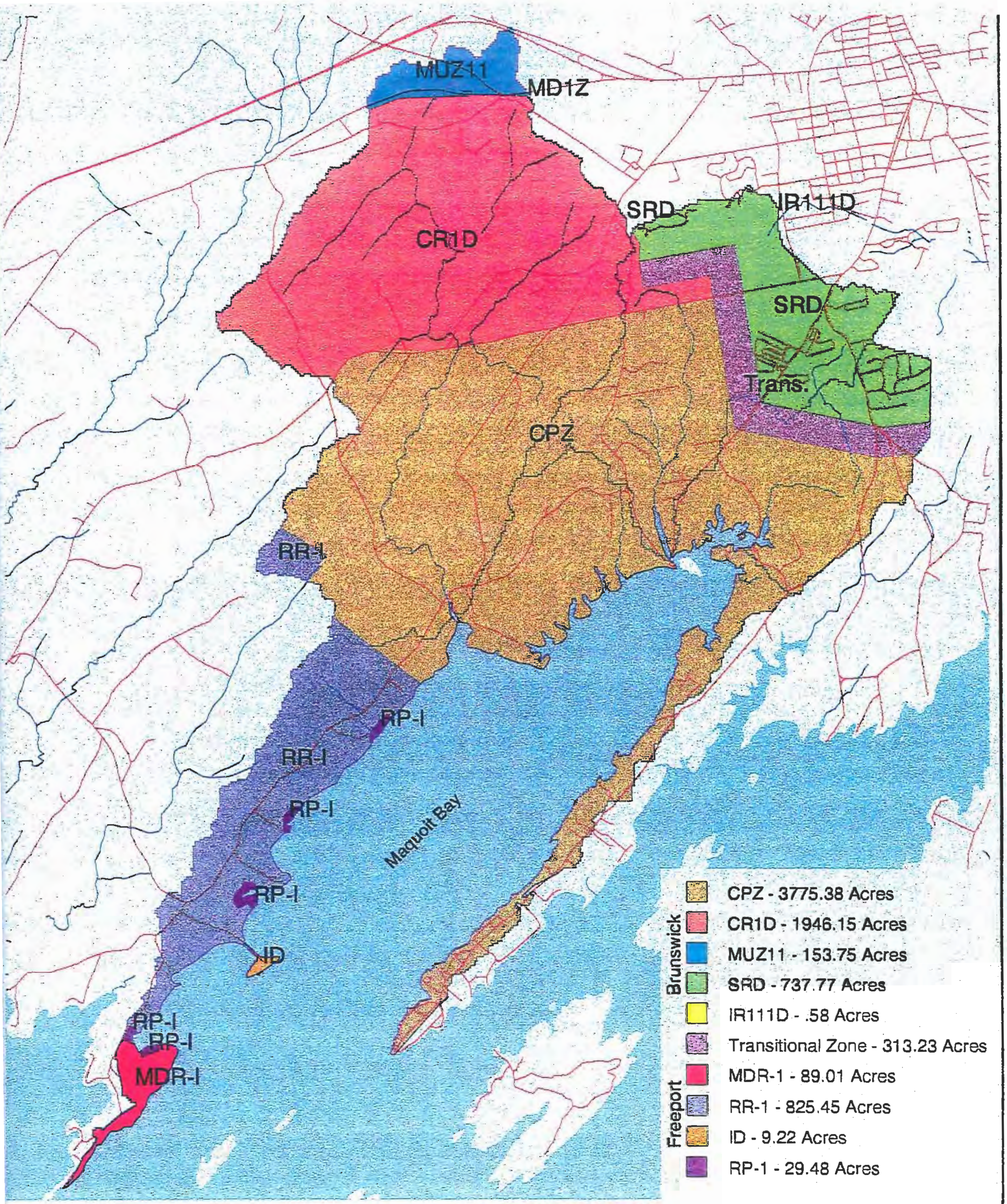


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FIGURE 10.
Maquoit Bay Drainage Basin
General Zoning Acreage

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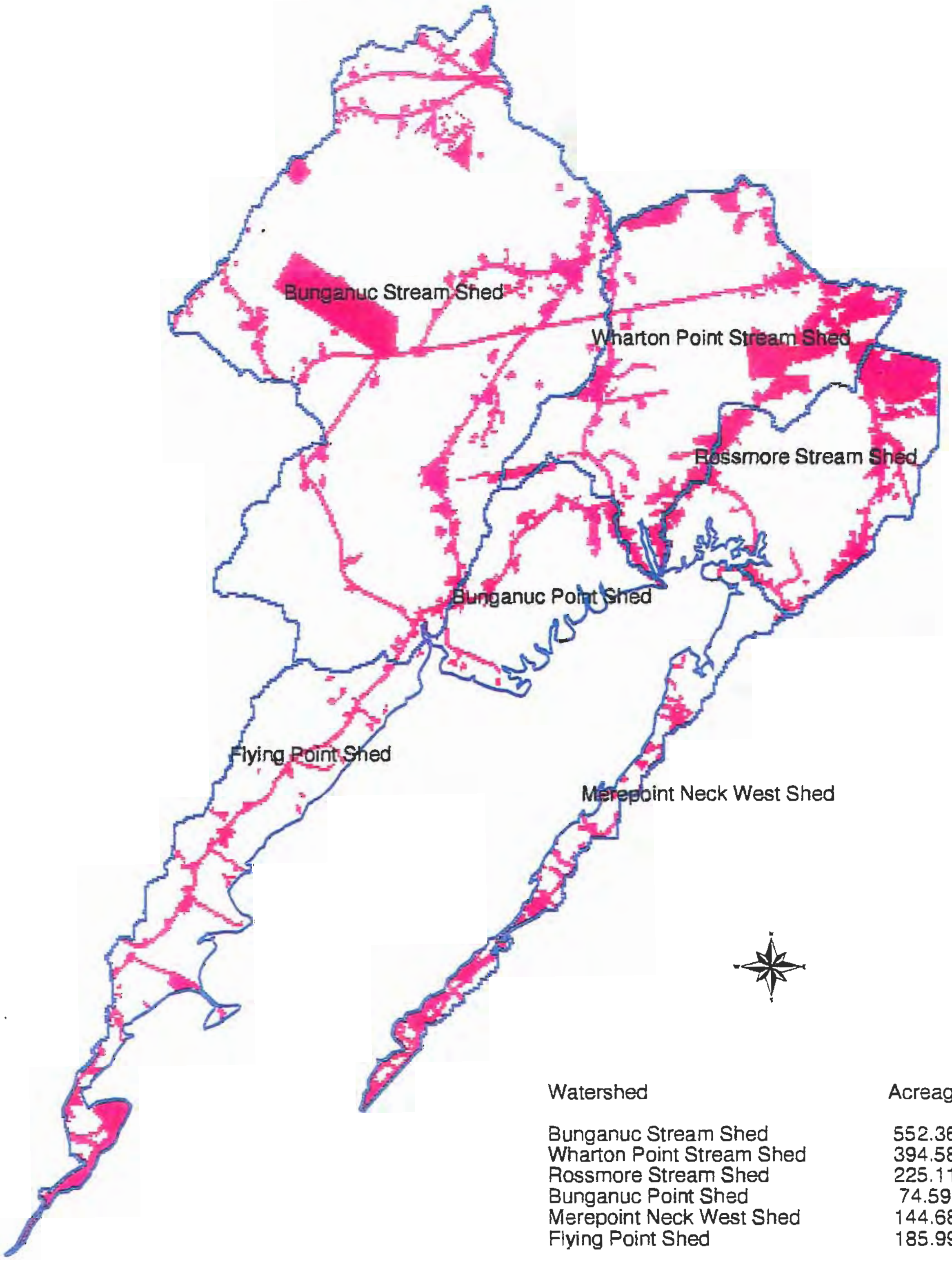

Watershed	Acreage
Bunganuc Stream Shed	552.36
Wharton Point Stream Shed	394.58
Rossmore Stream Shed	225.11
Bunganuc Point Shed	74.59
Merepoint Neck West Shed	144.68
Flying Point Shed	185.99

FIGURE 11.

Developed Lands Exclusion

Total Acreage in Maquoit Basin = 1577.31

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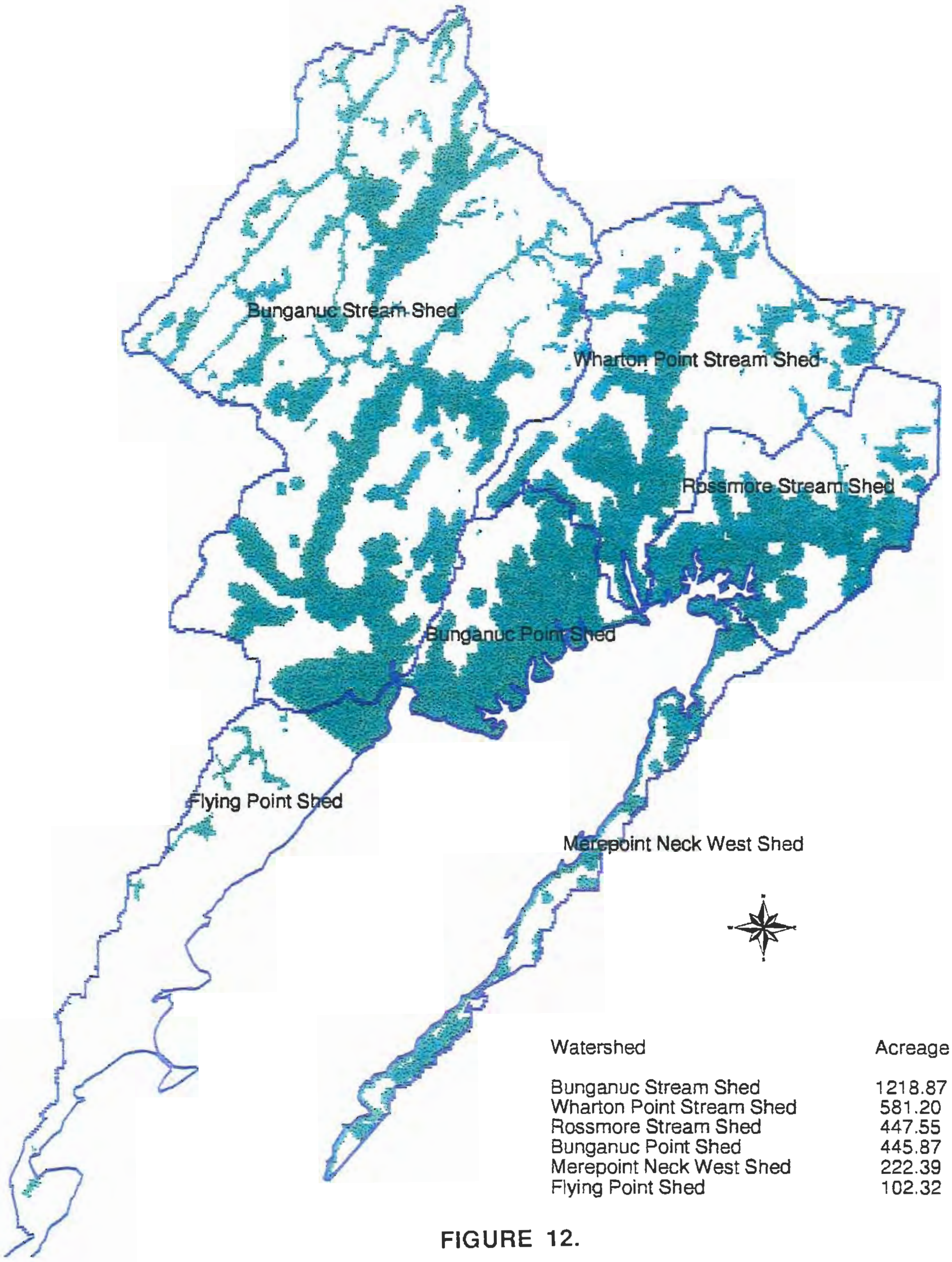

Watershed	Acreage
Bunganuc Stream Shed	1218.87
Wharton Point Stream Shed	581.20
Rossmore Stream Shed	447.55
Bunganuc Point Shed	445.87
Merepoint Neck West Shed	222.39
Flying Point Shed	102.32

FIGURE 12.

Wetlands Exclusion

Total Acreage in Maquoit Basin = 3018.20

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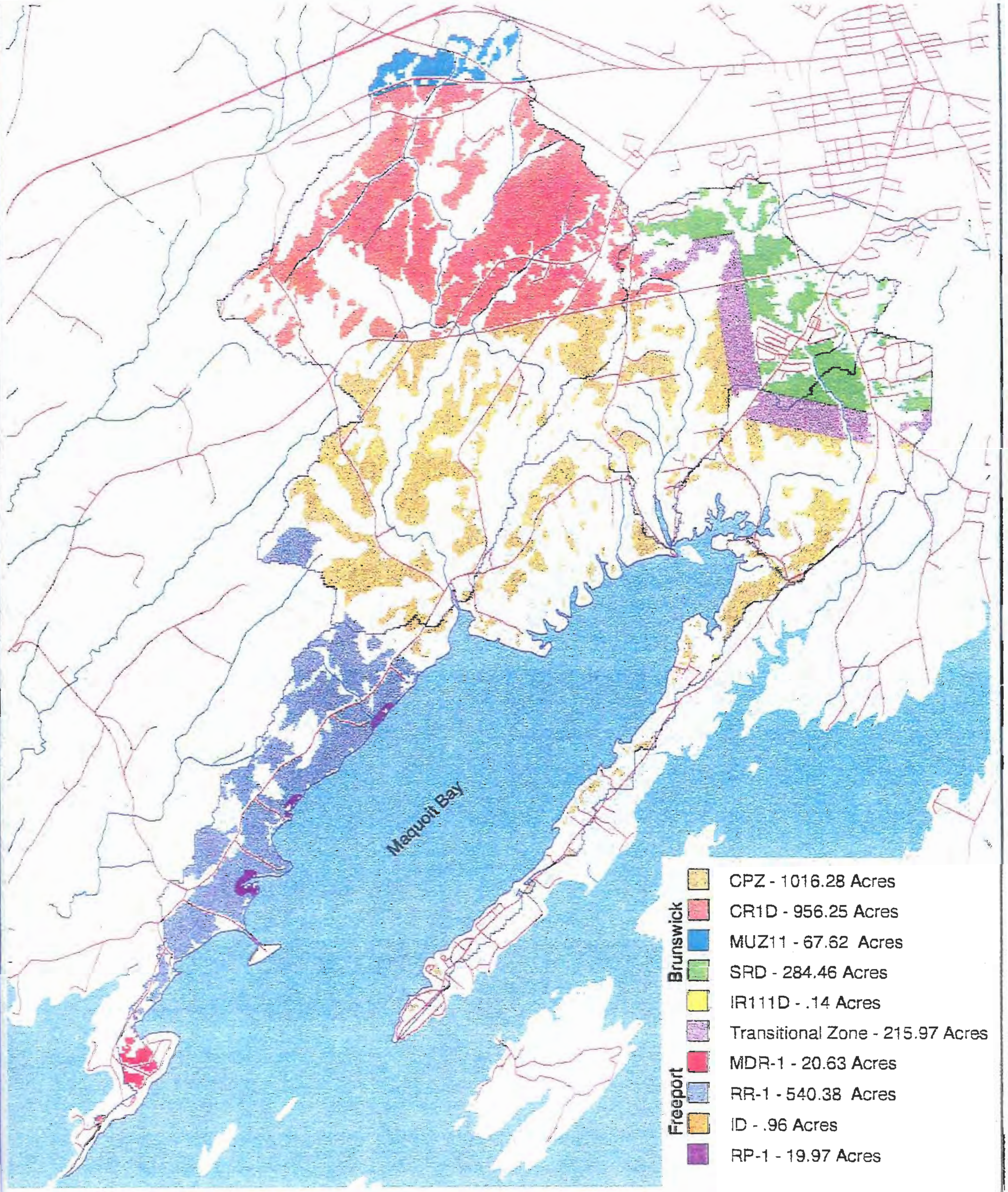

FIGURE 13.

Maquoit Bay Drainage Basin
General Zoning Net Developable Areas

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Specific Build-Out Assumptions and Sources of Information:

To calculate the land area available for future development, it was necessary to establish certain conditions as controlling the maximum amount of development that may occur. These conditions, or buildout assumptions, are described below. The assumptions chosen reflect the availability of information, its accuracy, and the objectives of the study.

1. All acreage figures associated with the various map coverages provided from the CBEP GIS databases were assumed accurate.

2. Land identified as "developed" was assumed to support no further development and was excluded from the further analysis (Figure 11). Developed land includes areas shown as "high density residential and low density residential", as well as the associated roads, lawn areas, and other features associated with developed land areas.

3. The Tax Assessor's Use Codes were used to exclude other areas which are unlikely to be built upon due to the type of ownership, including conservation, utility, cemetery, and other public lands.

4. Area occupied by existing road right of ways were calculated by multiplying linear distance by the following width dimensions for:

Collector/Commercial Road	66 feet
Local Road	60 feet
Minor Road	50 feet

5. Gross developable acreage includes areas shown as "cultivated fields, wet agriculture and fields, agriculture/crops, fallow fields, wet meadows, pasture, hardwood/softwood forest, vacant land, and all other area not included as developed.

6. Wetlands and areas of open water were considered to be not developable (Figure 12).

7. New on-site septic systems will not be allowed within the 100-year flood plains as depicted on the Flood Insurance rate maps/zoning maps.

8. In accordance with the Maine State Plumbing Code, areas with excessive slope were considered unsuitable area for on-site septic systems installations.

9. In accordance with the Maine State Plumbing Code, areas of bedrock within 20" of the ground surface were excluded from gross developable acreage as unsuitable area for on-site septic systems installations.

10. In accordance with the Maine State Plumbing Code, soils identified as Poorly and Very Poorly Drained with a seasonal high water table of 0"-12" were excluded from gross developable acreage as unsuitable area for on-site septic systems installations.

11. In accordance with the Maine State Plumbing Code, areas with a seasonal high depth to groundwater of 0.5 - 1.5 feet were excluded from gross developable acreage as areas that may be unsuitable for on-site septic system installations.

12. Future development within the subwatersheds was assumed to be controlled by the zoning ordinances in each town (Figure 10). Minimum lot size and frontage will comply with those listed in each respective district. Single family houses are allowed in residential zoning districts.

13. Areas occupied by future subdivision roads equaled from 5-12% of gross developable acreage within each subwatershed area depending upon the underlying zoning.

14. Reserved land (open space) requirement for new subdivisions equals 1.6% of gross developable acreage.

15. Areas within the current or planned service are for sanitary sewers will be connected and therefore development will not be constrained by on-site suitability factors.

The buildout analysis conducted according to the assumptions above indicates that under current zoning, an additional 1,603 single-family homes could be built within the developable areas of the watershed (Figure 13). It is presumed that all of the dwellings will utilize on-site septic systems. This represents slightly more than a tripling of the existing number of units (591) within the watershed (Table 3).

Table 3. Buildout Results

Subwatershed	Existing Dwellings	Potential Increase in Dwellings	Buildout Dwellings
• Bunganuc Stream	142	520	662
• Wharton Point Stream	53	692	745
• Rossmore Stream	100	230	330
• Flying Point Neck	152	136	288
• Merepoint Neck	123	9	132
• Bunganuc Point	21	16	37
TOTAL	591	1603	2194

IV. WATER QUALITY SAMPLING AND ANALYSIS IN MAQUOIT BAY WATERSHED

In order to determine the level of bacteria and nutrient loading from predominant land uses within the watershed, a field sampling and flow measurement program was undertaken. The program included three components:

1. stormwater runoff sampling at test sites;
2. sampling of three principal streams during baseflow and stormflow; and
3. shoreline survey

Prior to initiation of water quality sampling and measurements, a Quality Assurance Project Plan (QAPjP) was prepared and approved by EPA. The QAPjP describes procedures for data collection in the field, and laboratory analyses. It also describes necessary quality assurance/quality control methods to follow in the data collection and analysis process.

A. Test Sites: Predominant Land Uses

Within the Maquoit Bay watershed, six test sites (or polygons in GIS terminology) with predominant land covers were selected for the monitoring of contaminants in runoff (Figure 14). Initial candidate sites were identified by GIS by combing land use and topographic information and identifying "pour points", or locations where a small subwatershed discharges into a stream. The test sites contain predominantly one land use, although other uses exist in each (Table 4).

Table 4. Summary of Test Site Land Use Characteristics

Site	Total Acres	Predominant Land use	Acres Agricultural	Acres of Woods	Acres of Residential	Linear Feet of Roadway	Soils
BS-1	92	Agriculture	15	76	1	174	Clayey
BS-6	227	Agriculture	137	66	25	6,400	Clayey
GG-7	76	Agriculture	26	34	9	3,400	Sandy
BS-8	14	Residential	0	11	3	645	Clayey
BS-13	28	Residential	0	10	10	780	Sandy
BS-14	43	Forest	0	39	3	380	Mixed

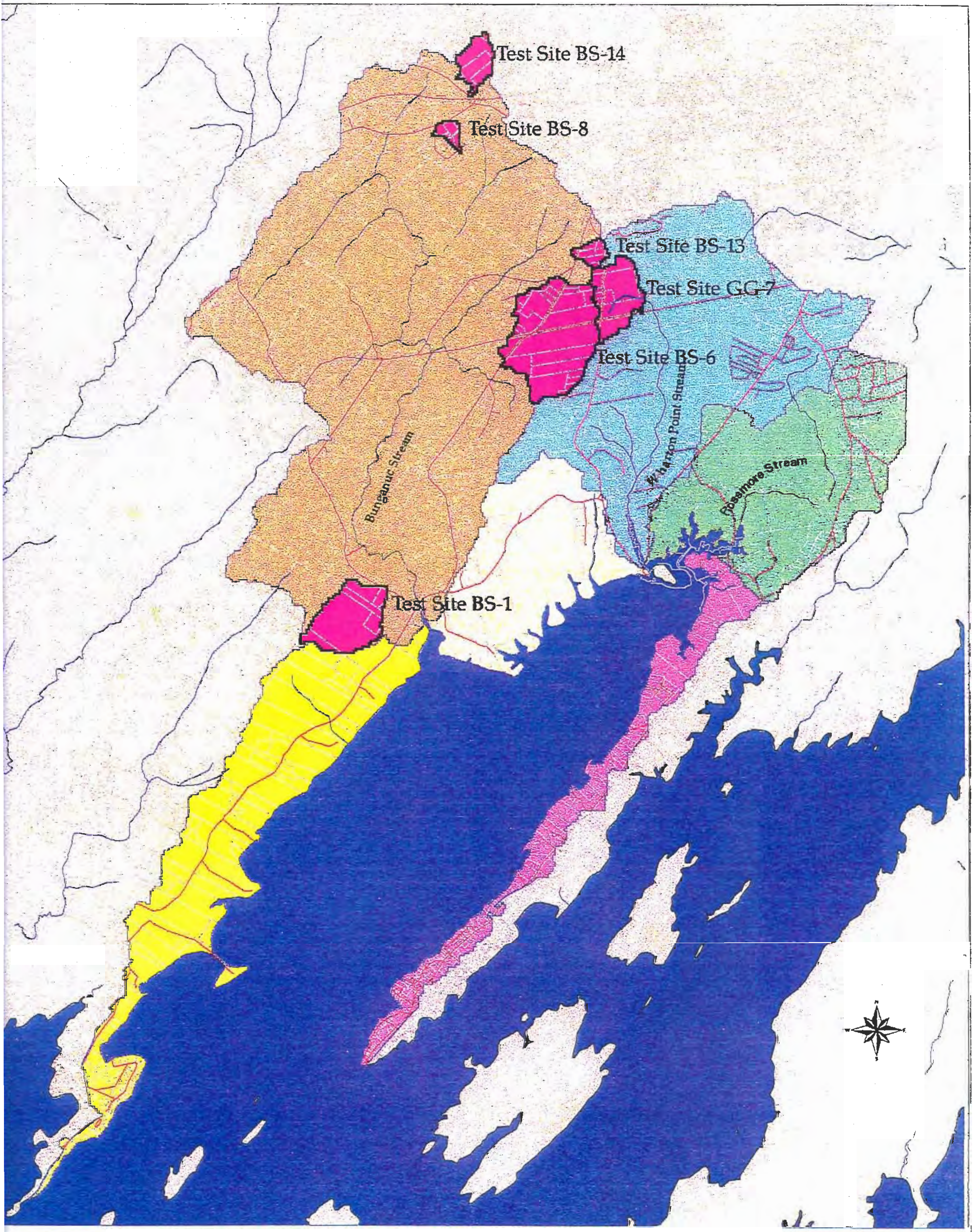

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FIGURE 14.

Watershed Test Sites

Horsley and Witten, Inc.

While each test site had areas of "other" land cover besides the predominant land use, field checking of the sites revealed that the other land covers would not compromise the data collection effort due, in some test sites, to the nature of the land cover, and in other test sites, to their relative position in the site. Specifically, mixed woods are not considered as significant a source of fecal coliform as residential septic systems, road runoff and agricultural activities.

At BS-1, a relatively flat area, the 76 wooded acres are on the site periphery while the agricultural acres immediately surround the discharge point. The same landscape relationship is found at GG-7 and BS-6, although these sites have somewhat greater slopes and certain wetland areas near the "pour point", or sampling location. Stormwater samples were collected from ephemeral streams just upland of the vegetated wetlands. Within the of BS-6 site, there are also 25 acres of residential land and there are 9 residential acres within site GG-7. Houses on both sites typically have large plots of land associated with them. At BS-8 and BS-13, the residential sites, mixed woods surrounded and intermingled with the houses. However, the houses (and septic systems) were aggregated relatively close to the monitoring point rather than spread across the site. The forest site, BS-14, was almost entirely mixed woods. This site also contains vegetated wetlands which may provide some attenuation of pollutants as stormwater moves through the area.

B. Test Sites: Sampling Procedures

Test site sampling was initiated by a "weather watcher" an H&W sampler residing near the watershed. A forecast of rain would be monitored. At a time after rainfall in the watershed began, depending on its intensity, the sampler would drive to each test site "pour point", or discharge point, to investigate if any discharge was observed. Once discharge was observed at some locations, the remainder of the sampling team members (an additional H&W sampler and two Wright-Pierce flow measurement personnel) were mobilized. The field personnel would break into two teams of one sampler and flow measurement person each, and begin to make designated rounds. H&W sampling policy for this project was to sample, at a minimum, two rounds at each site per rain event. This was achieved; two storms had fours rounds of sampling, one had three rounds and one had two rounds.

Water samples were obtained by catching runoff in sample bottles prior to reaching perennial streams. Three to four rounds of samples were taken at each station during each storm event sampled. The intervals between sampling rounds was dependent upon travel time to subsequent sites and averaged approximately one hour between rounds. Individual samples from each test site were mixed, or composited, to produce a sample that represented the entire storm. The percentage of each sample mixed into the composite was based on the relative proportion of runoff at the site at the time the sample was taken. Details on the compositing procedure are provided in Appendix F.

C. Test Sites: Results

Table 5 summarizes the average water quality conditions at the six test sites over storm events for total dissolved nitrogen and fecal coliform bacteria. The complete water quality data is presented in Table 6.

Total dissolved nitrogen (TDN) averaged 0.99 mg/L for the three agricultural test sites and 0.92 mg/L for the two residential sites. These concentrations are approximately twice the average concentration (0.52 mg/L) measured at the forest (control) site. Higher concentrations were expected at the agricultural sites, based upon other studies which commonly show higher concentrations of dissolved in agricultural runoff. The lower nitrogen concentrations at the agricultural sites is attributed to the paucity of manure applications to agricultural fields during the study period.

During H&W's reconnaissance of the watershed, prior to the commencement of water quality sampling, Scott Horsley and Michael Frimpter (H&W), observed what they describe as "liberal" applications of manure which covered many sections of road surfaces in the Bunganuc Stream watershed. During the sampling period, H&W employed a field inspector who surveyed the watershed on a daily basis and found only limited manure applications at the GG-7 test site.

Table 5. Average Water Quality Conditions at Test Sites

Average Fecal Coliform (colonies/100 mls)		
Test Sites		
BS-1		289
BS-6		183
GG-7		275
Average Agricultural		249
BS-8		434
BS-13		121
Average Residential		277
BS-14	Forest	28

Average Total Dissolved Nitrogen (mg/l)		
Test Sites		
BS-1	Agricultural	1.00
BS-6	Agricultural	0.82
GG-7	Agricultural	1.15
Average Agricultural		0.99
BS-8	Residential	0.86
BS-13	Residential	0.99
Average Residential		0.92
BS-14	Forest	0.52

Fecal coliforms averaged 249 colonies/100 mls for the three agricultural test sites and 277 colonies/100 mls for the two residential sites. These concentrations are approximately one order of magnitude higher than the average concentration (28 colonies/100 mls) measured at the forest (control) site. Similar to the discussion of nitrogen results, higher fecal coliform concentrations were expected at the agricultural test sites. The lower than expected fecal coliform concentrations are attributed to the very limited manure applications during the study period.

Table 6 Water Quality and Discharge Data for Test Sites

Date	Site	Land use	Q gal/storm	Fecal Coliform no./100ml	Total Suspended Solids mg/l	Total Phosphorous mg/l	Ortho-Phosphorous mg/l	Ammonia Nitrogen mg/l	Nitrate Nitrogen mg/l	Part. Nitrogen mg/l	Total Dissolved Nitrogen mg/l
5/16/94	BS-1	Agricultural	17,600	400	4	0.02	0.008	0.013	0.033	0.118	0.937
	BS-6	Agricultural	500,400	311	4	0.02	0.008	0.010	0.026	0.073	0.923
	GG-7	Agricultural	173,600	400	35	0.04	0.005	0.016	0.271	0.163	0.957
	BS-8	Residential	6,100	1200	4	0.03	0.012	0.039	0.159	0.054	0.575
	BS-13	Residential	49,400	360	11	0.00	0.006	0.017	0.401	0.078	1.091
	BS-14	Forest	33,500	1	4	0.02	0.002	0.006	0.007	0.019	0.572
11/28/94	BS-1	Agricultural	38,000	750	4	0.02	0.060	0.013	0.135	0.037	0.587
	BS-6	Agricultural	1,160,600	380	4	0.02	0.074	0.014	0.088	0.019.	0.589
	GG-7	Agricultural	114,100	100	17	0.02	0.046	0.016	0.226	0.021	0.692
	BS-8	Residential	3,500	520	4	0.03	0.059	0.019	0.477	0.022	0.849
	BS-13	Residential	25,900	50	6	0.00	0.088	0.008	0.294	0.053	0.778
	BS-14	Forest	29,800	110	4	0.01	0.025	0.009	0.014	0.023	0.422
4/4/95	BS-1	Agricultural	9,400	1	4	0.01	0.028	0.018	0.021	0.010	1.230
	BS-6	Agricultural	430,800	20	4	0.01	0.031	0.032	0.081	0.021	0.969
	GG-7	Agricultural	55,100	34	30	0.00	0.050	0.026	0.250	0.008	1.230
	BS-8	Residential	2,000	11	4	0.01	0.058	0.060	0.287	0.020	0.893
	BS-13	Residential	17,300	69	13	0.00	0.017	0.007	0.547	0.010	1.026
	BS-14	Forest	22,200	2	4	0.01	0.007	0.022	0.009	0.005	0.597
4/13/95	BS-1	Agricultural	46,300	5	4	0.01	0.001	0.010	0.099	0.010	1.243
	BS-6	Agricultural	1,855,700	22	7	0.01	0.013	0.013	0.055	0.017	0.785
	GG-7	Agricultural	207,300	32	57	0.00	0.046	0.025	0.172	0.014	1.720
	BS-8	Residential	13,900	8	4	0.01	0.034	0.089	0.324	0.011	1.140
	BS-13	Residential	51,600	7	16	0.02	0.025	0.031	0.392	0.032	1.060
	BS-14	Forest	40,000	0	4	0.01	0.016	0.012	0.013	0.015	0.506
DETECTION LIMITS						0.002	0.001	0.001	0.007	0.005	0.002

With the exception of site GG-7 on 4 May 1994 and 4 October 1994, no additional manure has been observed on the agricultural lands in the test sites throughout the study. At the GG-7 site on 4 May 1994, rainfall did not occur until twelve days after the application thus allowing sufficient time for appreciable surface die-off of fecal coliform bacteria. Appreciable rainfall did not occur until weeks after the October application of manure. At GG-7 during all applications observed, the manure was a dry, aged or composted product which was harrowed into the soil. This is much different than the fresh, wet manure observed spread throughout the watershed the previous year.

Fecal coliform data showed elevated concentrations at both residential and agricultural sites, particularly in the first two watershed sampling rounds. Interestingly, the fecal concentrations exhibited a marked decrease at both residential and agricultural sites during the last two watershed rounds of sampling in April 1995. One possible explanation for the fecal coliform reduction at the agricultural sites is that the early data represent samples taken closer to the time the last manure was applied.

The reduction of fecal coliform concentrations at the two residential locations (BS-8 and BS-13) over the last two watershed events was not expected. The winter was relatively wet, resulting in greater soil moisture in the spring. Soil moisture is conducive to bacteria survival so the fecal coliform concentration would not be expected to decrease so significantly. One explanation could be that a greater percentage of residential test site fecal coliform concentrations were the result of road runoff washed-off during previous storms. Another possible answer is that previous rainfall flushed fecal coliforms from the soils. A third possible explanation is the effect of temperature on the survival of fecal coliform organisms. The temperature during the two April sampling rounds was considerably colder than the first two rounds. The answer may also be a combination of the scenarios.

D. Stream Sampling and Analysis

Water quality samples and discharge measurements were collected throughout the year at the mouths of each of the three streams (Table 7). Sampling was accomplished by compositing individual discrete samples on a flow-weight basis taken through the storm events.

Table 8 includes computations of average concentrations for both baseflow and stormflow conditions in the streams. Average fecal coliform concentrations increased by several orders of magnitude during stormflow conditions for all three streams. However, nitrogen concentrations did not show significant increases during stormflow conditions. One possible explanation is that dissolved nitrogen is transported to the streams via groundwater flow during both baseflow and stormflow conditions, while bacteria are filtered as they flow through soil, and are therefore not observed during baseflow conditions. Conversely, fecal coliform bacteria are transported as particulates during stormflow conditions and are readily filtered as they move subsurface through soil which is the hydrologic pathway which provides baseflow to streams.

On September 23-24, 1994 a 3.7 inch storm event was sampled by securing discrete samples throughout the event. These samples were not composited, rather they were analyzed individually. The water quality data indicates that concentrations of fecal coliforms increase throughout the storm event as discharge increases in all three streams (see Table 7). This effect is most evident in Bunganuc, where concentrations increased from 100 organisms/100 mls at the beginning of the storm to 7,100 at the peak flow.) The relatively higher fecal coliform increases in Bunganuc Stream are attributable to the predominance of agricultural land uses and its close proximity to roads which direct stormwater to Bunganuc Stream. Similar increases for nitrogen were not observed.

Table 7 Stream Sampling Water Quality and Discharge Data

SAMPLE DATE	STREAM SAMPLES Stream	Discharge cfs	Fecal Coliforms no./100ml	TSS mg/l	Ortho Phosphorus mg/l	Total Phosphorus mg/l	Ammonia Nitrogen mg/l	Nitrate Nitrogen mg/l	Particulate Nitrogen mg/l	Total Dissolved Nitrogen mg/l
5/24/94 at baseflow	Bunganuc	3.52	6	5.00	0.003	0.02	0.01	0.06	0.043	0.54
	Rossmore	1.88	3	6.00	0.001	0.02	0.02	0.38	0.104	0.87
	Wharton Point	2.53	18	4.00	0.006	0.01	0.01	0.42	0.038	0.91
6/22/94 at baseflow	Bunganuc	0.187	8	4.00	0.002	0.03	0.07	0.28	0.089	0.78
	Rossmore	2.01	13	15.00	0.002	0.02	0.04	0.16	0.160	0.71
	Wharton Point	2.25	62	4.00	0.009	0.12	0.02	0.47	0.095	0.86
7/21/94 at baseflow	Bunganuc	0.17	42	4.00	0.002	0.08	0.02	0.03	0.142	0.52
	Rossmore	2.12	6	4.00	0.001	0.12	0.01	0.29	0.186	0.89
	Wharton Point	1.86	35	4.00	0.013	0.01	0.01	0.58	0.049	0.81
8/18/94 at stormflow 3.5 in. rainfall	Bunganuc	0.187	1,200	4.00	0.002	0.03	0.02	0.11	0.005	0.87
	Rossmore	3.06	15	4.00	0.001	0.02	0.04	0.22	0.005	0.75
	Wharton Point	4.15	420	25.00	0.051	0.10	0.04	0.34	0.005	1.01
9/21/94 at baseflow	Bunganuc	0.119	19	4.00	0.002	0.04	0.01	0.01	0.029	0.54
	Rossmore	1.21	1	4.00	0.008	0.04	0.04	0.27	0.058	0.47
	Wharton Point	1.6	34	4.00	0.009	0.03	0.01	0.59	0.000	0.69
9/23/94 at stormflow 3.7 in. rainfall	Bunganuc/14:13	0.137	190	4.00	0.004	0.060	0.02	0.02	0.026	0.50
	15:32	0.137	260	17.00	0.006	0.07	0.02	0.02	0.018	0.40
	17:10	0.173	174	13.00	0.007	0.09	0.02	0.02	0.043	0.59
	18:15	0.25	300	34.00	0.007	0.08	0.02	0.02	0.085	0.47
	19:00	0.3	650	4.00	0.003	0.180	0.01	0.04		0.30
	Bung. 9/24 08:(	71.84	7,100	42.00	0.010	0.083	0.13	0.25	0.075	0.98
	Bung. Geo. mean	12.14	279	14.40	0.005	0.096	0.02	0.02	0.034	0.45
	Rossmore/15:11	2.16	4	4.00	0.006	0.05	0.03	0.21	0.001	0.43
	16:45	2.16	6	4.00	0.004	0.05	0.03	0.20	0.064	0.48
	17:50	2.88	8	4.00	0.005	0.070	0.03	0.20	0.083	0.57
	19:00	2.88	13	4.00	0.004	0.490	0.02	0.16	0.074	0.34
	19:40	2.88	12	4.00	0.006	0.05	0.02	0.16	0.089	0.23
	Ross. 9/24 09:3	8.11	400	4.00	0.004	0.00	0.04	0.24	0.178	0.40
	Ross. Geom. Mean	2.592	8	4.00	0.005	0.14	0.03	0.18	0.062	0.41

SAMPLE DATE	Stream	Discharge cfs	Fecal Coliforms no./100ml	TSS mg/l	Ortho Phosphorus mg/l	Total Phosphorus mg/l	Ammonia Nitrogen mg/l	Nitrate Nitrogen mg/l	Particulate Nitrogen mg/l	Total Dissolved Nitrogen mg/l
	18:35	3.7	1,930	8.00	0.018	0.12	0.02	0.30	0.316	0.56
	19:20	9.23	5,600	13.00	0.014	0.25	0.02	0.24	0.460	0.59
	Whar. Geo. Mean	2.586	3,288	4.20	0.006	0.074	0.01	0.11	0.155	0.23
9/24/94 at stormflow 3.7 in. rainfall	Bunganuc/08:00	71.84	7,100	42.00	0.010	0.08	0.13	0.25	0.075	0.98
	Rossmore/09:30	8.11	400	4.00	0.004	0.05	0.04	0.24	0.178	0.40
10/26/94 at base flow	Bunganuc	0.691	5	4.00	0.003	0.05	0.03	0.09		0.62
	Rossmore	1.66	2	4.00	0.002	0.06	0.02	0.32		0.60
	Wharton Point	1.652	3	4.00	0.005	0.07	0.01	0.51		1.14
11/2/94 at stormflow 1.2 in. rainfall	Bunganuc	20.155	7,100	7.00	0.011	0.07	0.14	0.18		0.84
	Wharton Point	3.99	102	4.00	0.011	0.05	0.02	0.29		0.66
	Rossmore †		0							
	† Stream not gaged/sampled due to Spring Tide Influence									
11/28/94 at baseflow	Bunganuc	8.34	2	4.00	0.005	0.06	0.09	0.16		0.40
	Rossmore	2.86	1	4.00	0.005	0.06	0.01	0.62		0.86
	Wharton Point	3.12	20	16.00	0.011	0.05	0.02	0.52		0.81
12/6/94 at stormflow 1.5 in. rainfall	Bunganuc/0:740	41.81	355	16.00	0.013	0.01	0.02	0.17		0.70
	Bunganuc/11:50	39.59	292	7.00	0.009	0.08	0.02	0.16		0.74
	Average this storm	40.7	324	11.50	0.011	0.04	0.02	0.16	0.000	0.72
	Rossmore	4.38	11	4.00	0.004	0.03	0.03	0.62		0.99
	Wharton Point / 09:20	4.67	102	8.00	0.005	0.05	0.01	0.32		0.67
	Wharton Point / 13:46	4.12	46	4.00	0.005	0.06	0.0115	0.35		0.80
	Average this storm	4.395	74	6.00	0.005	0.06	0.01	0.33	0.000	0.73
4/13/95 at stormflow .89 in. rainfall	Bunganuc	85.9	29		0.007	0.06				
	Rossmore	5.64	2		0.004	0.02				
	Wharton Point	5.47	9		0.007	0.04				
	Average Baseflow Values									
	Bunganuc	2.17	14	4.17	0.003	0.05	0.04	0.11	0.050	0.56
	Rossmore	1.96	4	6.17	0.00	0.05	0.02	0.34	0.08	0.73
	Wharton Point	2.17	29	6.00	0.01	0.05	0.01	0.51	0.03	0.87
	Average Stormflow Values									
	Bunganuc	29.00	3,200	15.78	0.01	0.07	0.07	0.15	0.02	0.77
	Rossmore	4.54	108	4.00	0.00	0.06	0.03	0.31	0.06	0.64
	Wharton Point	3.78	971	9.80	0.02	0.07	0.02	0.27	0.04	0.66
DETECTION LIMITS					0.0010	0.0020	0.0010	0.0007	0.0005	0.0020

Table 8. Average Water Quality in Streams

Stream	Average Fecal Coliforms/100 mls At Baseflow	Average Fecal Coliforms/100 mls At Stormflow
Bunganuc Stream	14	3010
Rossmore Stream	4	108
Wharton Point	29	433

Stream	Average Total Dissolved Nitrogen at Baseflow (ppm)	Average Total Dissolved Nitrogen at Stormflow (ppm)
Bunganuc Stream	0.56	0.70
Rossmore Stream	0.73	0.67
Wharton Point	0.87	0.70

E. Shoreline Survey

H&W conducted a field evaluation on August 12, 1993 in which we toured the Maquoit Bay shoreline by airboat, courtesy of Alan Houston. Based on our evaluation, we believe that septic systems along the shores of Flying Point Neck and Merepoint Neck are a source of nutrients and bacteria to the Bay.

At nearly every location along Maquoit Bay, bedrock is exposed at the shoreline. Bedrock does not, however, outcrop at the shoreline at the head of the bay where the Maquoit Bay trough is filled with glaciomarine sediments. Here where the bedrock lies below sea level, the clayey and silty Presumpscot Formation capped by sandy outwash forms steep embankments to the shoreline, where it has not been eroded by the streams leading to the Bay. Along Merepoint Neck to the east and Flying Point Neck to the west the shoreline is predominantly hard bedrock with a very few locations where small troughs containing unconsolidated sediments occur.

Along Flying Point and Merepoint Necks the unconsolidated sediments that mantle the shallow bedrock are quite thin and bedrock is almost always found exposed above sea level at the shoreline. On these peninsulas, homes are located close to the shore, and many older summer cottages have been upgraded to year-round residences. Septic systems to serve these homes are constructed in the thin sediments, mostly of Presumpscot Formation, that overlie the hard bedrock. The bedrock floor beneath the sediments forms a fractured, and therefore leaky, bottom which may form a barrier to the downward seepage of septic system effluent. The effluent then flows along the bedrock surface and/or into fractures until it reaches an outcrop at the shoreline and seeps into the Bay, or until it reaches an open fracture through which it can rapidly run directly to the Bay. In either case, there is little to no attenuation of nutrients or bacteria.

Compared to the head of the Bay, sites along the peninsulas would not at first glance appear to be significant sources of nutrients and bacteria, because bay water circulation is less confined along the Neck shores than it is at the head of the Bay. However, an incoming tide may carry pollutants toward the head of the Bay.

In order to evaluate the nutrient and bacteria contribution from these shoreline septic systems, H&W performed sampling at or near the rock/sediment interface along the shores of both Necks. This sampling was designed to be qualitative in the sense of determining whether or not the septic systems are sources to the Bay. A quantitative evaluation of the loading from this source would have required a different sampling plan and a much large number of samples than the available resources could sustain.

H&W completed a shoreline septic seepage survey at 12 sites on Merepoint Neck on 21 June 1994. During the field work, sampling activities at some sites were videotaped. H&W also completed a shoreline septic seepage survey at 7 sites on Flying Point Neck on 3 August 1994.

Also on 3 August, three sites on Merepoint Neck were resampled a second time to test reproducibility. Photographs were taken of each site in order to pinpoint locations for repetitive sampling. The results of analyses of these samples are listed in Appendix E, and the sample site locations along with fecal coliform concentrations are shown in Figures 15 and 16. Extremely high concentrations of fecal coliforms were found at several points along both necks in Maquoit Bay.

Sample analysis from the shoreline surveys showed nutrient concentrations indicative of wastewater pollution at several sites. At sites BSS 2, 10, 11, and 12 on 21 June 1994, and BSS-2 on 3 August 1994, total dissolved nitrogen was measured at roughly 10% of the concentration of raw septic effluent. Ammonia-nitrogen was also in this category at BSS-2 and BSS-10 on 21 June 1994. High concentrations of suspended particulate nitrogen were also observed at sites on both necks.

Thirteen of 25 samples showed fecal coliform concentrations in excess of 100 colonies/100 mls. Most of these sites also had high nitrogen concentrations. At sites with elevated fecal concentrations but relatively low nitrogen concentrations, uptake by vegetation may be one mechanism affecting nitrogen concentrations in seepage during these summer dry-season conditions.

During the sampling on 3 August 1994 the BSS-10 site was revisited. However, due to high tide, the exact site could not be re-sampled. To gauge another potential source of contamination at this cove, a sample was collected from a small discharge of water from stormwater discharge pipe located here. This sample was designated BSS-10A. Data from this sample showed concentrations of pollutants indicating potential sewage input. This sample was collected under dry weather conditions and the quality of stormwater discharged at this site may be significantly different.

Two other sites were resampled during the 3 August 1994 sampling round for a comparison to the 21 June 1994 data. At site BSS-2, the fecal and nutrient data was in close agreement between sampling rounds. Site BSS-6 was successfully sampled for fecal coliform but, due to insufficient seepage recovery in the fracture, a sample for nutrients could not be obtained. The coliform data from the two dates at BSS-6 were not in agreement.

FIGURE 15.

Shoreline Sampling Locations

Bedrock Seepage Survey (BSS)

(BSS)	Round 1 Fecal Coliform Count	Round 2
1	tntc	
2	tntc	gt 20,000
3	1	
4	7	
5	14	
6	13	gt 20,000
7	tntc	
8	tntc	
9	4	
10	105	48
11	1	
12	0	

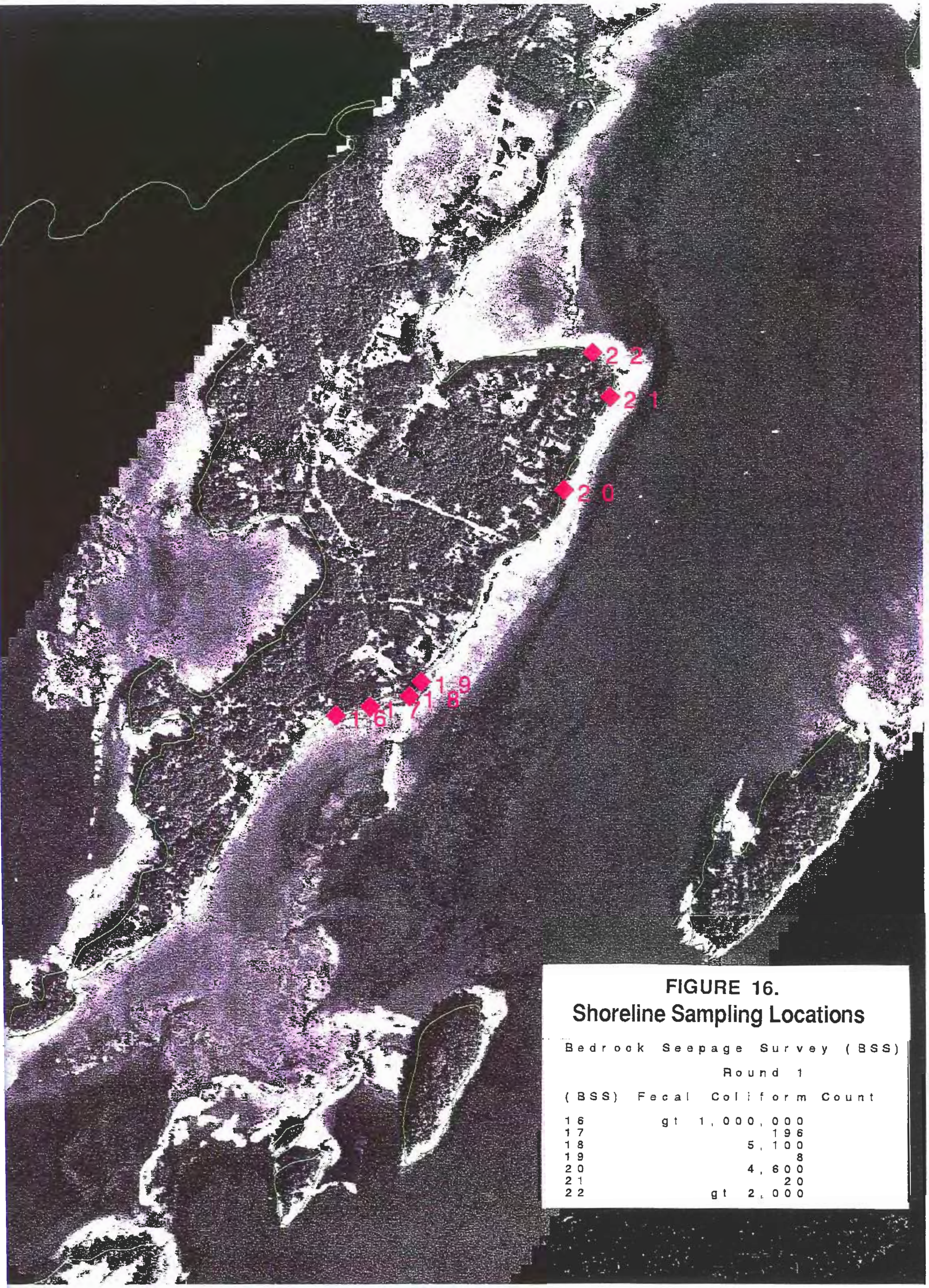

FIGURE 16.
Shoreline Sampling Locations

Bedrock Seepage Survey (BSS)

Round 1

(BSS)	Fecal Coliform Count
16	gt 1,000,000
17	196
18	5,100
19	8
20	4,600
21	20
22	gt 2,000

During the Merepoint Neck survey, holes were dug in upper beach areas in the drainage route from upland areas in order to penetrate the groundwater table for a sample. At three sites (BSS-1, -3, -4) high suspended clay content in the sample collected from these holes created a matrix problem during analysis for particulate nitrogen. During filtering of the water sample, an excess of suspended clay concentrated on the filter after only a very small volume of water passed through the filter. As a result, the sample could not be analyzed for aqueous concentrations of pollutants. However, this field filtration attempt illustrates the significant clay content of the soils and its low permeability. This Presumpscot clay formation is essentially ubiquitous on both Merepoint and Flying Point Necks.

In summary, 5 out of 19 sites (26 %) had Fecal Coliform greater than 20,000 per 100 ml, 10 out 19 sites (52 %) had total nitrogen greater than 1 mg/l, and 3 out of 19 sites (16 %) had total phosphorous greater than 1 mg/l. Water from these sites discharges directly into Maquoit Bay. These results show fecal coliform and nutrients in excess of natural expected values with sufficient frequency and concentrations to indicate without question that some, if not all, septic systems near the shores of Flying Point and Merepoint Necks are not functioning as intended. These conditions warrant further quantitative investigations, perhaps evaluation of the Maine Plumbing Code septic system regulations, and assessing the need for further on-site treatment of sewage or sewering of the homes on the Necks. This is discussed further in the Conclusions and Recommendations section (Section VII).

V. DEVELOPMENT OF THE BACTERIA MODEL

H&W developed two approaches to ranking and modeling fecal coliform loading in the Maquoit Bay watershed. Both approaches model potential sources of fecal coliform bacteria on the watershed scale. The first one is a spreadsheet model which estimates average fecal coliform loadings. This version is based on the water quality monitoring component of the project and on soil characteristics in the watershed. Attenuation of fecal coliform is assumed to be accounted for in these data.

The second approach is the FecaLOAD model and its associated ranking tables. The FecaLOAD approach calculates fecal coliform loadings by a specific rain event and assigns fecal coliform attenuation factors based on literature values. Attenuation and loading factors are determined by a ranking system based on the physical setting of the watershed. Both models arrive at fecal coliform loadings by watershed.

A. Background

Fecal coliform is a widely-used indicator organism for the potential contamination from other, more harmful septic-effluent and manure-borne microorganisms. Fecal coliform pollution in the Maquoit Bay watershed has been identified in the past by other researchers. Several publications describing fecal coliform pollution in the Maquoit Bay watershed were obtained and reviewed prior to undertaking this study. Overall, the focus of most of these reports was on Bunganuc Stream and its watershed because it is the major stream draining to Maquoit Bay, although the Bowdoin College work had various levels of analysis on all three watershed streams. The following reports discuss Bunganuc Stream and Maquoit Bay watershed issues in some detail:

- B. Hinckley, "Preliminary Report on Bunganuc Brook," November 1971
- C. Underhill, "Bunganuc Brook Survey Report," August, 1980
- Gilfillian and Laine, Bowdoin College, "Studies on the Status of Maquoit Bay: Preliminary Report to Baywatch". February, 1990.

These studies suggest that the largest fecal loading (or "fluxes" according to the Bowdoin Report) occur during large storms. The reported concentrations and loadings appear to be significant enough to result in shellfish bed closures at the head of the Bay.

Prior to model development, H&W completed a detailed review of the pertinent literature on fecal waste-associated microorganisms. This review, summarized below, identified fecal coliform sources, pathways and attenuation mechanisms for incorporation in the FecaLOAD (Fecal Coliform Loading) model. Because this model was designed to be a management tool, the pathways and attenuation mechanisms selected for incorporation into the model took the model-user's data collection needs and limitations into consideration.

1. Sources of Fecal Coliforms

The principal sources of fecal coliform organisms in the Maquoit Bay watershed are humans, cows, domestic pets and wildlife. Table 9 shows estimates of the numbers of source organisms residing within the Maquoit Bay watershed and the amounts of fecal coliform organisms typically generated by each of these sources. In the case of humans, fecal wastes are discharged to the subsurface soil environment via septic systems where the majority of the fecal organisms are attenuated by filtration in soils. However, fecal material from the three other source groups are deposited on the surface of the landscape. Cow manure is routinely spread over agricultural fields as a fertilizer.

The impacts associated with human fecal wastes are minimized (or eliminated) through the use of properly functioning septic systems. However, where septic systems fail hydraulically (surface breakouts) or hydrogeologically (inadequate soils to filter bacteria) impacts to downgradient surface waters may occur.

Table 9. Sources of Fecal Coliform Organisms Within The Maquoit Bay Watershed

Source	Estimated Number	Estimated # of Fecal Coliforms Generated/Organism	Total Estimated Loadings of FC (billion organisms/day)
Humans	1245(1)	2 billion orgs/day(4)	2490
Dogs & Cats	147(2)	5 billion orgs/day(5)	767
Cows	450	5 billion orgs/day(5)	2250
Wildlife	(3)	10 million orgs/day(6)	(3)

Notes:
1. The number of humans is estimated from 712 residential structures by an average occupancy of 2.4 persons/residence.
2. The number of cats and dogs was determined from Annual Reports for the towns of Brunswick and Freeport.
3. The number of FC-producing wildlife (birds and mammals) is unknown, and therefore, total loadings can not be determined.

References:
4. Converse, et al. 1991.
5. Koppelman, Lee ed. (1978). Animal Waste: Non-Point Pollution. Nausau - Suffolk (NY) Regional Planning Board. 32 pp.
6. Novotny and Olem, 1994 (For waterfowl).

2. Surface Transport of Fecal Coliforms

The extent of fecal coliform bacteria survival depends upon many environmental factors which control the viability of the organisms through a variety of means. The primary vehicle for fecal coliform transport to a receiving water is stormwater runoff. Prior to a rainfall event, temperature, solar radiation, and moisture seem to have the greatest effect on enteric bacterial survival in the soil (Moore, et al., 1982), thus influencing stormwater concentrations of fecal coliforms. Other factors such as timing of precipitation events and residence time were also shown to be significant factors.

Temperature: Moore, et al. (1982) found seasons, primarily summer and winter, to be significant to the die-off of fecal coliforms on the ground surface. Based on literature they evaluated, Moore, et al. (1982) developed the coefficients 0.51 log unit reduction/day during the summer months and 0.36 log unit reduction/day in the winter. This roughly corresponds with existing literature showing an inverse temperature-survival relationship with organisms from fecal wastes (DuBois, et al. 1976 and 1979, Teutsch, et al. 1991; and U.S. EPA 1988).

Solar Radiation: Fecal coliform survival on the land surface whether from manure application to cropland, or septic system effluent from breakout conditions, is reduced significantly by solar radiation and adhesion to vegetation. The longer fecal coliform remain exposed at the surface, the greater the likelihood of die-off by radiation (personal communication, G. Heufelder, 1994). Additionally, the distance from the fecal coliform source to the surface water must be included in the die-off assessment. A greater distance results in longer travel time and greater exposure to attenuative factors such as solar radiation.

Soil Moisture: Soil moisture appears to be a predominant factor controlling microbial survival in the soil (Reddy, et al., 1981). Survival time of bacteria increases with moisture content and moisture holding capacity of the soils (Teutsch, et al, 1991). In general, clay content increases soil moisture retention and therefore bacteria survival (Reddy, et al., 1981, Yates and Yates, 1988, and U.S. EPA, 1987). Because soil moisture is closely related to rainfall runoff generation, wet soils would potentially yield more bacteria for entrainment in runoff.

First Flush: Studies on cow manure applications to the land surface found the first runoff event (from simulated rainfall) to be critical in physical bacterial transport from the site. Most of the fecal coliform loss was from the first irrigation event initiated several hours after the manure application. After the initial fecal coliform loss, subsequent irrigation of the application area showed percentage losses of organisms less than two orders of magnitude than original percentage lost (Kunkle, 1979). Dunnigan and Dick (1980) reported similar findings for land applications of sewage sludge where high numbers of fecal coliforms were found in runoff until the wet weather ended and the sludge was "thoroughly dried." Moore, et al. (1982) found that the greater the precipitation, the greater the removal of bacteria. This is a simple function of loading in that greater runoff will result in the likelihood that more of the available fecal coliform bacteria will be entrained in runoff. However, Moore, et al. (1984) also found that the first inch of rainfall typically removes most of the bacteria available for entrainment in runoff.

Residence Time: In a livestock waste-application study, it was hypothesized that residence time of manure was also a controlling factor in fecal coliform entrainment in runoff. If a precipitation event occurred during manure application, 58% to 90% of the fecal coliforms were transported, (Crane, et al., 1978). These researchers also indicated that time sensitive processes were responsible for controlling the transfer from soil to liquid runoff through an adsorption or fixation type mechanism.

3. Subsurface Transport of Fecal Coliforms

Two major mechanisms whereby bacteria can be removed as they are transported in groundwater are filtration and adsorption (EPA, 1987) Reddy et al. (1981) used the term "retention by soil particles" to describe the interaction of these processes. Filtration and straining of bacteria is believed to be the major limitation in bacterial underground travel. Filtration occurs during septic effluent percolation if the bacteria are too large to pass through soil pore spaces. Mechanical straining is believed to be the cause of bacterial removal in groundwater, the critical factor being the ratio between bacterial and media diameter (Teutsch, et al., 1991).

Filtration: Pore size is a very important factor in retaining microorganisms. EPA reported that "the major factor affecting entrainment distance of enteric organisms is the soil type (EPA, 1988). Generally, as effluent percolates through a given depth of soil, the removal of bacteria is inversely proportional to the particle size of the soil (Butler, et al.). Many bacteria are large enough to be filtered out as water moves through the soil pores, but fractured bedrock and coarse-grained soils (gravel) permit rapid movement. Thus soils with smaller pores (silts and sands) are more efficient at bacteria removal than soils with larger pores like coarse-textured soils (EPA, 1987). Romero (1970) reported that "great numbers of bacteria are effectively removed by percolation through a few feet of sand... by mechanical and biological straining as a result of soil clogging." Studies have shown that most bacteria are attenuated within a distance of 4-100 feet in permeable sand (Carter and Knox, 1986). Fractures in bedrock provide virtually no bacteria filtration and bacteria can migrate significantly longer distances.

Adsorption: In general, retention of bacteria and viruses increases with an increase in soil clay content, cation exchange capacity and the specific surface area of the soil particles (Reddy, et al., 1981; Yates and Yates, 1988; EPA, 1987). The latter two factors are positively correlated with clay content. The major mechanism of virus removal is by chemical-physical adsorption onto clay particles due to the highly charged nature of clay. However, viruses can be desorbed from clay by rainfall and migrate further through the subsurface where they become readsorbed or remain freely suspended in the groundwater (EPA, 1987). Rainfall is the most common occurrence which results in the desorption of viruses in wastewater systems. In sandy and organic soils, Sobsy, et al., (1980), and Landry, et al. (1979) found that considerable quantities of retained virus were washed from the soils by rainfall. Overall, adsorption of viruses is the primary mechanism for their removal by on-site subsurface wastewater systems (septic systems), although a virus type which could serve as a predictive model for all virus movement in soil has not been identified (EPA, 1988; Yates and Yates, 1988).

4. Viruses

Unlike bacteria, viruses are generally not filtered out by soil pores as septic effluent percolates through the soil, unless there is a substantial clay content (Teutsch, et al., 1991). Virus particles are between one and two orders of magnitude smaller than bacteria. Therefore, filtration and mechanical straining can probably be neglected as a limiting factor in viral underground travel. Viruses have been shown to migrate distances of over 1,000 feet in sand and gravel and further in fractured bedrock (EPA, 1987). The most significant factor which determines viral survival (or inactivation) in the subsurface is temperature. A model developed by Yates (1987) estimates inactivation time based upon groundwater temperature. In coastal Maine the groundwater temperature is 7-8°C. At this temperature, viruses can be expected to survive for periods of 800-1,000 days.

5. Summary

Pathogen transport and fate is difficult to quantify given all of the attenuative factors. Attenuation coefficients are difficult to measure; in part because bacteria populations can both grow and die off at varying rates based on the factors (and/ or combinations of factors) described previously. These factors can be very difficult to quantify. In evaluating the most important factors in microorganism transport and fate, Yates and Yates (1988) point out that no one factor can be singled out as the most influencing. They found that:

> "Upon examination of the models that have been developed to predict the fate of microorganisms, one notices that [biological, chemical and physical factors known to influence virus and bacterial survival and transport in the subsurface] are not explicitly addressed in the equations used in the models. This is most likely due to the fact that much of the known information is qualitative in nature, and that it is difficult, and sometimes impossible, to generalize the results of one or several experiments to all microorganisms of concern under all environmental conditions which may be encountered."

Perhaps the most challenging aspect of modeling of fecal coliform, is the choice of which attenuation factors to incorporate into the model given the wide range identified in the literature. Evaluation of the numerous attenuation variables for bacteria would make the watershed modeling approach unwieldy for local environmental managers and planners. Therefore, for the Maquoit Bay watershed, FecaLOAD evaluated those factors discussed above which are accessible to, and/or easily estimated by, environmental managers and other model-users. These are factors within the broad fate and transport categories previously identified by Keswick and Gerba (1980), namely hydrogeological and meteorological such as soil properties based on the County Soil Survey with respect to suitability for sewage disposal, proximity of the potential source to the surface water resource, and precipitation/runoff.

B. Evaluation of the Relative Contributions of Indicator Bacteria

To estimate the relative loads from identified sources within the Maquoit Bay watershed, H&W developed two approaches for estimating the relative inputs of indicator bacteria from identified sources, one based on empirical data collected during the project and one based on qualitative hydrogeological factors. The first approach estimates average fecal coliform loadings for different land uses from each watershed. The second approach is the FecaLOAD model (Section C) developed by H&W which categorizes pollution sources.

1. Ranking System for Average Fecal Loading

To estimate average loads of fecal coliforms (FC) during storm events H&W developed a ranking system based upon actual water quality data, land uses and soil types. The water quality data from four rounds of stormwater sampling at the six test sites was utilized to develop average FC loads per storm event. It should be recognized that the field data is highly variable and is likely to be dependent upon numerous complex factors. This ranking system was developed to look at only the general trends (average loading). A more detailed model (FecaLOAD) was developed to attempt to incorporate some of the more complex factors which might explain the variability of field data. This more detailed model is presented in subsequent sections of this report.

The water quality data from the six test sites was utilized in developing the loading coefficients used in the ranking system. First, actual fecal coliform loads were calculated for each of the storm events which were sampled at the test sites. This was accomplished by multiplying measured fecal coliform concentrations by measured discharge (flow) rates.

The watersheds for each test site were then analyzed for land use and soil types (Table 10). Land uses were broken down into agricultural, residential, roads and forest. Soils were classified in accordance with the USDA Natural Resources Conservation Service (NRCS, formerly the Soil Conservation Service) four hydrologic soils groups. Runoff coefficients were

Table 10. Fecal Coliform Loading Analysis at Test Sites

Test Site	Land Use	Actual Mean FC Load	Total Acres	AG	Acres RES	Forest	AG	% RES	Forest
BS-1	AG	**672**	92	15	1	76	**0.16**	0.01	0.83
BS-6	AG	**22601**	227	137	25	66	**0.60**	0.11	0.29
GG-7	AG	**1531**	76	26	9	34	**0.34**	0.12	0.45
BS-8	RES	**173**	14		3	11	0.00	**0.21**	0.79
BS-13	RES	**361**	28		14	14	0.00	**0.50**	0.50
BS-14	FOR	**63**	43		2.5	40	0.00	0.06	**0.93**

Step #1 - Compute Forest Loading	1.5	M orgs/acre
Step #2 - Compute Residential Loading	24	M orgs/acre
Step #3 - Compute Agricultural Agricultural Loading		
BS-1	36	
BS-6	160	
GG-7	49	
Average	81	
Step #4 - Re-Compute Forest Loading	0.055	

identified using curve numbers for each hydrologic soil group and associated land use. Curve numbers (CN) approximate the percentage of rainfall which becomes surface runoff. It varies by soil type and land use.

From this analysis, BS-14 (43 acres) is comprised of 93% forest (40 acres) and 7% residential (3 acres) and exhibited an average loading of 62 million FC organisms/storm event. To compute the loading attributable to forested land, residential loading was initially set equal to forest and resulted in an average load of 1.5 million FC/acre. Most likely, residential loading from domestic animals and possible failing septic systems will be considerably higher, reducing the forest loading coefficient.

The residential loading coefficient was determined by first subtracting an estimated 20 million FC attributable to 14 acres of forested land from the average FC loading fro BS-13 (361 million FC) and then dividing by the number of residential acres (14), yielding an estimated residential FC loading of 24 million FC.

Agricultural loading was determined by subtracting the allocated FC loads from residential and forested segments of the three agricultural test sites (BS-1, BS-6 and GG-7) and dividing the remaining loading by the agricultural acres yielding an average loading rate of approximately 81 million FC/acre.

The ranking system was then further calibrated by applying NRCS curve numbers to estimate the relative runoff rates of the four hydrologic soils groups. Because the curve numbers were utilized to estimate the percentage of runoff and associated pollutant loadings, the individual input coefficients had to be adjusted upward.

The ranking system was then applied to the six sub-watersheds including the three streams (see Table 11). Predicted FC loadings for Bunganuc, Rossmore and Wharton Point streams were 60,800, 7,800 and 19,600 respectively. Actual average loadings in the three streams were 79,800, 4,220 and 16,000 respectively.

Table 11. Average Fecal Coliform Ranking and Loading Approach

Existing Conditions - Estimated

Fecal Coliform Loadings in Three Streams

Watershed:	FC Load	Hydrologic Soils Group								FC Load
Bunganuc Stream	M Orgs/acre	A		B		C		D		M orgs
		acres	CN*	acres	CN	acres	CN	acres	CN	
Ag (cultivated w/conservation)	100	51	62	51	71	254	78	254	81	47169
HD residential			61		75		83		87	
LD residential	50	21	51	21	68	105	79	105	84	9807
Roads (paved w//ditches)	20	17	82	17	89	84	92	84	94	3706
Forest	0.1	162	40	162	50	808	60	808	70	120
			Total FC Loading (M orgs/storm) =							60802

Watershed:	FC Load	Hydrologic Soils Group								FC Load
Rossmore	M Orgs/acre	A		B		C		D		M orgs
		acres	CN	acres	CN	acres	CN	acres	CN	
Ag (cultivated w/conservation)	100	6	62	6	71	1	78	1	81	957
HD residential			61		75		83		87	
LD residential	50	41	51	42	68	8	79	8	84	3126
Roads (paved w//ditches)	20	17	82	17	89	84	92	84	94	3706
Forest	0.1	246	40	246	50	48	60	48	70	28
			Total FC Loading (M orgs/storm) =							7817

Watershed:	FC Load	Hydrologic Soils Group								FC Load
Wharton Point	M Orgs/acre	A		B		C		D		M orgs
		acres	CN	acres	CN	acres	CN	acres	CN	
Ag (cultivated w/conservation)	100	76	62	76	71	30	78	30	81	14878
HD residential			61		75		83		87	
LD residential	50	19	51	19	68	7	79	8	84	1743
Roads (paved w//ditches)	20	60	82	60	89	23	92	23	94	2908
Forest	0.1	259	40	259	50	101	60	101	70	36
			Total FC Loading (M orgs/storm) =							19565

Reference: Soil runoff curve numbers (CN) are from U.S. Department of Agriculture Soil Conservation Service and generally can be used to estimate the relative percentage of rainfall which results as surface runoff from a variety of landscapes.

Table 11 Cont'd.

	Existing Conditions - Estimated										
	Average Fecal Coliform Loadings in Three Sub-Watersheds										
Watershed:	FC Load	Total	Hydrologic Soils Group								FC Load
Bunganuc Point	M orgs/acre	Acres	A		B		C		D		M orgs
			acres	CN	acres	CN	acres	CN	acres	CN	
Agricultural	100	63	5	62	5	71	26	78	26	81	4877
HD residential				61		75		83		87	
LD residential	50	21	2	51	2	68	9	79	9	84	819
Roads (paved w//ditches)	20	36	3	82	3	89	15	92	15	94	661
Forest	0.1	407	33	40	33	50	171	60	171	70	25
		600	48		48		252		252		
				Total FC Loading (M orgs/storm) =							6382
Watershed:	FC Load		Hydrologic Soils Group								FC Load
Merepoint Neck	M orgs/acre		A		B		C		D		M orgs
			acres	CN	acres	CN	acres	CN	acres	CN	
Agricultural	100	21	3	62	2	71	9	78	9	81	1724
HD residential				61		75		83		87	
LD residential	50	123	10	51	10	68	52	79	52	84	4796
Roads (paved w//ditches)	20	74	6	82	6	89	31	92	31	94	1359
Forest	0.1	232	19	40	19	50	97	60	97	70	14
		386	60		60		133		133		
				Total FC Loading (M orgs/storm) =							7893
Watershed:	FC Load		Hydrologic Soils Group								FC Load
Flying Point	M orgs/acre		A		B		C		D		M orgs
			acres	CN	acres	CN	acres	CN	acres	CN	
Agricultural	100	101	9	62	8	71	42	78	42	81	7846
HD residential				61		75		83		87	
LD residential	50	152	12	51	12	68	64	79	64	84	5926
Roads (paved w//ditches)	20	89	7	82	7	89	37	92	37	94	1634
Forest	0.1	690	55	40	55	50	290	60	290	70	43
		950	80		80		395		395		
				Total FC Loading (M orgs/storm) =							15449
Notes:	M orgs/acre = millions of organisms/acre										
	CN = Curve Number approximating % of rain which becomes surface runoff										

This ranking system can be easily used by other communities along the Maine coast that have similar land use characteristics/patterns. Adjustments to the model would be required in more urban settings. The required information is easily accessible. Where land use maps are not available, land uses can be interpreted from aerial photographs and USGS topographic maps. Soils classified by the four hydrologic groups can be obtained from the USDA Natural Resources Conservation Service, County Soil Survey Reports.

The pollution potential of an agricultural area with manure spreading and/or livestock grazing areas is also dependent upon the proximity of the area and the ability of soils to absorb manure-tainted runoff. It should be noted that, while manure application is not septic effluent, the Qualitative Ranking System classification is still relevant because the potential for those soils to generate runoff is a function of the same factors. For example, agricultural lands on thin soils (shallow to bedrock) with low permeability will become saturated by rainfall and generate runoff at a rate greater than those fields on deeper, more permeable soils. Manure spread on lands with shallow soils and close to a surface water represent a higher probability of causing bacterial pollution via stormwater runoff to that surface water.

While there may not be complete agreement over how to extrapolate known soils field values over a large area, the values listed in the Soil Survey were applied to the Maquoit Bay watershed. Initial field work performed by the NRCS provided good planning data by an accepted "nationwide uniform procedure" established by the NRCS to determine soils and extent of coverage in an area. While this information is not site-specific, it suffices for many projects which entail land and soil evaluation on a scale larger than the site-level.

C. Fecal Coliform Loading Model

The literature describes bacterial attenuation or die-off as a result of environmental factors previously discussed. However, from H&W's research, very little has been done in development of a watershed-scale bacteria loading model which accounts for this attenuation. As discussed in the literature review, several researchers have attempted to model the transport and fate of fecal coliform (and other bacteria and viruses) with limited success, but these models were complex and of little use to resource managers. Thus the challenge was to create a watershed ranking and modeling approach to predict fecal coliform loading to Maquoit Bay which accounts for the attenuation factors as discussed in the literature review. While the model does this, it cannot possibly take into account all of the biological mechanisms which occur in the watershed such as storage and re-growth of bacteria in temporary holding areas.

From discussions with potential model users it was discovered that in addition to accuracy, it is important that the model be easy to use, and that the input data be relatively easy to obtain or estimate. This was echoed at the May 1995 Casco Bay Estuary Project Management Committee meeting in Portland during which H&W received many questions and comments specifically addressing these models. The FecaLOAD modeling approach was developed with this in mind.

1. The FecaLOAD Pollution Potential Ranking System

H&W developed this version of a ranking system as a qualitative categorization of potential fecal coliform pollution sources based solely on hydrogeological conditions for which information is available through a county soil survey (Tables 12 through 16). Ranking of the potential sources is used as the first step in modeling and determines where the sources are input into the model.

Table 12. Depth to Seasonal High Water Table

Range (ft.)	Ranking	Potential for Effluent Surfacing
0-1	10	High
1-2	9	↓
2-3	7	
3-4	5	
4-5	3	
>5	1	Low

Sources of Information:
State: Maine County Soil Survey, U.S.D.A. Natural Resources Cons. Service
Local: Town Engineers Office, Public Health Office, Planning Office

Table 13. Soil Permeability

Range (inches/hour)*	Ranking	Potential for Effluent Surfacing
<.02	10	High
.02-.63	7	↓
.63-2.0	5	
2.0-6.3	3	
>6.3	1	Low

* Cumberland Co. Soil Survey

Sources of Information:
State: Maine County Soil Survey, Natural Resources Cons. Service (S.C.S.) field office
Local: Town Engineers Office, Public Health Office, Planning Office

Table 14. Depth to Bedrock

Range (inches)	Ranking	Potential for Effluent Surfacing
0-12	10	High
12-24	9	↓
24-36	7	↓
36-48	5	↓
48-60	3	↓
>60	1	Low

Sources of Information:
State: Maine County Soil Survey, Natural Resources Cons. Service (S.C.S.) field office
Local: Town Engineers Office, Public Health Office, Planning Office

Table 15. Distance to Surface Water

Radius (ft.)	Ranking	Proximity Potential for Contamination by runoff
0-100	10	High
100-500	7	↓
500-1000	5	↓
>1000	0	Low

Sources of Information:
Maps w/a scale: Topographic Maps (U.S.G.S.), Land Use Maps, Zoning Maps, Planning Maps.

How to determine distance:
Measure distance of predominant land use, i.e., dwellings w/ septic systems, agricultural manure spreading, livestock areas, etc. from water resource (stream, coastal, etc.)

Table 16. Model Categories Determined From Ranking.

Rating	Model Input Position	Pollution Potential*
0-10	Category I	V. Low
10-20	Category II	Low
20-30	Category III	Moderate
30-40	Category IV	High

* Pollution "potential" is a subjective analysis of the combination of soil factors leading to soil saturation and consequent runoff leading to conditions for effluent to surface.

How to use the rating:
Add the Qualitative Ratings from from Factors 1 through 4.
Match the Index Value to the associated Qualitative Index.
Input the total number of UNITS that apply to the ranking under"SOURCES" in the model.

Potential fecal coliform pollution sources in the Maquoit Bay watershed were ranked according to this system using both manual methods and GIS. Individual dwellings were counted off USGS topographic quadrangle maps (Brunswick, 1980; Freeport, 1970; Orrs Island, 1978; Lisbon Falls South, 1979) and evaluated by the soil type (and associated hydrogeologic characteristics) on which they were situated. Agricultural lands were also subject to the soils assessment. The distance of the dwellings and agricultural lands to the Bay or a stream was determined by using the map scale. Placement of the dwellings in the different model input positions of Category I, Category II, Category III, and Category IV were the result of the ranking. These categories have associated with them various attenuation and loading calculations ranging from nonpolluting (in Category I) to the greatest potential for fecal coliform pollution (in Category IV).

For septic systems, the ranking system considers hydrogeological conditions and distance to a surface water. The hydrogeological factors include depth to seasonal high water table, soil permeability, and depth to bedrock which are evaluated together in the NRCS Cumberland County Soil Survey classification for sewage effluent filter fields. Low permeability soils are unable to accept hydraulic loadings from septic systems during peak flow times and wet periods of the year. One or a combination of these factors may lead to surfacing or "breakout" of septic system effluent (hydraulic failure) or may result in inadequate filtration within the soils prior to discharge to a downgradient surface water (hydrogeologic failure). These factors are summed and the resulting values guide assignment of septic systems and agricultural lands to model categories I-IV. (Appendix C). These factors are accounted for in the NRCS classifications of Slight, Moderate, Severe, and Very Severe for a soil's limitations to percolate and treat septic effluent.

The rationale for use of these factors is straightforward: A septic system failure leading to surface break-out is typically caused by a the inability of the soils to absorb the effluent due to one or a combination of hydrogeological factors. This situation is exacerbated by excess water from runoff making the septic system a likely candidate for bacterial pollution of a water resource, but only if the septic system is in relatively close proximity to that resource. A poorly performing septic system in the watershed, located high in the watershed and far from access to any stream or other surface water, will not be a likely source of bacterial pollution, whereas a marginally functioning system, immediately adjacent to a stream, may be a more significant threat.

However, it should be noted that compliance with the Maine Subsurface Wastewater Disposal Code (a/k/a the "Plumbing Code") through engineering of systems on a site-specific basis, would override this ranking.

Ideally, the ranking of septic systems in the Maquoit Bay watershed would involve a small site-by-site review of septic systems to quantify which septic systems are in compliance with the Code, those on "severe" and "very severe" soils, and those which have been engineered for difficult areas. While this would provide the best information for modeling, a site-by-site assessment was beyond the scope of this project.

2. Model Description

From the FecaLOAD model inputs, the model will calculate outputs, by land use, for 1.) volume of runoff, 2.) loadings of fecal coliforms, and 3.) average concentration of fecal coliforms in the runoff. The model user can then assess the existing conditions of the modeled watershed and their relationship to a water resource of concern. The user can also run different scenarios in the model such as the watershed at buildout conditions or test sensitivity of particular land use changes such as increases in impervious surface and/or decreases in agriculture, among others. The FecaLOAD model is, generally, a three-step process, as follows:

1. An "inventory of sources," determines all of the inputs within the watershed.

2. The potential sources of pollution are ranked as previously described (Tables 12-16). This rates the likelihood of fecal coliform bacteria transport from each source based on hydrogeological factors and distance. The ranking system output places the sources in the model-categories. I, II, III and IV representing the range of no predicted fecal coliform pollution to a worst case fecal coliform pollution respectively.

3. The model is then run with a known or hypothetical rain event and prior watershed antecedent moisture conditions (or AMCs). Attenuative (die-off) factors are applied through model equations.

Several coefficients are applied in the model equations to calculate volume of runoff and loadings of fecal coliform bacteria. These and the attenuation calculations are presented and referenced in Table 17 . A wide range of values have been reported in the literature due to an infinite number of physical, biological and chemical conditions under which fecal coliform bacteria enter and move through the environment. These values are typically on the order of one to three orders of magnitude apart. To select one of these values as a coefficient for modeling would misrepresent this range. However, to model a range of coefficients would also preclude the model's utility as a management tool. Tables 18 and 19 illustrate the modeled loadings with coefficients from each extreme of the literature range of fecal coliform. Bunganuc Stream is used here to illustrate actual outputs.

The model must predict a reasonable fecal coliform loading on which management and planning decisions can be made. As the model evolved, the decision was made to select median coefficient values for the potential fecal coliform sources. These medians (listed on the following pages) were used by H&W to predict loadings on the test-site scale and also form the foundation on which the model was calibrated with water quality data collected during the project. A FecaLOAD User's Guide (Appendix A) provides sources of information and data input steps.

Table 17. Fecal Coliform Loading and Concentration Values Used in Model Calculations

AVERAGE DAILY LOADING OF FECAL COLIFORM

	Range of Literature Values	H&W Selected Model Input
HUMAN SOURCES		
SEPTIC EFFLUENT: Reference (1)	10^4 - 10^7 FC/100 ml	10^6/100 ml effluent

Table 17. Cont'd

AVERAGE DAILY WASTEWATER DISCHARGE		
Typical Home Reference (2), (3), (4), (5)	45 - 100 gallons/person/day	70 gallons/person/day
<u>AGRICULTURE SOURCES</u>		
AGRICULTURAL RUNOFF:		
NO manure application Reference (6)		10^1 FC/100 ml of runoff (not calibrated)
ANNUAL MANURE LAND-APPLIED Reference (7)	10 to 20 tons/acre/year	10 tons/acre/year
AVERAGE DAILY MANURE Reference (8)	12 - 115 lbs/animal/day	53 lbs/animal/day
LIVESTOCK MANURE Reference (9), (10)	10^4 - 10^7 FC/g manure	10^6/g manure

<u>MEDIAN CURBSIDE ACCUMULATION OF FECAL COLIFORM</u>

	Typical Values	Model Coefficient Value
ROAD WIDTHS: Reference (11)		
Residential	22 feet	22 feet
Major roads and highways	56 feet	56 feet
Commercial/industrial	56 feet	56 feet

	Range of Values	Model Coefficient Value
ROAD RUNOFF: Reference (12)		
Residential Low Density Roads	10^5 -10^7 FC/ft curb	2.6 x 10^6 FC/ft. curb
Residential High Density Roads	10^5 - 10^6 FC/ft curb	4 x 10^5 FC/ft. curb
Industrial/ Commercial Roads	10^5 - 10^6 FC/ft. curb	1.6 x 10^6 FC/ft. curb
Highways	10^5 - 10^7 FC/ft. curb	6.5 x 10^6 FC/ft curb

Table 17. Cont'd

SELECTED CALCULATIONS

VOLUME OF ROAD RUNOFF :

Road width X length X (2.3×10^{-5} acres/ft.) = Acres of road surface. Acres of road surface X inches of rain / 12 inches = acre-ft. Acre feet X 325,851 gallons per acre-foot = volume of road runoff (gallons).

VOLUME OF WATERSHED RUNOFF:

Reference (13), (14)

Acres of land cover X CN (curve number) -associated runoff inches (for a given rainfall on that land cover) = acre-ft. X 325,851 gallons/acre-ft. = runoff gallons.

The watershed runoff calculations in the model were developed from empirical data by the Natural Resources Conservation Service (NRCS). NRCS data are applied in the model as composite "curve number" (CN) runoff values which are determined from hydrologic soil groups Reference (15).

SURFACE DIE -OFF

Moore et al. (16) developed coefficients for fecal coliform die-off from a range of literature values (0.179 - 0.526 $days^{-1}$) cited in his Tillamook Bay, Oregon study. Moore found that die-off rate varies with climatic changes and soil pH. Due to the mostly acidic (pH 4.4 - 5.2) soils of Tillamook Bay, he arrived at a winter coefficient of 0.36 and a summer coefficient 0.51. These coefficients were applied for modeling Maquoit Bay due to similar climatic conditions (namely distinct winter and summer seasons) and soil conditions; Maquoit Bay watershed soils are also generally acidic (pH 4.0 - pH 6.0). (17)

The calculation for fecal coliform die-off is as follows:

$$N_t = N_0 (10^{-kt})$$

where:

N_t = Number of fecal coliforms at time t (this is the number of fecal coliforms available for entrainment in surface runoff)

Table 17. Cont'd

N_0 = Number of fecal coliforms at time 0

t = Time in days

k = First order die-off rate constant. From Moore, et al. (Typical values used 0.51 in warm months 0.36 in cold months

Notes Referenced in Table

(1) Converse, et al. "Bacterial and Nutrient Removal in Wisconsin At-Grade On-Site Systems." *IN* On-Site Wastewater Treatment. Proceedings of the 6th National Symposium on Individual and Small Community Sewage Systems, 16-17 December 1991, Chicago, Illinois. American Society of Agricultural Engineers, 50.

(2) Metcalf & Eddy, Inc. 1991. Wastewater engineering: treatment disposal reuse. McGraw Hill, Inc. 1991 (Septic system effluent rates range 35-50 gal./per person/day and an average occupancy of 2.4-2.8 residents/home.)

(3) US EPA. 1980. On-site wastewater treatment and disposal systems design manual.

(4) Porter, K. S. 1978. Nitrates in the Long Island comprehensive waste treatment management plan: VII Summary Documentation, Long Island Regional Planning Board, Hauppauge, New York.

(5) Massachusetts Audubon Society. April, 1986. Protecting and maintaining private wells.

(6) Background coefficients were derived from sample concentrations from four H&W rounds of sampling agricultural-land runoff in Maine from May 1994 through April 1995. These areas had observed manure application approximately 7 months before the sampling project began. Samples were collected once in May 1994, once in November 1994, and twice in April 1995. The sample FC concentrations exhibited a decrease over the course of the sampling. Therefore, geometric means of FC concentrations were determined from these samples and calibrated as background coefficients for the model.

(7) Maine Department of Agriculture, Personal communication with Russel Libby, Researcher, March 1994. (Manure application range of 10 - 20 tons/acre.)

(8) Moore, J.A., M.E. Grismer, S.R. Crane, and J.R. Miner. 1982. Evaluating Dairy Waste Management Systems' Influence on Fecal Coliform Concentration in Runoff. Department of Agricultural Engineering, Agricultural Experiment Station bulletin 658, Oregon State University, Corvallis, p 15. (Average of daily manure production from known cattle weights for dairy and beef cows and horses (range of 12 lbs to 115 lbs./day))

(9) Moore, J.A., M.E. Grismer, S.R. Crane, and J.R. Miner. 1982. "Evaluating Dairy Waste Management Systems' Influence on Fecal Coliform Concentration in Runoff." Agricultural Experiment Station Bulletin No. 658, Oregon State University, Corvallis, Oregon. 1982, Table 4.

(10) Koppelman, Lee ed. (1978). Animal Waste: Non-Point Pollution. Nausau-Suffolk (NY) Regional Planning Board. 32 pp.

(11) Massachusetts Executive Office of Transportation and Commerce, Engineering Department, (personal communication, 4 August 1995)

(12) Novotny, V. and H. Olem. 1994. Water Quality: Prevention, Identification and Management of Diffuse Pollution. New York: Van Nostrand Reinhold. Note: This source sites Ellis (1986) who incorporated roadside fecal coliform values from the Nationwide Urban Runoff Program (NURP) Study by US EPA in 1981.

(13) U.S. Department of Agriculture, 1972. Soil Conservation Service, SCS National Engineering Handbook, Section 4, Hydrology.

(14) U.S. Department of Agriculture/SCS, Amherst, MA. March 1974. Estimating Runoff: The Modified Soil Cover Complex Method,

(15) U.S. Department of Agriculture, Massachusetts Agricultural Experiment Station, May, 1984. "Soil Survey of Essex County, Massachusetts"

(16) Moore, J.A., M.E. Grismer, S.R. Crane, and J.R. Miner. 1982. "Evaluating Dairy Waste Management Systems' Influence on Fecal Coliform Concentration in Runoff." Agricultural Experiment Station Bulletin No. 658, Oregon State University, Corvallis, Oregon. 1982, Table 4.

(17) U.S. Department of Agriculture, Maine Agricultural Experiment Station, August 1974. "Soil Survey, Cumberland County, Maine"

TABLE 18. BUNGANUC STREAM SUBWATERSHED LOW EXTREME OF FC COEFFICIENTS					
EXISTING CONDITIONS (1995), AND NO MANURE APPLICATION					
1	2	3	4	5	6
SOURCES BY CATEGORY	UNITS BY CATEGORY	Default Values	Watershed Runoff by Land Use (gallons)	Fecal Coliform Loading by Land Use (Millions/storm)	Average Fecal Coliform Concentration in Runoff fc/100 ml
HYDROLOGIC INPUTS:					
	1.50				
Time since Last Rain (days)	3.00				
Amount Rainfall in previous 5 days (inches)	0.5				
LAND USE INPUTS:					
Commercial/Industrial Acreage			0	No Loading	
Meadows/Parks/Cemeteries	163		53,114	No Loading	
Forest/Woods	2,221		723,715	27	1
RESIDENTIAL					
No. Homes on Septic Systems:					
Category I	85				
Category II	42				
Category III	15				
Category IV			493,556	1,773	95
Average Residential acreage per house	1.60				
LAND USE ACREAGE:		Tons manure per acre			
Days Since Manure Applied	365.00	10			
If no manure in 1 year enter 365 for background concentrations					
Agricultural Acreage:					
Category I	150				
Category II	86				
Category III	150				
Category IV	250		276,322	3,138	300
Grazing Acres	5				
# Head of Livestock:					
Category I	10				
Category II	10	Days Between			
Category III	10	Animal Grazing			
Category IV	10	3.00	2,172	4	51
ROAD RUNOFF:		Road Acres Auto.-calculated			
Low Density Resid.	4200	2.96	118,026	3,200	700
High Density Resid.	10	0.01	281	4	335
Major Roads/H'ways	6,350	8.94	356,888	12,446	900
Commercial/Industrial	6,350	8.94	356,888	8,319	602
Agricultural/Woods	48,600	34.21	1,365,728	7	0
			Total Watershed Runoff (Gallons)	Total fc Loading (Millions)	Average Runoff FC Conc. (fc/100 ml)
			3,746,688	28,918	204

Table 19. BUNGANUC STREAM SUBWATERSHED HIGH EXTREME OF FC COEFFICIENTS					
EXISTING CONDITIONS (1995), AND NO MANURE APPLICATION					
1	2	3	4	5	6
SOURCES BY CATEGORY	UNITS BY CATEGORY	Default Values	Watershed Runoff by Land Use (gallons)	Fecal Coliform Loading by Land Use (Millions/storm)	Average Fecal Coliform Concentration in Runoff fc/100 ml
HYDROLOGIC INPUTS:					
Rain event (inches)	1.50				
Time since Last Rain (days)	3.00				
Amount Rainfall in previous 5 days (inches)	0.5				
LAND USE INPUTS:					
Commercial/Industrial Acreage			0	No Loading	
Meadows/Parks/Cemeteries	163		53,114	No Loading	
Forest/Woods	2,221		723,715	27	1
RESIDENTIAL	No. of Homes				
Distance to Surface Water Category	with Septic Systems				
I. Surface Water >1000 ft.	85				
II. Surface Water 300-1000 ft.	42				
III. Surface Water 100-300 ft.	15				
IV. Surface Water 0-100 ft.			493,556	10,303	551
Average Residential acreage per house	1.60				
LAND USE ACREAGE:		Tons manure per acre			
Days Since Manure Applied	365.00	10			
If no manure in 1 year enter 365 for background concentrations					
Agricultural Acreage:					
I. Surface Water >1000 ft.	150				
II. Surface Water 300-1000 ft.	86				
III. Surface Water 100-300 ft.	150				
IV. Surface Water 0-100 ft.	250		276,322	3,138	300
Grazing Acres	5				
# Head of Livestock:					
I. Surface Water >1000 ft.	10				
II. Surface Water 300-1000 ft.	10	Days Between			
III. Surface Water 100-300 ft.	10	Animal Grazing			
IV. Surface Water 0-100 ft.	10	3.00	2,172	24	296
ROAD RUNOFF:		Road Acres Auto.-calculated			
Low Density Resid.	4200	2.96	118,026	18,648	4,077
High Density Resid.	10	0.01	281	21	1,956
Major Roads/H'ways	6,350	8.94	356,888	72,390	5,235
Commercial/Industrial	6,350	8.94	356,888	48,578	3,513
Agricultural/Woods	48,600	34.21	1,365,728	7	0
			Total Watershed Runoff (Gallons) 3,746,688	Total fc Loading (Millions) 153,136	Average Runoff FC Conc. (fc/100 ml) 1,080

3. Model Calibration

H&W calibrated the FecaLOAD model with both actual runoff and water quality data collected from the six test sites and streams in the watershed. Due to the wide variation of fecal coliform concentrations found in the environment, H&W selected a goal of one order of magnitude where possible, and two orders of magnitude in limited instances as an upper limit of acceptability between actual and modeled fecal coliform concentrations calculated for runoff and fecal coliform loading.

Model calibration was performed first on the test-site scale and then verified on the subwatershed scale. Actual test-site water quality data, discharge data, and calculated fecal coliform loadings were compared to modeled runoff volume, fecal coliform loadings and fecal coliform concentration at each test site. This was done for the four rain events at all six test sites. Table 17 provides a comparison, by rain event, of modeled values after calibration to actual measured values. The model successfully predicted test site runoff corresponding to actual runoff measurements, in most cases, for all four storms monitored (Table 17). For sites BS-6 and GG-7, agricultural test sites, predicted runoff did not routinely correspond to actual runoff measurements. This is primarily because both of these areas are drained by perennial streams from which the stream flow was included in the stormwater runoff measurements.

Table 18 provides a summary of general calibration steps for runoff values, and Table 19 provides calibration steps for fecal coliform loading. A detailed description of the calibration steps for runoff and fecal coliform loading are provided in Appendix H, followed by a discussion of the steps employed. Model runs on the subwatershed scale used the model test-site values to predict a subwatershed runoff and fecal coliform loading by rain event. This loading was compared to actual stream water quality data and calculated loadings in Table 5.

Table 20 . Comparison of Modeled Test Site Runoff and FC Concentrations to Actual Data by Rain Event

1/1/04 Date	Rain Event inches	Site/land use	Test Site Measured Runoff Ave. gal/storm	Test Site Modeled Runoff Gal/storm	Test Site Measured Conc. (no./100 ml)	Test Site Model Conc.* (no./100 ml)	Variance by order of magnitude
5/16/94	1.10	BS-1 (agriculture)	17,600	32,098	400	46	1
		BS-6 (agriculture)	500,000	219,613	311	31	1
		GG-7 (agriculture)	174,000	51,323	380	62	1
		BS-8 (residential)	6,100	21,000	1200	210	1
		BS-13 (residential)	49,400	35,000	360	160	0
		BS-14 (forest)	33,500	24,085	1	1	0
11/28/94	1.30	BS-1 (agriculture)	40,000	39,321	750	50	1
		BS-6 (agriculture)	1,161,000	270,335	380	33	1
		GG-7 (agriculture)	114,200	63,587	100	67	1
		BS-8 (residential)	3,500	25,000	520	180	0
		BS-13 (residential)	26,000	35,000	50	160	1
		BS-14 (forest)	30,000	29,409	110	1	2
4/4/95	0.40	BS-1 (agriculture)	9,400	42,443	1	24	1
		BS-6 (agriculture)	431,000	161,455	20	28	0
		GG-7 (agriculture)	55,200	45,328	34	47	0
		BS-8 (residential)	2,000	11,500	11	390	1
		BS-13 (residential)	17,300	22,000	69	250	1
		BS-14 (forest)	22,200	26,050	2	1	0
4/13/95	0.89	BS-1 (agriculture)	46,300	44,040	5	23	1
		BS-6 (agriculture)	1,860,000	220,527	22	20	1
		GG-7 (agriculture)	207,300	55,949	32	38	1
		BS-8 (residential)	13,900	21,000	8	170	2
		BS-13 (residential)	52,000	37,000	7	150	2
		BS-14 (forest)	40,000	29,519	0	1	0
					Average Variance by Order of Magnitude =		0.83

Notes: (1) Sample locations at Sites GG-7 and BS-6 are perennial streams. Baseflow accounts for a portion of the measured storm runoff.
(2) Some model loadings are similar for April 4 and 13 because input rain values < 1 in. default to the model loading EQ. for a 1 in. rain.
(3) Model-calculated concentrations of "1" denote calculated concentrations which were less than 1.
* Model Concentration Calculated from Model Loading ÷ Test Site Modeled Runoff

Table 21. Summary of General Calibration Steps for Runoff Volume

Site/Land Use	Initial Model Output For Fecal Coliform Loading	Calibration Required	Second Run Output for Fecal Coliform Loading
BS-1 Agriculture	< Actual Measurement	Increase Watershed Runoff	Approximate Actual Measurement
BS-6 Agriculture	< Actual Measurement	Increase Watershed Runoff	Approximate Actual Measurement
GG-7 Agriculture	< Actual Measurement	Increase Watershed Runoff	Approximate Actual Measurement
BS-8 Residential	Approximate Measurement	No Adjustment	N/A
BS-13 Residential	Approximate Measurement	No Adjustment	N/A
BS-14 Forest	> Actual Measurement	Decrease Curve Number	Approximate Actual Measurement

Calculation of Agricultural Fecal Coliform Loadings With No Observed Manure Application: One intent of the water quality sampling component of this project was to collect data to calibrate model predictions. Stormwater runoff samples from sites with predominant land covers of residential, agricultural and forest would, by project design, provide these data. While septic effluent breakout from marginal hydrogeologic conditions for septic systems, and road runoff are the suspected sources of fecal coliforms from residential sites, land applied manure and manure from grazing livestock are the suspected sources of fecal coliforms from agricultural areas. H&W observed fresh manure on fields and along drainage ditches within the study area in the late summer and early fall of 1993 when scoping the project. These observations, and a survey of watershed soils and hydrogeology, indicated that runoff sampling of these areas would produce the required water quality data for model calibration. However, soon after the water quality sampling and flow measurement began, no manure applications were observed on agricultural fields.

Table 22. Summary of General Calibration Steps for Fecal Coliform Loading

Site ID and Land Cover Type	Initial Model Run Output	Calibration 1	Result 1	Calibration 2	Result 3
BS-1 Agricultural	< Actual Data	Include Background Fecal Coliform	Approximate Actual Data	N/A	N/A
BS-6 Agricultural	< Actual Data	Include Background Fecal Coliform	Approx. Actual Data	N/A	N/A
GG-7 Agricultural	< Actual Data	Include Background Fecal Coliform	Approximate Actual Data	N/A	N/A
BS-8 Residential	<< Actual Data		< Actual Data	Change to Category III	Approximate Actual data
BS-13 Residential	>> Actual Data	Reduced Roadside Solids	< Actual Data	Change to Category III	Approximate Actual Data
BS-14 Forest	> Actual Data	Change 3 Houses in BS-14 from Category III to II	Approximate Actual Data	N/A	N/A

Consequently, the fecal coliform loading for manure application on agricultural lands could not be calibrated because of these conditions which were out of H&W's control. While it is not a calibrated modeling output, the model will still predict fecal coliform loadings based on literature values. Additionally, based on the water quality data collected from these agricultural test sites, H&W was successful in developing a coefficient for background fecal coliforms in the model to apply to those agricultural test sites with no recent manure application.

4. Model Predictions

Three rain events were selected for the model runs on the subwatershed scale: 0.5 inch, 1.5 inches and 3.0 inches. Additionally, each of these rain events was modeled with an associated antecedent moisture condition (AMC). AMC reflects the level of saturation of the watershed and controls rainfall-runoff response time as well as volume of runoff. The AMCs used in this modeling approach reflecting observed rain events on the Maquoit Bay watershed are as follows: for "dry" (<0.5 inches of rain in the previous five days), "normal" (0.5 to 2.5 inches of rain in the previous five days) and "wet" (> 2.5 inches of rain in the previous five days). For each of these rain-runoff conditions, the model was also run under the following levels of watershed land use:

1) existing level (1995) of development and agriculture;

2) buildout conditions with an assumed 50% reduction in agriculture (future developed land was taken from a reduction in agricultural and forested acreage).

Modeling actual manure application required estimates of the percentage of the watersheds' agricultural lands which actually receive manure application. Acquisition of this information proved difficult. Thus, for a sensitivity analysis, the model was run under the two levels of watershed land use discussed above, in addition to the following two scenarios (other inputs did not change):

1) Background agricultural fecal coliform concentrations. Assumed that no manure was land-applied.

2) Manure application at a rate of 10 tons per acre per year. Rainfall was assumed to occur one day after manure application.

a. Modeling the Watersheds With No Manure Application

The model was run with all input variables under existing conditions, and with the agricultural acreage exhibiting only background fecal coliform concentration. The results are summarized in Table 23. The complete model predictions, under different scenarios, are provided in the Appendix B.

Table 23. Summary of Fecal Load Results Under Existing Conditions By Rainfall and AMC

AMC	0.5-inch Rainfall Dry to Wet	1.5-inch Rainfall Dry to Wet	3-inch Rainfall Dry to Wet
WATERSHED	fc/100 ml	fc/100 ml	fc/100 ml
Bunganuc Stream	120-110	120-130	900-700
Wharton Point	90-80	70-80	500-200
Rossmore Stream	9 -12	7 - 8	13 - 12
Bunganuc Point	100 - 90	90 - 80	500 - 300
Flying Point	10 - 70	7 - 30	5 - 7
Merepoint	50 - 90	50 - 70	150 - 100

These data correspond to observations by H&W from the water quality samples as well as with the observations by the Bowdoin Report, cited previously in this report, which found that the greater magnitude storm events appear to flush out the watershed (from a loading standpoint) of the available "reservoirs" of fecal coliforms in the watersheds. During sampling and stream discharge measurements associated with a 3.7-inch storm over September 23 and 24, 1994, H&W observed the trends in fecal coliform concentrations which support this analysis (Table 24). This phenomenon can best be explained by the relatively long time of concentration associated with these rural/agricultural watersheds when compared to more urbanized watersheds characterized by a substantially higher proportion of impervious surfaces. In the case of the Maquoit watersheds, pervious surfaces retain the early portions of storm events until the soils become saturated and result in surface runoff.

Table 24. Discharge and Water Quality Data on 23 September 1994

Date/Time:	Discharge (cfs)	fc/100 ml
Bunganuc Stream		
9/23 @ 14:13	0.14	190
15:32	0.14	190
17:10	0.17	174
18:15	0.25	300
19:00	0.3	650
9/24 @ 08:00	72	7100
Geometric Mean		478
Rossmore Stream		
9/23 15:11	2.16	4
16:45	2.16	6
17:50	2.88	8
19:00	2.88	13
19:40	2.88	12
9/24 @ 09:30	8.11	400
Geometric Mean		15
Wharton Point Stream		
9/23 @ 14:48	3.06	850
16:30	3.06	720
17:35	3.7	1230
18:35	3.7	1930
19:20	9.23	5600
Geometric Mean		1521

Watershed flushing-out is particularly evident in data from Bunganuc Stream and Wharton Point Stream subwatersheds, the two largest in the Maquoit Bay watershed. Rossmore Stream's watershed is close in size to Wharton Point but has two important differences: 1) it has a generally "sandy" geology which promotes infiltration over runoff, and 2) it has an impoundment upstream of the sample location which may be attenuating fecal coliforms and other pollutants. It was not until late in the September 23-24 storm runoff period that high fecal coliform concentrations (400 fc/100 ml) were observed in the Rossmore stream samples. Yet the trend is identical to the other streams.

b. Modeling the Watersheds with Assumed Manure Application

The model was run with a median concentration of fecal coliforms (developed from the range of literature values) associated with all input source variables under existing development conditions, and agricultural acreage with manure application. These results are summarized in Table 25. Assuming that manure is applied to fields in the watershed, the resulting fecal coliform concentrations exhibit the runoff response described previously by Moore, et al., in that the first inch of rain physically removes most of the fecal coliforms from agricultural lands with manure. The fecal coliforms available during a three-inch rain event modeled here result in concentrations diluted by the greater volumes of runoff reflecting the model output by AMC "dry to wet" conditions ranging from high to low.

Under the manure-application scenarios summarized above, the model assumed that all agricultural lands in the watershed had manure application at the rate of 10 tons per acre per year. Other application rates are possible but through the literature review and communication with agricultural experts, H&W found the typical range to be 10-20 tons per acre per year. While this could not be verified for the Maquoit Bay watershed during this study, the model output does show correspondence to high fecal coliform concentrations observed in the past. Table 26 provides a summary of historical high fecal "coliform" concentrations observed in Bunganuc "Brook" (Hinckley, 1971) This report does not differentiate between fecal coliforms and total coliforms.

Table 25. Summary of Model Calculated Fecal Coliform Concentrations with Agricultural Manure Application

AMC	0.5-inch Rainfall Dry to Wet	1.5-inch Rainfall Dry to Wet	3-inch Rainfall Dry to Wet
WATERSHED	fc /100 ml	fc/100 ml	fc/100 ml
Bunganuc Stream	2,000,000 - 1,000,000	800,000 - 700,000	90,000 - 80,000
Wharton Point	800,000 - 600,000	300,000	70,000 - 40,000
Rossmore Stream	50,000 - 40,000	20,000 - 10,000	4,000 - 2,000
Bunganuc Point	800,000 - 700,000	500,000 - 300,000	70,000 - 40,000
Flying Point Neck	300,000 - 200,000	90,000 - 80,000	20,000 - 10,000
Merepoint Neck	300,000 - 200,000	90,000 - 80,000	20,000 - 10,000

Table 26. Summary of Historical Fecal Coliform Concentrations Measured in Bunganuc Stream (Hinckley, 1971)

November 1957 MPN/ 100 ml	1968-1970 MPN/100 ml	September 1971 MPN/100 ml	October 1971 MPN/100 ml
2,400	>1,100 (Apr.)	42,000	11,000
46,000	>1,100 (May)	41,000	32,000
46,000	>1,100 (June)	39,000	18,000
	4,600 (June)	310,000	24,000
		130,000	40,000

5. Interpretation of Model Results

A series of interesting interpretations can be derived from the modeling results for existing conditions, and the comparison of these results to the bacteria sampling data collected from within the watershed.

First, the water quality data from sampling events in the streams suggests that bacteria concentrations increase as flow increases during the later stages of a storm event (see Table 24). The model results for Bunganuc and Rossmore Streams provide a reasonable match to these measured concentrations (Table 23). Wharton Point showed higher fecal coliform concentrations (geometric mean = 1521) than the model predicted (200-500). This may be due to wildlife sources in and around the impoundment just upstream from the sampling point.

At first glance, the trend of increasing bacteria concentrations during storm events contradicts some of the literature reports described earlier that suggest the first flush of runoff contains the greatest concentrations of bacteria. However, it is important to distinguish between the sampling data collected by H&W in the streams, and the literature data used to analyze first flush concentrations, The literature data was developed from sampling at the source of contamination, either in direct road discharge (Novotny and Olem, 1994) or on agricultural fields (Moore, et al, 1994). In these locations one would expect to see higher concentrations in the first component of the runoff, and decreasing concentrations over time.

The bacterial concentrations in the stream, however, represent the integration of many discreet "pour points" or subwatersheds within the watershed. The first flush from areas adjacent to the stream will enter the stream more quickly than the first flush from areas higher in the watershed. The net result is the water quality trend exhibited in the stream data (Table 24). As more bacteria reach the stream from higher in the watershed the stream bacteria concentration increases.

The model predicts agriculture land uses with manure application are the greatest source of bacteria in the watershed. This is true even though manure was not applied during the course of our study and fecal loadings continue from residues of previous manure applications (perhaps the previous year). The second largest source appears to be residential areas which encompass septic systems and road runoff.

Third, the runoff component of the FecaLoad model provides reasonable estimates of runoff from different land uses in the watershed. It also provides reasonable estimates of the flows measured in the streams. These flow estimates provide part of the foundation of the model and can be used to interpret the relative loadings from each source. If a large source of bacteria is located in an area with low runoff (such as in sandy soils) the overall loading to the surface water is less than if the runoff from the site is higher.

6. Buildout Analysis

The buildout analysis described in Section III indicates that under current zoning, another 1603 single-family homes with on-site septic systems could be built within the watershed (See Table 3 in Section III). This represents slightly more than a tripling of the existing number of units (591) within the watershed.

The model was run under buildout conditions (full development according to zoning) representing an additional 1603 dwellings over the Maquoit Bay watershed. The buildout dwellings were spread over each subwatershed proportional to the existing conditions. (Appendix C shows existing and buildout rankings by subwatershed). These dwellings were assumed to be on septic systems and sited according to the Maine Subsurface Wastewater Code. However, it was also assumed that from the new developments, the same proportion of systems as in Category III (potential for breakout) of the existing development were placed under Category III in the buildout. Both the existing and buildout conditions of each subwatershed are presented in Appendix B for fecal modeling, and in Appendix D for nitrogen modeling.

Under the first model run for buildout conditions, the acreage increase associated with development was subtracted from a 50% reduction in agricultural acreage. The model results showed that there was not a significant change in the fecal coliform concentrations. In fact, the trends under existing and buildout, with the same agricultural acreage, approximated those in Table 23. This indicates two things: 1) that residential buildout is not a significant factor with respect to fecal coliform pollution on the watershed scale if most of the dwellings are sited properly, and 2) that agricultural manure application, especially on lands in close proximity to surface waters, may be potentially the most significant pollution source in the watershed.

To test the sensitivity of the model to agricultural manure application, and to test statement 2), above, a third scenario was run. Under this scenario, the agricultural acreage was reduced by 50% and placed in the meadow/open-space category. This was performed under two conditions: 1) with no manure applications, and 2) with manure application. Model results showed for condition #1 that there was a significant reduction in background fecal coliform concentrations as a result of the change. Overall, the fecal coliform concentrations dropped as AMC conditions went from "dry" to "wet" indicating dilution by the greater runoff volumes associated with "wet" AMC's.

Table 27. Scenario #1: Summary of FecaLOAD Results Under Buildout With No Manure Applications (fecal coliforms/100 mls) and a 50% Reduction in Agricultural Acreage

RAINFALL AMC	0.5 inch rainfall Dry to Wet	1.5 inch rainfall Dry to Wet	3 inch rainfall Dry to Wet
WATERSHED	fc/100 ml	fc/100 ml	fc/100 ml
Bunganuc Stream	100 - 90	90 - 80	300 - 200
Wharton Point	50	50	200 - 100
Rossmore Stream	9 - 12	5 - 8	9 - 8
Bunganuc Point	80	70	200 - 100
Flying Point	30 - 70	20 - 40	50 - 40
Merepoint	30 - 90	20 - 60	80 - 70

Table 28. Scenario #2: Summary of FecaLOAD Results Under Buildout Conditions, and a 50% Reduction in Agricultural Acreage with Manure Application (fecal coliforms/100 mls)

AMC	0.5 inch rainfall Dry to Wet	1.5 inch rainfall Dry to Wet	3 inch rainfall Dry to Wet
WATERSHED	fc /100 ml	fc / 100 ml	fc /100 ml
Bunganuc Stream	80,000- 800,000	500,000 - 300,000	50 ,000- 30,000
Wharton Point	300,000 - 200,000	100,000 - 80,000	30,000 - 10,000
Rossmore Stream	20,000 - 10,000	8,000 - 7,000	1,000 - 800
Bunganuc Point	500,000 - 400,000	200,000 - 100,000	30,000 - 20,000
Flying Point	90,000 - 80,000	50,000 - 40,000	6,000 - 4,000
Merepoint	100,000 - 80,000	60,000 - 50,000	9,000 - 7,000

Under scenario #2, above, there was a noticeable decrease in fecal concentrations from manure application, when compared to Table 10, due to less watershed agricultural acreage. This was observed when comparisons were made to each of the subwatersheds under scenarios where agriculture acreage was modeled at 10 tons of manure per acre per year at existing (1995) conditions. If a greater percentage of fecal coliforms had been from sources other than agriculture, then the reduction in fecal coliforms would not have been as dramatic. Thus, even with increased development at buildout, agriculture appears to be a significant source of fecal coliform.

7. Transferability to Other Areas

H&W has completed a Model User's Guide. This is Appendix A. The User's Guide is a descriptive text with step-by-step instruction on model inputs. Additionally, guidance is provided on sources of information, assumptions and interpretation of the model outcome.

A disk containing both the FecaLOAD model and the nitrogen loading model has been provided with the report. The format of the FecaLOAD model has been improved (and made easier to use) since it was applied to the Casco Bay project. This newer version is included with this report.

VI. NITROGEN LOADING MODEL

A. Identification and Quantification of Existing Nitrogen Sources to Maquoit Bay

A nitrogen loading (mass-balance) model has been developed for the Maquoit Bay watershed to estimate the relative loadings of nitrogen from principal sources. The model is intended to be transferable to other watersheds along the Maine coast. It is based upon previous nitrogen loading models prepared by the United States Geological Survey (Frimpter, et al., 1990), Cornell University (Porter, 1978) and Horsley & Witten, Inc. (Nelson, et al., 1988). The model is based on site-specific data including surficial geology, soils, climate, types of septic systems, and agricultural practices.

1. Precipitation

Precipitation is a significant source of nitrogen to the watershed and directly to the Bay. Atmospheric loading rates have been estimated for forested areas at six pounds per acre per year and for agricultural/rural areas at 12 pounds per acre per year (Reckhow, et al., 1980). These loading estimates are consistent with the actual nitrogen concentrations (average 1.2 mg/liter) measured in precipitation collected in Maine by the National Atmospheric Deposition Program which converts to a loading rate of 12.2 pounds per acre per year.

The amount of nitrogen loading derived from precipitation sources which is exported from the watershed must account for attenuation by vegetation and soils within the watershed. Pionke and Urban (1985) report that based upon field studies at agriculture sites in upstate New York, approximately 30% of the precipitation-derived nitrogen is exported from agricultural fields (converting to a loading rate of 3.7 pounds of nitrogen per acre per year). Reckhow, et al. (1980) suggest an export rate of 2.2 pounds of nitrogen from forested areas (this would account for precipitation and forest ecosystem losses). H&W has used an export coefficient of 2.2 pounds per acre per year and allocated this between recharge and runoff based upon soil types.

2. Septic Systems

Raw sewage contains 20-100 mg/liter and an average of 60 mg/liter of total nitrogen (Nelson, et al, 1988). At an average domestic sewage flow of 55 gallons/day per capita and an average occupancy rate of 3 persons per house, this equals 10 pounds of nitrogen/day per capita or 30 pounds of nitrogen/day per dwelling unit. After flowing through the septic tank discharging from the leaching field, the effluent passes through a biological mat that forms within the soil immediately beneath the leaching area. An analysis of the scientific literature shows that approximately 50% of the nitrogen load is removed through biochemical reactions (including denitrification) within the septic tank and the attenuation zone beneath the leaching field (Nelson, et al., 1988; Frimpter, 1990). Therefore, a persistence factor of 50% is used to estimate the loadings of nitrogen from septic systems that discharge to the subsurface. This persistence factor is then further reduced by the ratio of recharge/runoff estimated by soil types in each subwatershed.

The model allows for different attenuation and persistence factors to be applied to those septic systems which have been rated (according to the H&W methodology) as Class III and Class IV. In these cases, the septic effluent may discharge at the land's surface with little attenuation. Notwithstanding surface flow attenuation factors, those "failing" systems within close proximity to streams are likely to have a higher nitrogen loading.

3. Lawns

Homeowners and commercial applicators apply approximately three pounds of nitrogen per 1,000 square feet of lawn area. A combination of fast-release and slow-release fertilizers are utilized to provide instant results and longer-term maintenance. Based upon field surveys and aerial photographs the average lawn size within the Maquoit Bay watershed is estimated at 5,000 square feet. Based upon studies conducted on Long Island and Cape Cod, approximately 40% of the applied nitrogen is taken up by grass. The remainder (60%) is available for transport. Within the Maquoit watershed, where sandy soils are less common, the majority of this transport is expected to occur via runoff (or overland flow). An initial persistence factor of 50% has been used as an estimated export rate from lawns. The nitrogen loading from lawn fertilizers is then allocated between recharge and runoff based upon the ratio of soil types and their estimated recharge and runoff rates found in the watershed. For example, the Bunganuc Stream subwatershed is comprised of 79% clay soils and 21% sandy soils. In this case, nitrogen loading from lawn fertilizers via surface runoff is estimated by multiplying 79% times 50% yielding an estimated persistence of 40%.

4. Agricultural Fields/Manure Applications

The predominant agricultural crop in the Maquoit watershed is hay. Interviews with the Agricultural Extension Agent and a local farmer indicate that manure is applied as a fertilizer to most or all of the hayfields. Applications occur from May through October at a rate of approximately 10-20 tons of manure per acre per year. The USGS nitrogen loading model indicates that manure typically contains approximately five pounds of nitrogen per ton of manure (Frimpter, 1990). It also indicates that appreciable nitrogen losses (36% over seven days at 68 degrees) result through volatilization during the summer season as the applied manure is exposed to a dry warm climate. Therefore, the amount of nitrogen available to be transported from the agricultural fields will be, in part, dependent upon the number of days between the original manure application and the first storm event. Over time, the crop will also uptake nitrogen from the manure, making less available for transport/export.

A previous watershed study conducted in an agriculturally-dominated watershed in New York accounted for the nitrogen inputs and outputs (Pionke and Urban, 1985). Their study showed that on the average 14% of the nitrogen applied as fertilizer was transported from the watershed. The balance was taken up by the crop and volatilized to the atmosphere.

During our study period, no manure applications were observed in our study areas. As a result we computed a nitrogen loading rate based upon our actual stormwater quality monitoring at our three agricultural test sites (BS-1, BS-6, GG-7). Utilizing measured concentrations of nitrogen and runoff rates, we have calculated an export rate of 4.5 pounds of nitrogen is stormwater runoff per acre per year. The model then allocates this loading between recharge and runoff based upon soil types.

Table 29. Nitrogen Loading Rates for Hay Fields in the Maquoit Bay Watershed

Scenario	Loading Rate (lbs/acre-year)
1. Worst Case Conditions - Major Rainstorms immediately following manure applications (100% export)	50-100
2. Average Conditions - based upon volatilization losses (36%) and uptake (50% of remaining)	16-32
3. Average Conditions - based upon NY state study (Pionke and Urban, 1985) showing 14% average export rate	7-14
4. Background Conditions - based upon residuals from previous year's manure applications and actual water quality data from Maquoit Bay test sites	4.5

For the purpose of watershed modeling, H&W has compiled a range of potential nitrogen loading rates from the various sources discussed above (see Table 14). Model runs utilized the mean of "average conditions" (17.25 lbs N/acre-year) and background conditions (4.5 lbs N/acre-year).

5. Livestock

Approximately 450 cows are estimated to reside within the Maquoit watershed (Agricultural Extension Agent and Town Annual Reports from Brunswick and Freeport, 1992). Nitrogen loading rates for beef cows was estimated at 124 pounds per animal per year, and for dairy cows at 146 pounds per animal per year (Frimpter, 1990).

Presently, it is unknown if (and to what extent) the livestock within the watershed is the source of the manure which is applied to the agricultural fields. However, the estimated nitrogen loading from 450 cows at 139 lbs N per year equals 60,750 pounds N per year is within the estimated range of manure-fertilizer applications over the 1046 areas of agricultural land within the watershed (52,300-104,600 pounds N/yr.). If these livestock are the source of the manure, the nitrogen loading model must be careful not to double count these loadings. However, to be conservative we have modeled nitrogen loading from livestock as additional to manure applications..

Where feedlots and/or manure storage areas exist, the nitrogen loading from these areas can be very significant at rates as high as 2,600 pounds of nitrogen per acre per year (Reckhow, et al., 1980).

6. Road Drainage

Sources of contaminants in road drainage include wet and dry deposition, soil erosion, street dirt and litter, leaf litter, and animal waste. Precipitation is the major source of nitrogen in stormwater. Novotny, et al. (1985) found that wet deposition (precipitation) accounted for approximately 50% of the nitrogen in runoff in the Milwaukee area. Soil erosion during storm events accounted for an additional 30%. Other sources in order of significance were street dirt, litter and dry deposition. Halverson, et al. (1984) analyzed precipitation in a non-industrial urban area in Central Pennsylvania. The results indicate that the percentage contribution of nitrogen from precipitation varied from 100% for a highway to approximately 50% for a residential street.

The total nitrogen concentration in runoff was estimated to be 2.0 mg/l. Older studies by Lager, et al. (1968) and Loehr (1974) would indicate a higher value in the range of 3 mg/l. Nevertheless, more recent studies (Koppelman, 1982; Howie and Waller, 1986; Novotny, et al., 1985; Schmidt and Spencer, 1986) indicate lower concentrations of nitrogen in urban runoff. The use of 2.0 mg/l is consistent with local measurements of nitrogen in precipitation (1.2 mg/l) and the findings by Novotny, et al. (1985) that precipitation may comprise 50% of runoff nitrogen. The average concentration of 2.0 mg/l converts to a loading rate of 8.7 lbs of nitrogen per acre of roads per year.

7. Sludge Disposal

An estimated 16,000 cubic yards of sludge was disposed within the Bunganuc Stream subwatershed during the 1967-1982 period. This has been raised as a major concern by a number of residents at a public hearing conducted at the Brunswick Public Library in March 1994. Converting the volume of sludge by assuming 55 lbs of sludge per cubic foot and 2% dry weight nitrogen yields an estimated total amount of nitrogen at 160,000 pounds. Although water quality monitoring at the downgradient streams and monitoring wells has been conducted over the last decade, it is difficult to estimate the amount of transport from this sludge disposal area. In part, this is complicated because of a sanitary landfill located in the same area which also contributes to the measured pollutants. For the initial modeling, H&W has assumed that 2% of the nitrogen is leached over a 50-year period (and transported to the stream) from the sludge disposal area on an annual basis. This loading estimate was adjusted to 0.2% by the calibration phase. The Town Department of Public Works is amending their water quality monitoring program at this site to better assess this situation.

8. Calibration and Confirmation of Model

To calibrate the nitrogen loading model, H&W reviewed water quality data collected on Bunganuc Stream over the 18-month study period (see Section 4.0). Bunganuc Stream was selected because of the predominance of watershed test sites (five of the six) within this watershed as well as extensive stream water quality and flow data. Table 30 summarizes the average stream quality data under both baseflow and stormflow conditions.

Table 30. Average Concentrations of Total Nitrogen in Bunganuc Stream (mg/liter) (based upon four rounds of samples)

	Measured	Modeled
Baseflow	0.61	0.57
Stormflow	0.79	0.61

To calibrate the model to match the observed water quality conditions, H&W made two adjustments. First, nitrogen loadings were allocated to groundwater recharge (resulting in stream baseflow) and surface runoff (resulting in stormflows). This was accomplished by classifying the soil in the watershed into "clayey" and "sandy" categories and assigning recharge/runoff estimates (0.25 inches per year - runoff/1.5 inches per year - recharge for sandy soils and 1.5 inches per year - runoff/0.25 inches per year - recharge for clayey soils. The second adjustment was to reduce the annual loading from the sludge landfill so as to best match the observed nitrogen concentrations in the stream.

The calibrated model was then applied to the other two stream subwatersheds for validation purposes. With the exception of baseflow conditions in Wharton Point Stream the correlations were 75% or better comparing measured and modeled nitrogen concentrations. An impoundment near the mouth of Wharton Point Stream is believed to magnify nitrogen concentrations by providing a wildlife habitat for mammals and birds. The results of this is shown in Table 31.

Table 31. Average Concentrations of Total Nitrogen In Rossmore and Wharton Point Streams (mg/liter)

Stream	Measured	Modeled
Rossmore (baseflow)	0.81	0.77
Rossmore (stormflow)	0.71	0.89
Wharton Point (baseflow)	0.90	0.39
Wharton Point (stormflow)	0.81	0.61

9. Calculation of Maquoit Bay Flushing Rate

Research by Gilfillian and others at Bowdoin College has produced an estimate of the flushing time of Maquoit Bay of six days, ranging from 5-15 days (Kresja, 1990).

H&W has applied an analytical model to estimate the average flushing rate of Maquoit Bay. This model (Pilson, 1985) utilizes Bay volume, mean salinity, and fresh water inputs.

$T=VF/Fw*86400$	where	T	=	flushing rate in days
		VF	=	volume freshwater in cubic feet
		Fw	=	freshwater input in cubic feet/second
		86,400	=	number of seconds/day
and				
$Vf=Vc(1-Sc/Sb)$	where	Vc	=	volume of waterbody at mean tide in cubic feet
		Sc	=	mean salinity in waterbody in parts per thousand
		Sb	=	salinity in ocean in parts per thousand

Maquoit Bay's volume is estimated at 12.5 billion gallons based upon area (five square miles) and mean depth of 12 feet. The mean salinity is estimated at 21 parts per thousand (0/00), based upon 420 measurements at 13 stations by Alan Houston during the 1992-1994 period. Freshwater inputs to Maquoit Bay were estimated by the watershed area. It estimates the average flushing rate of the Bay to be three to five days.

10. Model Predictions

The results of the nitrogen loading model for existing conditions are shown under several scenarios in Tables 32 and 33 and Appendix D. The results indicate that under existing conditions the largest source of nitrogen to the Bay is direct precipitation (33%), followed by forested cover of the watershed (18%), agricultural fields (19%), livestock (12%), and septic systems (9%). The analysis also compares the nitrogen loading to standards prepared by the Buzzards Bay Program. For shallow (less than three meters average depth) poorly flushed (greater than five days residence time) embayments the recommended standard is 5g N per square meter per year. This comparison suggests that the existing nitrogen loading (58,600 lbs. N/year) is 54% of the critical nitrogen loading rate of 109,000 lbs. N/year.

These buildout scenarios were also run. These results indicate that additional potential residential development can increase the total nitrogen loading from 58,655 lbs N/year (Scenario #1) to 75,563 lbs N/year (Scenario #3) assuming that manure applications to agricultural lands remain constant. Scenarios #2 and #4 portray the changes in nitrogen loading which could result from no manure applications and higher application rates respectively. These data suggest that these potential buildout nitrogen loading rates would be within acceptable nitrogen loading ranges (65-92% of the actual loading rate), indicating that the Coastal Protection Zone development restrictions were warranted.

Table 32. Nitrogen Modeling Results By Subwatershed

	Scenario #1 Existing Land Use No Manure		Scenario #2 Buildout No Manure		Scenario #3 Buildout With Manure (17.25 lbs N/acre-year)		Scenario #4 Buildout With Manure (50 lbs N/acre-year)	
Bunganuc Stream	18032	31%	19112	27%	24302	32%	37633	38%
Wharton Stream	3185	5%	6459	9%	6541	9%	6751	7%
Rossmore Stream	4506	8%	10876	15%	12124	16%	15331	15%
Bunganuc Point	1961	3%	1749	2%	2206	3%	3284	3%
Merepoint	3091	5%	2798	4%	3238	4%	4370	4%
Flying Point	8680	15%	10591	15%	7951	11%	13503	13%
Direct Precipitation	19200	33%	19200	27%	19200	25%	19200	19%
TOTAL	58655		70785		75563		100071	

Table 33. Nitrogen Modeling Results By Source

	Scenario #1 Existing Land Use No Manure		Scenario #2 Buildout No Manure		Scenario #3 Buildout With Manure (17.25 lbs N/acre-year)		Scenario #4 Buildout With Manure (50 lbs N/acre-year)	
Septic (III/IV)	3475	6%	10087	14%	10087	13%	10087	10%
Septic (I/II)	1578	3%	6897	10%	6897	9%	6897	7%
Lawns	2955	5%	11035	16%	11035	15%	11035	11%
Agriculture/Manure	11139	19%	2906	4%	11139	15%	32192	32%
Cows	6912	12%	6912	10%	3456	5%	6912	7%
Forest	10714	18%	10714	15%	10714	14%	10714	11%
Sludge Disposal	320	1%	320	0%	320	0%	320	0%
Road Drainage	2362	4%	2714	4%	2714	4%	2714	3%
Direct Precipitation	19200	33%	19200	27%	19200	25%	19200	19%
TOTAL	58655		70785		75563		100071	

VII. CONCLUSIONS AND RECOMMENDATIONS

- Current pollutant loadings measured in stormwater and stream samples and suggested by watershed modeling indicate that nitrogen loading under existing conditions does not significantly threaten Maquoit Bay. However, fecal coliform loadings via streams and shoreline seeps appear be responsible for the long-term shellfishing closures in Maquoit Bay.

- The two principal sources of fecal coliform bacteria (in order of relative importance) impacting Maquoit Bay are agriculture and residential land uses. Agricultural sources appear to be related to manure applications to hayfields. Although feedlot areas were not able to be pinpointed during the study, they are also suspected to be significant agricultural sources. Residential sources of fecal coliforms include failing septic systems and domestic pets. A few hydraulically-failing septic systems were actually observed in the field during the study period. Others were suspected based upon poor soils and age. Domestic animals (cats and dogs) represent a chronic and difficult-to-control source of fecal coliforms readily available for contamination into stormwater runoff.

- Under buildout conditions, nitrogen loading may threaten Maquoit Bay water quality. Three scenarios were examined: 1) no agricultural manure applications; 2) manure applications at average fertilization rates; and 3) manure applications at high fertilization rates. The results of these analyses indicate that under buildout conditions, nitrogen loading could approach 92% of the critical loading rate.

- Under buildout conditions, fecal coliforms continue to threaten Maquoit Bay water quality. Six buildout scenarios were examined (three rain events under both with and without agricultural manure applications). Even with a 50% decrease in agricultural acreage to accommodate the residential growth programmed by zoning, manure applications will continue to threaten water quality.

- The nitrogen loading and fecal coliform loading models are applicable to other coastal communities throughout the Maine coast. They can be used for both diagnostic purposes (trying to determine the relative contributions of sources to an existing water quality problem) and predictive purposes (to examine the adequacy of land use controls such as zoning).

- Average fecal coliform concentrations increased dramatically during stormflow conditions by several orders of magnitude for all three streams. However, nitrogen concentrations did not show significant increases during stormflow conditions. Two possible explanations are: 1) dissolved nitrogen is transported to the streams via groundwater flow during both baseflow and stormflow conditions and concentrations are therefore relatively constant, and 2) bacteria are transported as particulates during stormflow and are filtered as they flow subsurface through soil, and are therefore not observed during baseflow conditions in streams.

- The shoreline survey conducted by Horsley & Witten, Inc. revealed high fecal coliform concentrations at many seeps observed along the rocky shores of Merepoint Neck and Flying Point Neck. In summary, 5 out of 19 sites (26 %) had Fecal Coliform greater than 20,000 per 100 ml, 10 out 19 sites (52 %) had total nitrogen greater than 1 mg/l, and 3 out of 19 sites (16 %) had total phosphorous greater than 1 mg/l. Water from these sites discharges directly into Maquoit Bay. These results show fecal coliform and nutrients in excess of natural expected values with sufficient frequency and concentrations to indicate without question that some, if not all, septic systems near the shores of Flying Point and Merepoint Necks are not functioning as intended. These conditions warrant further quantitative investigations, perhaps leading to revision of the Maine Plumbing Code septic system regulations, and potentially revealing the need for further on-site treatment of sewage or sewering of the homes on the Necks.

- The test-site water quality data collected through the project, as well as the modeling results, indicate that agricultural lands are the greatest fecal coliform source in the watershed, even at background fecal coliform concentrations due to the large land area to which background concentrations are applied to modeled runoff.

Under the manure-application scenario, the agricultural lands in the subwatersheds of Bunganuc Stream, Wharton Point Stream and Rossmore Stream appear to load the greatest numbers of fecal coliforms to Maquoit Bay via their streams. Under background fecal coliform concentrations, which were developed directly off the test sites, the agricultural areas exhibit the greatest potential, as a predominant land use, to load fecal coliforms to the Bay via streams draining the watershed. Under buildout conditions, the runoff was predicted to increase significantly due to the increase in impervious surface area throughout the watershed. Fecal coliform loading is predicted to increase but concentrations are diluted by the increase in runoff.

- Prior water quality studies of Maquoit Bay suggest that the most significant fecal loadings (or "fluxes") are related to large storms. This finding corresponds to H&W observations, however, H&W did observe storm events, preceded by dry periods, which did not produce loadings of fecal coliform as large as would be expected. Thus a large storm-to-flux generalization should not be applied without taking into account watershed factors we have identified in the modeling approach. In addition to rainfall, H&W found factors such as watershed antecedent moisture conditions (AMCs), time since last large rainfall, and time since application of manure to be important.

- Two types of septic system failures occur within the Maquoit watershed: hydraulic and hydrogeologic. Hydraulic failures have been recognized by engineers as a clogging of the leaching area (either the holes in the leaching structure or the pore spaces in the surrounding soils) and the subsequent "backing-up" of sewage at the land's surface or within the house. These types of failures are easily observed when they occur and can be detected during lot-to-lot surveys if the inspector visits the property at the time of failure.

  A hydrogeologic failure occurs when the soils below and downgradient from the septic system cannot adequately filter the bacteria from the septic effluent during its residence time in the subsurface prior to discharge to a downgradient water body (or drinking water well). Several of the predominant soil types within the Maquoit watershed present severe and very severe limitations in this regard. For example, the "Hollis" soil is characterized by shallow bedrock (within 18" of the surface) providing little opportunity for the filtration of fecal coliform organisms. Most evident during this study were the hydrogeologic failures of septic systems located along the shorelines of Merepoint and Flying Point Neck which are in close proximity to Maquoit Bay.

- The FecaLOAD model developed as part of this project is capable of predicting fecal coliform loadings within one order of magnitude (x10) of actual concentrations. It appears to have excellent potential in assisting coastal communities to determine where sources of fecal coliform pollution may exist. It may also prove to be a useful tool in predicting future pollution problems associated with continued development in coastal areas. The model was calibrated with water quality data collected as part of this study over a one-year period. H&W recommends that the model be applied in other areas where water quality data exists (or where it can be developed) for further model validation purposes.

- Fecal coliform monitoring within Maquoit Bay should be revised to include sampling during (and immediately following) storm events. The results of this study clearly show that the most significant fecal loadings occur during storm events, and more specifically during the larger storm events (greater than 1 inch of precipitation). Such a monitoring program could lead to opening the shellfish beds in the upper bay during dry periods, limiting the shellfish closures to "rainfall closures".

- Future water quality sampling should include some analyses for viruses in water from the three principle streams and shoreline seeps. Preliminary analyses suggest that viruses from septic systems can survive for 800-1000 days at average temperatures in groundwater for this region (7-8°C).

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APPENDIX A

The FecaLOAD Model

User Guide

INTRODUCTION

FecaLOAD is a computer model designed to quantify fecal coliform bacteria loading from land uses in coastal watersheds. It was developed by Horsley & Witten, Inc. (H&W) in Microsoft® Excel (version 4.0), a spreadsheet program, and can be run on Macintosh® and IBM® compatible computers.

Fecal coliform bacteria (*Escherichia coli* and similar types) are considered indicators of the presence of pathogens through contamination by animal waste. The presence of such indicators are used by local and state health officials to decide whether coastal waters are safe for shellfishing or swimming.

Sources of these bacteria, their pathways through the watershed, loading coefficients, and attenuation mechanisms, identified through a literature review, have been incorporated into FecaLOAD and are explained in the text below. H&W developed FecaLOAD in 1994 to serve as both an analytical and a management tool for environmental and land use planners. Data required for FecaLOAD can be easily obtained from available government documents.

Stormwater runoff has been identified as the primary means of transport of potentially harmful pathogens into coastal waters. Coastal communities that were once thought to have pristine waters routinely experience "rainfall closures" of their shellfish beds. FecaLOAD was therefore designed to show fecal coliform inputs from land uses within coastal watersheds associated with runoff from a rainfall event.

FecaLOAD was applied and calibrated to three coastal watersheds at Maquoit Bay, Maine, using data on precipitation, runoff and water quality collected over a one year period. That calibration showed a close correlation between the model and field tests. This provided confidence that FecaLOAD can be useful as a management tool, and can be applied to other coastal watersheds in Maine.

This document is designed to help planners and local officials understand and best utilize the capabilities of FecaLOAD.

PURPOSE OF MODEL

The intended use of FecaLOAD is to calculate fecal coliform loading from the various land uses within a watershed. Environmental managers, land use planners and local officials can use FecaLOAD to evaluate water quality impacts from existing conditions as well as to provide predictions of impacts under differing development scenarios. These may range from specific proposed land use changes (e.g. creating a housing subdivision out of agricultural land) to conditions under a full buildout (if all the development within the watershed allowable with zoning bylaws were to be completed).

BACKGROUND INFORMATION: FECAL COLIFORM SOURCES, FATE, AND TRANSPORT

Sources of Fecal Coliforms

Non-point source pollution is primarily responsible for bacterial contamination to coastal waters. It is caused when rainwater or snow melt flows over land that has been affected by some sort of land use, such as commercial, industrial, residential, agriculture, grazing land, road surface, and open land (parks, beaches), and washes pollutants that have accumulated on those land surface into storm drains, streams, and rivers, and eventually into coastal waters.

The origin of the fecal coliform bacteria in non-point source pollution is humans, livestock, domestic pets and wildlife. Estimates of the number of fecal coliform organisms derived from each source are provided in Table 1. Wildlife, primarily waterfowl, and marinas have been found to contribute relatively minimal quantities of fecal coliform, except when they concentrate in areas where they are fed by people.[1]

The quantity of fecal coliform bacteria (number of organisms) contained in the runoff from a given rainfall event is classified as its bacterial load. Thus, loadings of fecal coliforms occur when stormwater runoff enters coastal waters.

Table 1. Sources of Fecal Coliform Organisms

Source	Estimated # of Fecal Coliforms/Source
Humans	2 billion fecal coliforms/day[2]
Dogs & Cats	5 billion fecal coliforms/day[3]
Cows	5 billion fecal coliforms/day[4]
Wildlife	10 million fecal coliforms/day[5]

Research has provided the ability to estimate the number of fecal coliform organisms typically generated by most of the common land uses. These are shown in detail in Appendix A.

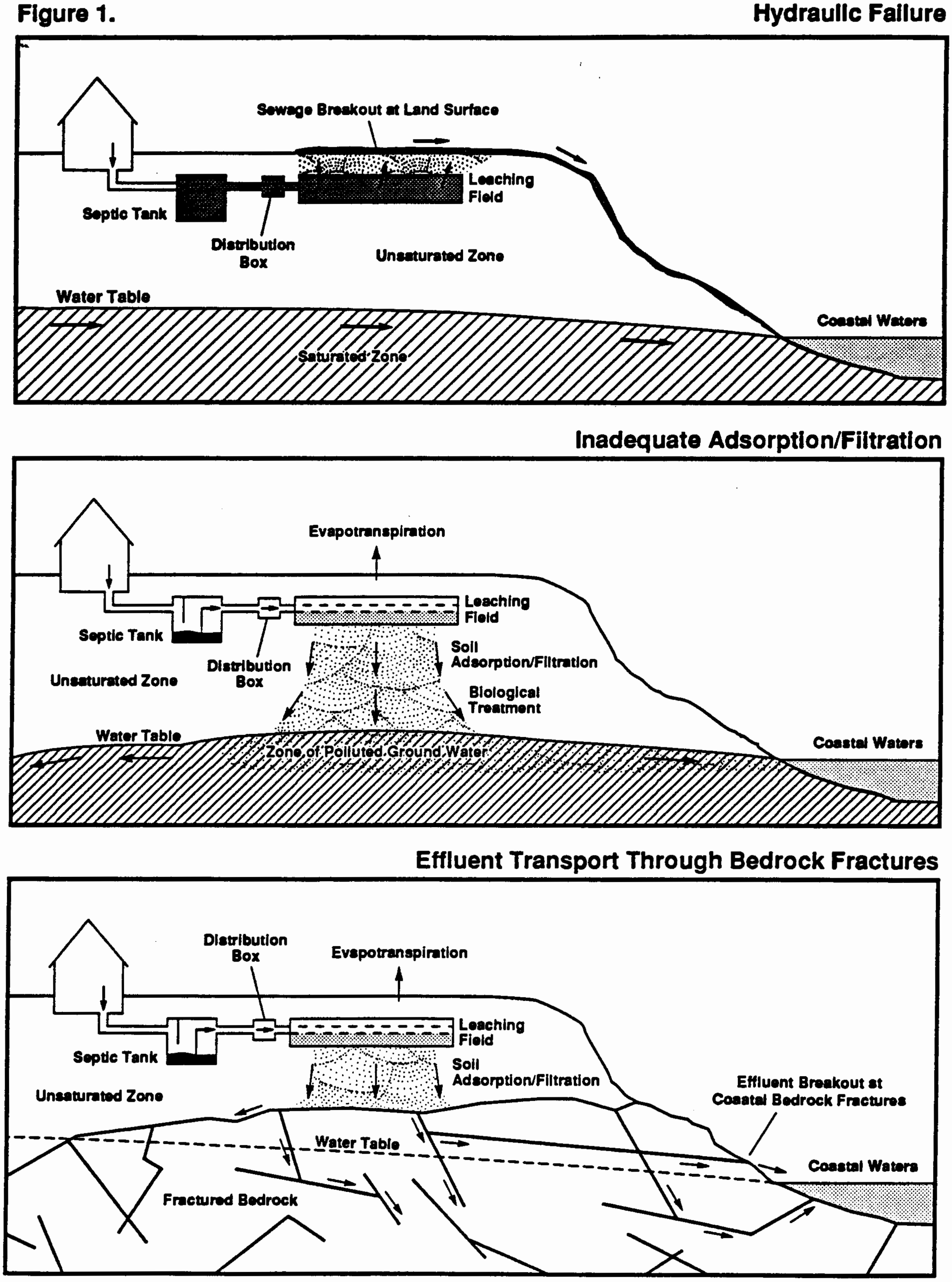
Fecal coliform derived from human waste is typically discharged into the subsurface environment via septic system effluent or into a wastewater collection system. Water quality impacts associated with septic effluent are minimized, or eliminated, through the use of properly functioning septic systems. However, where septic systems fail hydraulically (surface breakouts) or hydrogeologically (inadequate soils to attenuate bacteria) adverse impacts to downgradient surface waters may occur (Figure 1). In some instances septic systems are located within the water table. In these cases, maximum potential for contamination from fecal material is most likely to occur. Loading from sewered residences in the watershed is assumed, for the purposes of this discussion, not to occur due to standard disinfection practices associated with wastewater treatment plants.

Fecal coliform bacteria from livestock, domestic pets, and wildlife are deposited on the surface of the watershed. In rural areas, cow manure is typically applied to the ground surface as a crop fertilizer, a practice that greatly increases the amount of fecal coliforms available for entrainment in runoff. In residential and open land areas, dogs and cats commonly deposit fecal matter onto road surfaces and adjacent areas. Fecal coliforms that accumulate on road surfaces in residential, commercial, industrial, open land, and on major roads or highways are sources of fecal coliform loadings for those land uses.

Surface Transport of Fecal Coliforms

The primary transport mechanism for fecal coliform to a receiving water is stormwater runoff. The quantity of fecal coliform bacteria available for

Figure 1.


Hydraulic Failure
Sewage Breakout at Land Surface
Leaching Field
Septic Tank
Distribution Box
Unsaturated Zone
Water Table
Coastal Waters
Saturated Zone
Inadequate Adsorption/Filtration
Evapotranspiration
Leaching Field
Septic Tank
Soil Adsorption/Filtration
Distribution Box
Unsaturated Zone
Biological Treatment
Water Table
Coastal Waters
Zone of Polluted Ground Water
Effluent Transport Through Bedrock Fractures
Distribution Box
Evapotranspiration
Leaching Field
Septic Tank
Soil Adsorption/Filtration
Effluent Breakout at Coastal Bedrock Fractures
Unsaturated Zone
Water Table
Coastal Waters
Fractured Bedrock

entrainment in stormwater runoff is primarily a function of the amount of waste available, temperature, solar radiation, soil pH, and soil moisture. Because soil moisture is controlled by climatic conditions prior to the precipitation event, the timing of the rainfall or snow melt is also a significant factor because it will often determine how much water will be available for the "first flush" of the watershed. More details on each of the factors controlling fecal coliform quantities are provided below.

Temperature:

Studies on the effect of temperature on survival of coliform bacteria shows that they tend to die off as temperature increases.[6] Die-off rates are reported to approximately double with a 10 °C rise in temperature, at least for temperatures in the 5-30 °C range.[7]

Solar Radiation:

Bacteria die-off rates rise as exposure to sunlight is increased.[8] (There does seem to be some seasonal fluctuation to this general rule.[9]) Generally however, fecal coliforms derived from sources far from receiving waters experience more exposure to solar radiation during transport, and thus die off more readily than fecal coliforms derived from sources near receiving waters. Consequently, inputs originating farther from the receiving waters may be less important than those located closer to the water body.

Soil pH:

In general, bacteria survival decreases in low pH soils. Bacteria attenuation occurs in soils with pH levels between 3-4. Coliform bacteria survival is greatest in soils that are slightly acidic to neutral soils.[10]

Soil Moisture:

Survival time of bacteria increases with the moisture content of the soil.[11] This can be due to greater available moisture or the greater moisture-holding capacity of the soils. Soils rich in clay are capable of retaining larger volumes of water than other soils because of the ability of clay material to absorb water. Consequently, clay content increases soil moisture retention, and therefore bacteria survival.[12] Because the amount of water that runs off a land surface rather than percolating depends on the degree of soil saturation, wet soils generally have greater runoff and therefore have a greater ability to pick up and carry bacteria.

First Flush:

Because stormwater runoff is the primary transport mechanism for bacteria, larger rain events carry more bacteria from the watershed into adjacent waters. However, fecal coliform loading does not continually increase as the amount of rainfall increases. The first inch of rainfall typically removes most of the bacteria available for entrainment in runoff.[13] As rainfall exceeds one inch, fecal coliform concentrations will decrease significantly, even though total loading will continue to slightly increase.

Subsurface Transport of Fecal Coliforms

Septic effluent is the principal source of fecal coliforms found underground. Once below the surface, bacteria is removed from the effluent primarily through filtration and adsorption.[14] Filtration occurs during septic effluent percolation where the bacteria are too large to pass through pore spaces in the soil matrix. Adsorption is a process by which microorganisms adhere to clay particles in the soil. While these two processes are the primary means of attenuating bacteria that has been discharged directly into the subsurface, they also affect bacteria that infiltrates soil from the ground surface.

Filtration:

As bacteria are transported through the soil, their rate of removal is depends on the particle size of the soil.[15] Many bacteria are large enough to be filtered out as water percolates through soil pores, but fractured bedrock and coarse-grained soils such as gravels, which have larger spaces between particles, permit rapid movement. Thus, soils with smaller pores (silts and fine sands) are more efficient at removing bacteria than soils with larger pores such as coarse-textured soils. Most bacteria are filtered out within a distance of 4-100 feet in permeable sand.[16] Fractures in bedrock provide virtually no bacteria filtration, and bacteria can migrate significantly longer distances. Therefore, septic systems placed in soils with a shallow depth to bedrock (less than four feet) represent a more significant risk to downgradient waters.

Adsorption:

In addition to filtration, subsurface attenuation occurs when bacteria adhere to soil particles.[17] Bacteria are adsorbed more effectively by fine soils than coarser soils, generally because fine soils containing a higher content of clay material which has a high sorptive capacity.

Ranking of Pollution Potential
(FecaLOAD Qualitative Ranking System)

H&W developed a ranking system to predict potential fecal coliform pollution from non-sewered residential, agricultural, and pasture land uses. FecaLOAD automatically calculates rankings for these land uses so the model user does not have to. The ranking system is a function of hydrogeological conditions and proximity to receiving surface waters. The hydrogeological factors include 1) depth to seasonal high water table, 2) soil permeability, and 3) depth to bedrock. These are evaluated together in the NRCS County Soil Survey Table for Sanitary Facilities (Table 2) in which the suitability of each soil type is classified as Slight, Moderate, or Severe according to its difficulty in treating septic effluent (Table 2, second column: Septic tank absorption fields). If any of these factors cause the soil to be classified as Moderate or Severe, or if the land use is in close proximity to surface water, adverse impacts to downgradient surface waters may occur. This ranking approach is discussed below for non-sewered residential, agricultural, and pasture land.

Table 2. Example of NRCS Table of Sanitary Facilities

Soil name and map symbol	Septic tank absorption fields	Sewage lagoon areas	Trench sanitary landfill	Area sanitary landfill
CrB*:				
Charlton-----	Moderate: large stones.	Severe: seepage.	Severe: seepage.	Severe: seepage.
Rock Outcrop.				
Hollis-------	Severe: depth to rock.	Severe: depth to rock.	Severe: depth to rock.	Severe: seepage.
CrC*:				
Charlton-----	Moderate: Slope, large stones.	Severe: seepage, slope.	Severe: seepage.	Severe: seepage.
Rock outcrop.				
Hollis-------	Severe: depth to rock.	Severe: slope, depth to rock, seepage.	Severe: depth to rock, seepage.	Severe: seepage.
CrD*:				
Charlton-----	Severe: slope.	Severe: seepage, slope.	Severe: seepage.	Severe: seepage, slope.

Source: Soil Survey of Essex County, Massachusetts, Northern Part, USDA, Soil Conservation Service

Residential Land on Septic Systems

For residential land on septic systems, the Soil Suitability Rating and proximity to surface water combine in the manner shown in Table 3 to arrive at a Category Ranking, where Category I indicates no pollution potential, Category II indicates moderate pollution potential, and Category III indicates the greatest pollution potential.

Table 3. Qualitative Rankings for Residential Land Uses on Septic Systems

Proximity to Surface Water	NRCS Soil Suitability		
	Slight	Moderate	Severe
<100	Cat II	Cat III	Cat III
100-500	Cat II	Cat II	Cat III
>500	Cat I	Cat I	Cat II

The rationale for use of these factors is as follows: A septic system failure leading to surface break-out is typically caused by the inability of the underlying soil to assimilate the effluent due to one or a combination of hydrogeological factors. The effluent running over the surface not only exposes the contaminant but also provides a medium for its transport, thereby making the septic system a likely candidate for potential bacterial pollution of a water resource--but only if the septic system is in relatively close proximity to that resource. A poorly functioning septic system located high in the watershed and far away (more than 500 feet) from a stream poses less of a threat as a marginally functioning system located immediately adjacent to a stream. The lone exception to this is where septic effluent discharges onto a fractured bedrock aquifer near receiving waters. Because of the ability of effluent to travel longer distances through fractures, fecal coliform bacteria is more likely to reach surface water with minimal attenuation. To account for the elevated pollution potential associated with these conditions, residential land on septic systems in Severe soils located beyond 500 feet from surface water is considered Category II.

Agricultural and Pasture Land

The pollution potential of an agricultural area with manure spreading and/or livestock grazing is also dependent on proximity of the area to surface water and the ability of soils to attenuate manure-tainted runoff. For example, agricultural lands on thin soils (shallow depth to bedrock) with low permeability will become saturated by rainfall and display runoff rates greater than fields with deeper, more permeable soils. Manure spread on lands with shallow and/or poorly permeable soils and close to a surface water body represent a higher probability of causing bacterial pollution via stormwater runoff to downgradient surface waters than manure which is spread on thicker and/or more permeable soils located far from surface water.

For Agriculture and Pasture Land, the soil data and proximity to surface water combine in the manner shown in Table 4 to arrive at its Category Ranking, where Category I indicates no pollution potential, Category II indicates moderate pollution potential, and Category III indicates the greatest pollution potential.

Table 4. Qualitative Category Rankings for Agriculture and Pasture Land Uses

Proximity to Surface Water	NRCS Soil Suitability		
	Slight	Moderate	Severe
<100	Cat III	Cat III	Cat III
100-500	Cat II	Cat II	Cat III
>500	Cat I	Cat I	Cat I

Summary

In evaluating the multitude of environmental factors in microorganism transport and fate, no one factor can be singled out as the most influencing. Yates and Yates, writing in 1988, state that:

> "Upon examination of the models that have been developed to predict the fate of microorganisms, one notices that [biological, chemical and physical factors known to influence...bacterial survival and transport in the subsurface] are not explicitly addressed in the equations used in the models. This is most likely due to the fact that much of the known information is qualitative in nature, and that it is difficult, and sometimes impossible, to generalize the results of one or several experiments to all microorganisms of concern under all environmental conditions which may be encountered."[18]

Perhaps the most challenging aspect of modeling fecal coliform loading is the choice of which attenuation factors to incorporate into the model, given the wide range identified in the scientific literature. Attenuation coefficients are difficult to measure; in part because bacteria populations both grow and die off at varying rates based on one or more of the factors previously described. The parameters discussed above were selected for incorporation into FecaLOAD because they represent the most important environmental conditions affecting bacterial sources, fate, and transport, and are accessible to, and/or easily determined by, environmental managers and other model-users. Modeling coastal water quality using the FecaLOAD approach allows the model user to obtain the required data without the burden of cumbersome research, and produce reliable estimates of fecal coliform loadings and watershed runoff. Because of the frequency with which bacteria grow and die-off, modeling the amount of living bacteria at any one time must allow for these fluctuations. FecaLOAD was therefore calibrated to be able to predict fecal coliform loadings to within one order of magnitude of actual water quality data collected during a storm event.

WORKING THE MODEL; FecaLOAD DATA REQUIREMENTS

Where to get the Data

In order to run the FecaLOAD model, information on watershed/sub-watershed boundaries, local precipitation, hydrogeologic characteristics, and land uses must be obtained. This information comes from a variety of sources including local, state and federal government documents, and from the computerized databases maintained at the Casco Bay Estuary Project and the Maine Office of GIS. Where and how to obtain the required data for each input parameter is discussed below for both manual and GIS based methods.

Major coastal watershed boundaries have been mapped by the USGS Water Resources Division (USGS - WRD). Some of these areas have also been mapped on a sub-watershed level.

Precipitation Data

Precipitation data may be obtained via direct measurement from a rain gage or from the National Weather Service (NWS). The NWS can provide both current and historical information. If the user wishes to compare past water quality data relative to specific precipitation events, historical records are available from the NWS - Climatological Summary.

Data Required:
- Inches of rainfall for the storm event being modeled
- Time since last rainfall (in days)
- Amount of rainfall in previous five days (in inches)

Soil Characteristics

Information on soil characteristics is located in the U.S. Department of Agriculture - Natural Resource Conservation Service (NRCS) (formerly the Soil Conservation Service, or SCS) County Soil Survey. The NRCS County Soil Survey includes maps that define locations of different soil types (Figure 2), and a table of Sanitary Facilities (Table 2). Location of each soil type can be determined from the soils maps. The Soil Suitability Rating from the Sanitary Facilities Table is an expression of the combined effects of depth to seasonal high water table, depth to bedrock, and permeability.

Manual Method
Superimpose, or overlay, the soils map from the NRCS County Soil Survey with the Land Use map in order to determine the soil type beneath each land use.

GIS Method
Soils information for each soil type may be digitized from the NRCS maps, and the resulting soil units coded according to their Soil Suitability Rating.

Data Required:
Soil Suitability Rating for each soil type.

Land Use Data

Each land use carries its own loading coefficient which is included in the model. Consequently, the total acreage for each land use within a watershed must be determined. The best sources of information on land use is through the Casco Bay Estuary Project Land Use Maps (Figure 3). For some portions of coastal Maine, this information has been entered into a computerized GIS database. Check with the Maine Office of GIS or your Regional Planning Agency to see if computerized data for your watershed is available.

Land use maps typically categorize numerous land uses (Table 5). The Maine Office of GIS is in the process of updating information for 23 different land uses. FecaLOAD uses nine land use categories, therefore, some FecaLOAD categories incorporate more than one land use (Table 5).

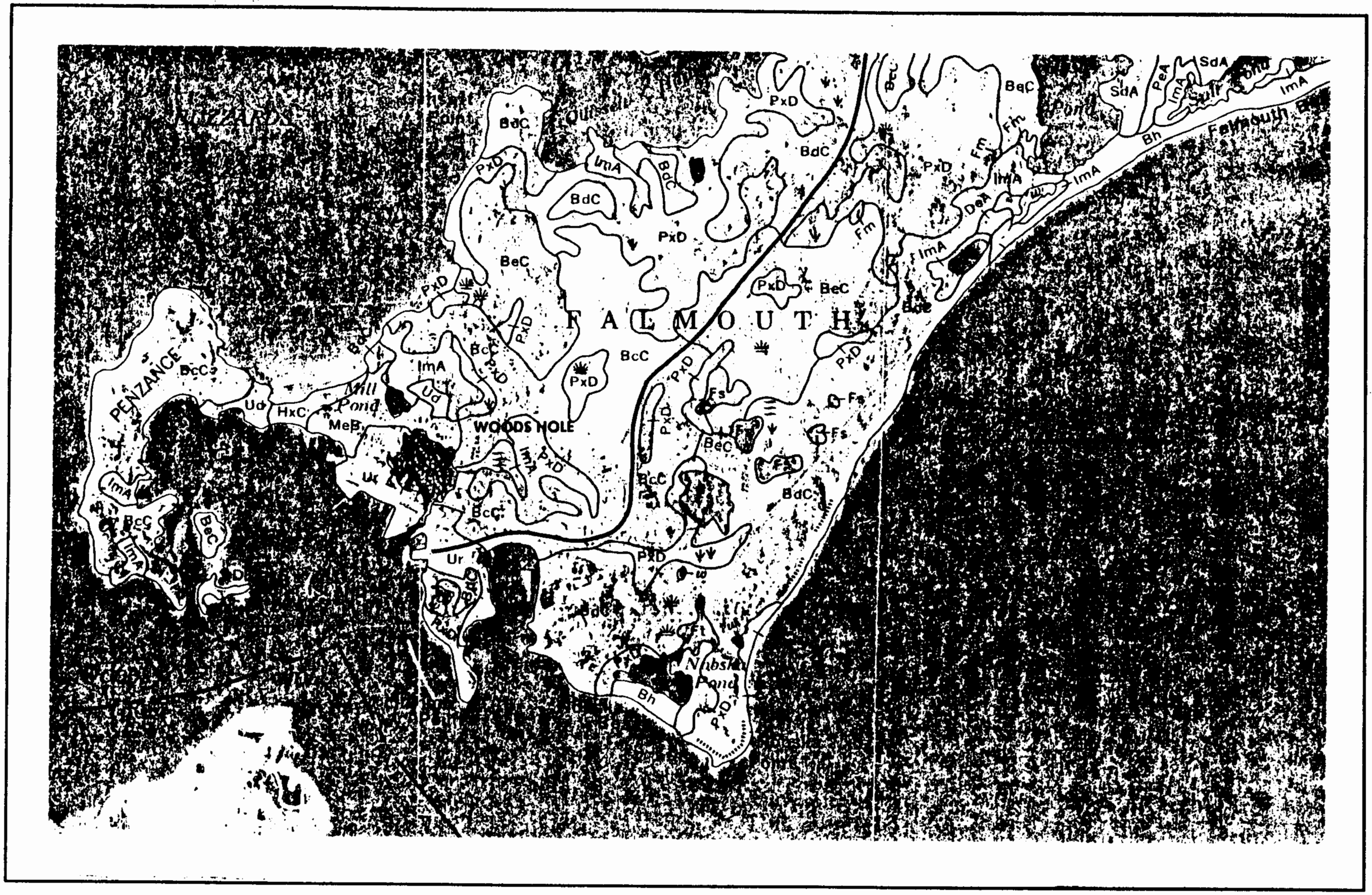


Figure 2.
Soil Survey Map Example

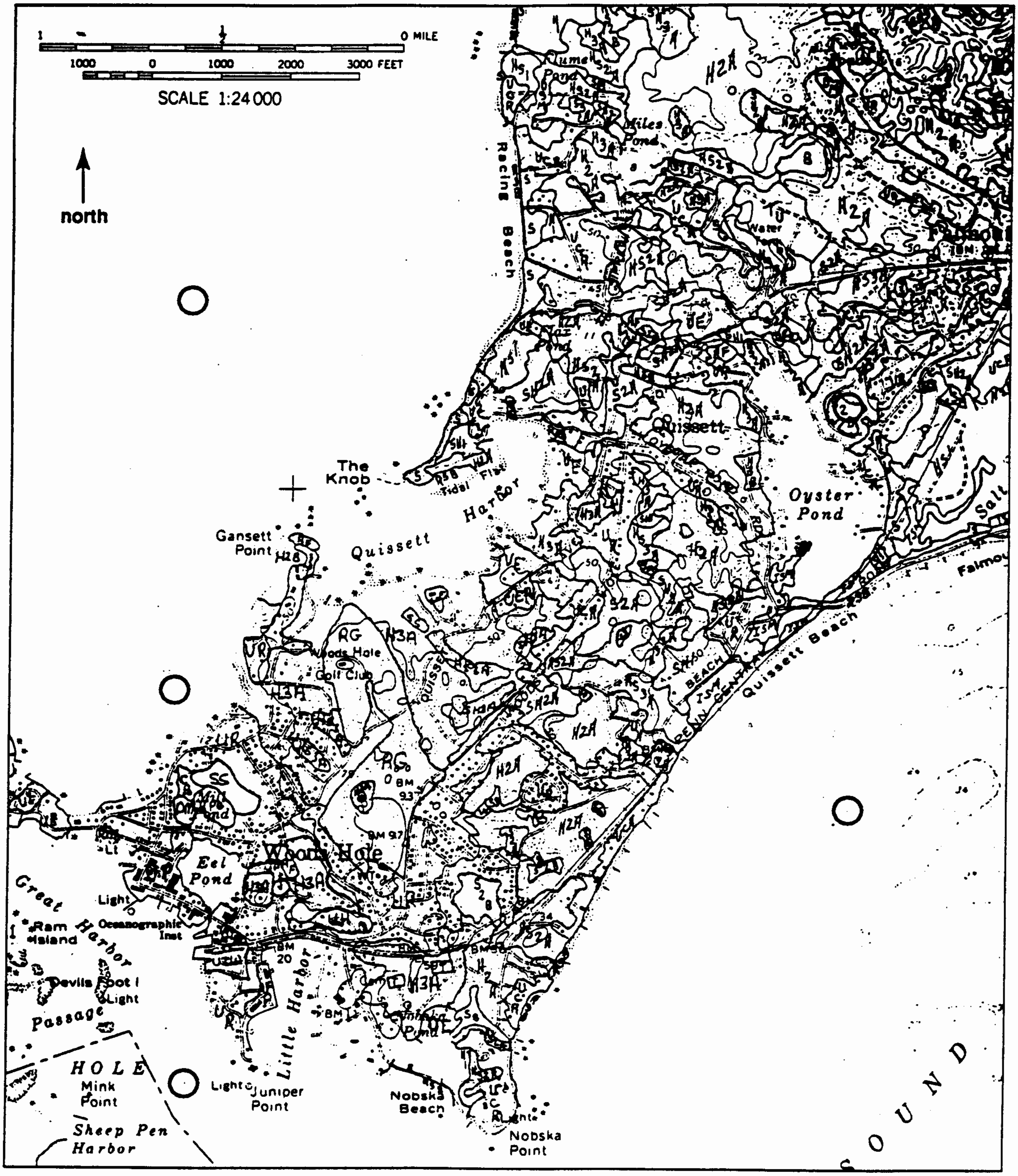


Figure 3.

Maconnell Land Use Map Example

Table 5. Land Use Classifications and Corresponding FecaLOAD Land Uses.

Land Use	Definition	Corresponding FecaLOAD Land Use
Cropland	Intensive Agriculture	Agriculture
Pasture	Extensive Agriculture	Pasture
Forest	Forest	Forest
Wetland	Nonforested Freshwater Wetland	Not Modeled
Mining	Sand, Gravel & Rock	Industrial
Open Land	Abandoned Agriculture, power lines, areas of no vegetation	Open Land
Participation Recreation	Golf, Tennis, Playgrounds, Skiing	Open Land
Spectator Recreation	Stadiums, Racetracks, Fairgrounds, Drive-ins	Open Land
Water Based Recreation	Beaches, Marinas	Open Land
Residential	Multi-family	Multifamily Residential
Residential	Smaller than 1/4 acre lots	High density Residential
Residential	1/4 - 1/2 acre lots	Medium density Residential
Residential	Larger than 1/2 acre lots	Low density Residential
Salt Wetland	Salt Marsh	Not Modeled
Commercial	General Urban, Shopping Center	Commercial
Industrial	Light & Heavy Industry	Industrial
Urban Open	Parks, Cemeteries, Public & Institutional Greenspace, also Vacant Undeveloped land	Open Land
Transportation	Airports, Docks, Divided Hwy., Freight Storage, Railroads	Commercial
Waste Disposal	Landfills, sewage lagoons	Not Modeled
Water	Fresh water, coastal embayment	Not Modeled
Woody Perennial	Orchard, Nursery, Cranberry bog	Agriculture

Existing Land Use Data

Available land use information may not be up-to-date, especially in rapidly growing coastal communities. Land uses in communities that have experienced increased development since the time when the land use maps were developed may be different, or partly different, than those shown on the Casco Bay Estuary Project or Maine Office of GIS land use maps. To reconcile any such differences, the Casco Bay Estuary Project or Maine Office of GIS maps should be compared to more up-to-date information from local Assessor's records, and the data updated accordingly. Acreage for each land use can be calculated directly from the Assessor's maps, or can be transferred from the Assessor's maps to a USGS topographic map and then calculated.

Once land uses within the watershed have been identified, a spreadsheet should be developed which sub-divides each land area by: 1) number of dwellings, 2) proximity to surface water, 3) whether the land area is sewered or on septic, 4) acreage, and 5) zoning (Table 4). This information constitutes existing land use conditions in the watershed.

Table 4. Example Table of Input Data

Land Use	Soil Suitability Rating	Proximity to Surface Waters	Sewered	Acres	Zoning Code
Agriculture	Moderate	<100	N	2.60	RRA
Agriculture	Moderate	>500	Y	4.10	RRA
Commercial	Severe	<100	Y	8.64	C
Commercial	Severe	100-500	Y	0.08	I
Forest	Moderate	<100	N	25.34	RRA
Industrial	Severe	>500	Y	0.02	I
Industrial	Severe	<100	Y	5.03	I
Pasture	Severe	100-500	N	27.96	RRA
Resid 1/4 - 1/2 Acre	Severe	<100	N	0.86	RRA
Resid < 1/4 Acre	Moderate	100-500	N	6.70	RRA
Resid < 1/4 Acre	Slight	<100	N	1.68	RRA
Resid < 1/4 Acre	Severe	>500	Y	4.95	RRA
Resid > 1/2 Acre	Severe	100-500	N	6.00	RRA
Open Land	Severe	100-500	N	2.96	RRA
Open Land	Moderate	100-500	Y	1.16	RRA

Total Watershed Acreage = 98.08

These data will be used by FecaLOAD to rank the pollution potential of residential, agriculture, and pasture land uses according to the Soil Suitability Rating of the underlying soil, as well as their proximity to surface water. This ranking system is addressed in detail in Ranking of Pollution Potential (FecaLOAD Qualitative Ranking System).

Land Use Data Required:

- commercial acreage
- industrial acreage
- residential acreage on sewer systems
- residential acreage on septic systems (for low, medium, and high density, and multi-family areas)
- number of dwellings on sewer systems
- agricultural (croplands) acreage
- pasture (in use for livestock) acreage
- open land acreage
- forested land

Sources of this information are listed below for manual as well as GIS-based methods.

Manual Method

Commercial Acreage:
Commercial land acreage may be determined using a Planimeter to trace the boundaries of commercial land areas occurring within the watershed on the Casco Bay Estuary Project land use maps, or from topographic or Assessors' maps--provided the commercial land information has been transferred to the latter two. Commercial acreage can also be measured from aerial photographs.

Industrial Acreage:
Same method as above.

Open Land Acreage:
Same method as above.

Residential Acreage:
Residential acreage is determined by totaling the acreage for each type of residential land use (low, medium, and high density, and multi-family). This is done using a planimeter as described above (Commercial Acreage).

The number of residential dwellings in the watershed is needed because, for residential areas, fecal coliform loading is attributable, in part, to the number of dwellings for each residential land use. Determining the number of dwellings may be done directly by counting the number of dwellings from the local assessors maps or doing a "windshield survey" (driving around and counting houses). It can also be done indirectly by FecaLOAD. In the event that direct data is not available, FecaLOAD is designed to automatically calculate the number of dwellings based on acreages of each residential category and their corresponding housing density factors as follows:

Multi-family: 5.0 dwellings/acre
High density (less than 1/4 acre lots): 3.7 dwellings/acre
Medium density (1/4 - 1/2 acre lots): 2.0 dwellings/acre
Low density (greater than 1/2 acre lots): 1.0 dwellings/acre

To indirectly determine the number of dwellings, multiply the number of acres of the land area by the housing density value of the residential category. Once the total number of dwellings has been estimated, the number of residences that are serviced by septic and sewer systems must be determined. FecaLOAD calculates loading and runoff from residences on septic systems; only runoff is calculated for sewered residences. The municipal Department of Public Works, Town Engineer, or the local Planning Department should have a map of sewered areas within the community.

Agriculture:
Information of location of agricultural areas may be available at the local Agricultural Extension Office of the NRCS. Other sources of information include the Maine Department of Agriculture, and local Planning/Zoning offices. As with commercial and industrial land discussed above, it is possible to identify the boundaries of agricultural land through a "windshield survey". These boundaries must then be transferred to a topographic or Assessors' map.

Determining the agriculture acreage that receives manure as fertilizer is difficult. This information may be obtained from Agricultural Extension Office or the farmers themselves. This information is sometimes considered proprietary and not readily available.

Once the agricultural areas have been transferred to a map, the acreage can be determined using a planimeter.

Pasture and Livestock:
Information on pasture acreage may be obtained from the Agricultural Extension Office, Town Planning Department, directly from farmers, or through a "windshield survey". The model requires that, for pasture land in the watershed, a number be entered for the average number of livestock per acre. "Livestock" actually means large animals, thus horses are also included in this number. Medium sized farm animals such as goats, pigs, and sheep are considered 1/3 that of a large farm animal. The number of livestock per acre may be obtained from similar sources. The latter information is sometimes considered proprietary and not readily available.

GIS Method

Land use information can be obtained from the Maine Office of GIS, the Casco Bay Estuary Project, a Regional Planning Agency, or, in some cases, through the municipal Planning Department. The Casco Bay Estuary Project maintains land use data for communities located between Kittery and Wisscasset. If your watershed is located outside this area, contact your local Planning Agency.

Commercial:
Commercial land is one of the features identified on the land use maps. The Casco Bay Estuary Project has these data and the acreage for each watershed may be derived from them.

Industrial:
Same as above.

Open Land:
Same as above.

Residential:
As with the data for Commercial, Industrial and Open Land, Residential land for low, medium, and high density, and multi-family may be derived from the Land Use maps digitized and stored in the Casco Bay Estuary Project database.

The total number of dwellings may be estimated by multiplying the total of each residential category by the factors provided above.

Once the total number of dwellings is known, this information must be related with location of sewered residences to determine the number of residences on septic and sewer systems. Regional Planning agencies maintain this information in GIS format for some communities. If it is not available on a GIS database, use the manual methodology to determine the number of residences on septic and sewer systems.

Agriculture:
Same as above.

GIS does not contain information necessary for determining the agriculture acreage that receives manure as fertilizer. It may be possible to obtain this information from Agricultural Extension Office or the farmers themselves. This information is sometimes considered proprietary and not readily available.

Pasture and Livestock:
Pasture acreage may be determined from the Casco Bay Estuary Project land use coverage. It may be possible to obtain information on numbers of livestock per acre from the Agricultural Extension Office, Town Planning Department, or directly from farmers. This information is sometimes considered proprietary and not readily available.

Buildout Land Use Data

By including zoning in the Input Data spreadsheet as shown in Table 4, the user can model fecal coliform loading from future land use conditions, such as full-development, or buildout, conditions. Local zoning maps and bylaws/ordinances should be consulted to determine the extent to which land areas within each land use category may be developed.

Buildout scenarios are based not only on local zoning, but also the minimum lot size and minimum road frontage requirements for each community. Since these bylaws/ordinances vary from one community to another, contact the local Assessors office for this information. Once this information has been obtained, each land area may be built-out by determining the maximum number of dwellings allowable for the size of the land area. A simplified example is provided below:

Land area acreage: 6 acres
Number of Existing Dwellings: 2
Minimum Lot Size (Bylaw or Ordinance): 2 acre

In this example, because of the minimum 2 acre zoning requirement, there would be one additional dwelling added to this land area under full buildout conditions. If the minimum lot size requirement was 1 acre zoning, there could be 4 dwellings added to the land area. It is important to keep in mind that this buildout is based only on minimum lot size. In many communities, there are additional conditions, such as minimum road frontage, that must also be met to develop land.

Building out a watershed results in a conversion of land use from its existing state to a more developed state. The example above demonstrates how dwellings are added to residentially zoned land. Agriculture, Pasture, and Open land may also be converted to residential areas if it is permitted by zoning. Commercial and Industrial land may be expanded providing the expansion is within the allowable limit of the minimum lot requirement. From a modeling standpoint, converting land from one land use to another, or intensifying the existing use of the land, results in a corresponding change in runoff and fecal coliform loading when it rains.

The same type of input data as shown in Table 4 is required for modeling buildout conditions. The only difference between existing and buildout land use conditions is that existing conditions is determined directly from current document/maps, whereas buildout conditions are determined from the existing land use data, zoning maps, and bylaws/ordinances. Thus, existing conditions must first be established in order to be able to determine buildout conditions.

Once all land areas have been built-out, the data is put into the same format as that shown in Table 4.

Roads

Road length (in feet) must be determined for all roads passing through each land use in the watershed. This includes a breakdown of road length through each residential land use (low, medium, and high density, and multi-family). It can be measured directly from a USGS topographic map or Assessors' map. Road length for each land use must then be added to the input data spreadsheet. Average road widths for each land use are incorporated into FecaLOAD. These values can be found in Appendix A. For roads bounded by two different land use types, the segment length will have to be divided in two with half attributed to each land use category.

Roads that are located within areas classified as Recreation fall under the Open Land category. Roads that are located within areas classified as wetlands and open water (bridges) are not modeled. Fecal coliform loadings from domestic animals such as dogs and cats are included in the runoff from road surfaces for residential and open land uses. In some instances, birds congregating on bridges provide direct input of fecal matter into surface water bodies; however, the level of precision of the model does not account for these isolated situations.

Data Required:

Road Length (in feet) for:

- Commercial/Industrial Land
- Low Density Residential Land
- Medium Density Residential Land
- High Density Residential Land
- Multifamily Residential Land
- Major Roads/Highways Land
- Open Land
- Agricultural Land
- Pasture Land
- Forested Land

FecaLOAD DATA ENTRY

FecaLOAD is designed for ease of data entry. Since FecaLOAD is a Microsoft® Excel spreadsheet, data is entered into rectangular boxes called "cells". These cells are identified by a letter-number combination which designates where in the spreadsheet the column (letter) and row (number) meet, much like coordinates on a graph. The sections of FecaLOAD where model inputs are entered and model output is generated are provided in Appendix B. Step-by-step instructions on how data is entered into FecaLOAD are listed below.

Heading Information (Column B):

1. Enter the watershed name in B2.
2. Enter Land Use Conditions (Existing or Buildout) in B3.

Land Use Inputs (Column E):

3. Enter the number of acres of Commercial Land in E5.
4. Enter the number of acres of Industrial Land in E6.
5. Enter the number of acres of Open Land in E7.
6. Enter the number of acres of Sewered Residential Land (total for all residential categories) in E8.
7. Enter the number of acres of Forested Land in E9.

Note: Information in this section will be combined with the hydrologic inputs to calculate volume of stormwater runoff for the watershed.

Residential Acreage on Septic Systems (Column E):

Each category of residential land is further subdivided by Soil Suitability and Proximity to Surface Water. The number of acres of each residential category is required for all combinations of these two parameters.

8. Enter acres of Low Density Residential in Severe Soils and <100 feet to surface water in E10.
9. Enter acres of Low Density Residential in Severe Soils and between 100-500 feet to surface water in E11.
10. Enter acres of Low Density Residential in Severe Soils and >500 feet to surface water in E12.
11. Enter acres of Low Density Residential in Moderate Soils and <100 feet to surface water in E13.
12. Enter acres of Low Density Residential in Moderate Soils and between 100-500 feet to surface water in E14.
13. Enter acres of Low Density Residential in Moderate Soils and >500 feet to surface water in E15.
14. Enter acres of Low Density Residential in Slight Soils and <100 feet to surface water in E16.
15. Enter acres of Low Density Residential in Slight Soils and between 100-500 feet to surface water in E17.
16. Enter acres of Low Density Residential in Slight Soils and >500 feet to surface water in E18.
17. Enter acres of Medium Density Residential in Severe Soils and <100 feet to surface water in E19.
18. Enter acres of Medium Density Residential in Severe Soils and between 100-500 feet to surface water in E20.
19. Enter acres of Medium Density Residential in Severe Soils and >500 feet to surface water in E21.
20. Enter acres of Medium Density Residential in Moderate Soils and <100 feet to surface water in E22.
21. Enter acres of Medium Density Residential in Moderate Soils and between 100-500 feet to surface water in E23.

22. Enter acres of Medium Density Residential in Moderate Soils and >500 feet to surface water in E24.
23. Enter acres of Medium Density Residential in Slight Soils and <100 feet to surface water in E25.
24. Enter acres of Medium Density Residential in Slight Soils and between 100-500 feet to surface water in E26.
25. Enter acres of Medium Density Residential in Slight Soils and >500 feet to surface water in E27.
26. Enter acres of High Density Residential in Severe Soils and <100 feet to surface water in E28.
27. Enter acres of High Density Residential in Severe Soils and between 100-500 feet to surface water in E29.
28. Enter acres of High Density Residential in Severe Soils and >500 feet to surface water in E30.
29. Enter acres of High Density Residential in Moderate Soils and <100 feet to surface water in E31.
30. Enter acres of High Density Residential in Moderate Soils and between 100-500 feet to surface water in E32.
31. Enter acres of High Density Residential in Moderate Soils and >500 feet to surface water in E33.
32. Enter acres of High Density Residential in Slight Soils and <100 feet to surface water in E34.
33. Enter acres of High Density Residential in Slight Soils and between 100-500 feet to surface water in E35.
34. Enter acres of High Density Residential in Slight Soils and >500 feet to surface water in E36.
35. Enter acres of Multi-family Residential in Severe Soils and <100 feet to surface water in E37.
36. Enter acres of Multi-family Residential in Severe Soils and between 100-500 feet to surface water in E38.
37. Enter acres of Multi-family Residential in Severe Soils and >500 feet to surface water in E39.
38. Enter acres of Multi-family Residential in Moderate Soils and <100 feet to surface water in E40.
39. Enter acres of Multi-family Residential in Moderate Soils and between 100-500 feet to surface water in E41.
40. Enter acres of Multi-family Residential in Moderate Soils and >500 feet to surface water in E42.
41. Enter acres of Multi-family Residential in Slight Soils and <100 feet to surface water in E43.
42. Enter acres of Multi-family Residential in Slight Soils and between 100-500 feet to surface water in E44.
43. Enter acres of Multi-family Residential in Slight Soils and >500 feet to surface water in E45.

Residential Dwellings on Septic Systems (Column F) - ENTRY NOT REQUIRED: The number of residential dwellings for each residential category is required for all combinations of these two parameters. *THESE DATA ARE NOT REQUIRED TO BE ENTERED. FecaLOAD WILL AUTOMATICALLY CALCULATE THE NUMBER OF DWELLINGS FOR EACH RESIDENTIAL CATEGORY BASED ON THEIR ACREAGES AND THE LAND USE HOUSING DENSITY VALUES.* However, if the model user prefers to enter these data instead, this is done in Column F.

44. Enter acres of Low Density Residential in Severe Soils and <100 feet to surface water in F10.
45. Enter acres of Low Density Residential in Severe Soils and between 100-500 feet to surface water in F11.
46. Enter acres of Low Density Residential in Severe Soils and >500 feet to surface water in F12.
47. Enter acres of Low Density Residential in Moderate Soils and <100 feet to surface water in F13.
48. Enter acres of Low Density Residential in Moderate Soils and between 100-500 feet to surface water in F14.
49. Enter acres of Low Density Residential in Moderate Soils and >500 feet to surface water in F15.
50. Enter acres of Low Density Residential in Slight Soils and <100 feet to surface water in F16.

51. Enter acres of Low Density Residential in Slight Soils and between 100-500 feet to surface water in E17.
52. Enter acres of Low Density Residential in Slight Soils and >500 feet to surface water in F18.
53. Enter acres of Medium Density Residential in Severe Soils and <100 feet to surface water in F19.
54. Enter acres of Medium Density Residential in Severe Soils and between 100-500 feet to surface water in F20.
55. Enter acres of Medium Density Residential in Severe Soils and >500 feet to surface water in F21.
56. Enter acres of Medium Density Residential in Moderate Soils and <100 feet to surface water in E22.
57. Enter acres of Medium Density Residential in Moderate Soils and between 100-500 feet to surface water in F23.
58. Enter acres of Medium Density Residential in Moderate Soils and >500 feet to surface water in E24.
59. Enter acres of Medium Density Residential in Slight Soils and <100 feet to surface water in F25.
60. Enter acres of Medium Density Residential in Slight Soils and between 100-500 feet to surface water in F26.
61. Enter acres of Medium Density Residential in Slight Soils and >500 feet to surface water in F27.
62. Enter acres of High Density Residential in Severe Soils and <100 feet to surface water in F28.
63. Enter acres of High Density Residential in Severe Soils and between 100-500 feet to surface water in F29.
64. Enter acres of High Density Residential in Severe Soils and >500 feet to surface water in F30.
65. Enter acres of High Density Residential in Moderate Soils and <100 feet to surface water in F31.
66. Enter acres of High Density Residential in Moderate Soils and between 100-500 feet to surface water in F32.
67. Enter acres of High Density Residential in Moderate Soils and >500 feet to surface water in F33.
68. Enter acres of High Density Residential in Slight Soils and <100 feet to surface water in F34.
69. Enter acres of High Density Residential in Slight Soils and between 100-500 feet to surface water in F35.
70. Enter acres of High Density Residential in Slight Soils and >500 feet to surface water in F36.
71. Enter acres of Multi-family Residential in Severe Soils and <100 feet to surface water in F37.
72. Enter acres of Multi-family Residential in Severe Soils and between 100-500 feet to surface water in F38.
73. Enter acres of Multi-family Residential in Severe Soils and >500 feet to surface water in F39.
74. Enter acres of Multi-family Residential in Moderate Soils and <100 feet to surface water in F40.
75. Enter acres of Multi-family Residential in Moderate Soils and between 100-500 feet to surface water in F41.
76. Enter acres of Multi-family Residential in Moderate Soils and >500 feet to surface water in F42.
77. Enter acres of Multi-family Residential in Slight Soils and <100 feet to surface water in F43.
78. Enter acres of Multi-family Residential in Slight Soils and between 100-500 feet to surface water in E44.
79. Enter acres of Multi-family Residential in Slight Soils and >500 feet to surface water in F45.

Agricultural Acreage (Column E):

Agricultural Land is further subdivided by Soil Suitability and Proximity to Surface Water. The number of acres of Agricultural Land is required for all combinations of these two parameters.

80. Enter Agricultural Land in Severe Soils and <100 feet to surface water in E46.
81. Enter Agricultural Land in Severe Soils and between 100-500 feet to surface water E47
82. Enter Agricultural Land in Severe Soils and >500 feet to surface water in E48.
83. Enter Agricultural Land in Moderate Soils and <100 feet to surface water in E49.

84. Enter Agricultural Land in Moderate Soils and between 100-500 feet to surface water E50.
85. Enter Agricultural Land in Moderate Soils and >500 feet to surface water in E51.
86. Enter Agricultural Land in Slight Soils and <100 feet to surface water in E52.
87. Enter Agricultural Land in Slight Soils and between 100-500 feet to surface water E53.
88. Enter Agricultural Land in Slight Soils and >500 feet to surface water in E54.

Pasture Acreage (Column E):

Pasture Land is further is further subdivided by Soil Suitability and Proximity to Surface Water. The number of acres of Pasture Land is required for all combinations of these two parameters.

89. Enter acres of Pasture Land in Severe Soils and <100 feet to surface water in E55.
90. Enter acres of Pasture Land in Severe Soils and between 100-500 feet to surface water in E56.
91. Enter acres of Pasture Land in Severe Soils and >500 feet to surface water in E57.
92. Enter acres of Pasture Land in Moderate Soils and <100 feet to surface water in E58.
93. Enter acres of Pasture Land in Moderate Soils and between 100-500 feet to surface water in E59.
94. Enter acres of Pasture Land in Moderate Soils and >500 feet to surface water in E60.
95. Enter acres of Pasture Land in Slight Soils and <100 feet to surface water in E61.
96. Enter acres of Pasture Land in Slight Soils and between 100-500 feet to surface water in E62.
97. Enter acres of Pasture Land in Slight Soils and >500 feet to surface water in E63.

Land Uses Not Modeled (Column E):

98. Enter acres of Salt Wetland in E66.
99. Enter acres of Freshwater Wetland in E67.
100. Enter acres of Water in E68.
101. Enter acres of Waste Disposal Land in E69.

Total Watershed Acreage (Column B)

102. Enter the total watershed acreage in B71.

This number should come from the raw data sheet, and should equal the number in B72. The number in B72 is automatically calculated, and represent the sum total of all acreages entered. Comparing the number in B71 with the auto-calculated number in B72 allows the model user to see if any acreages have not been entered or have been entered incorrectly.

Average Number Livestock/acre (Column B):

103. Enter the average number of Livestock per acre for all pasture land in B77.

Days Between Grazing (Column B):

Note: The default number of days between grazing is 1 (cell B78). The default value can be changed if more accurate information is available.

Road Runoff (Column B):

104. Enter Road Length (feet) for Low Density Residential in B81.
105. Enter Road Length (feet) for Medium Density Residential in B82.
106. Enter Road Length (feet) for High Density Residential in B83.
107. Enter Road Length (feet) for Multi-family Residential in B84.
108. Enter Road Length (feet) for Major Roads/Highways in B85.
109. Enter Road Length (feet) for Commercial/Industrial in B86.

110. Enter Road Length (feet) for Open Land in B87.
111. Enter Road Length (feet) for Agricultural in B88.
112. Enter Road Length (feet) for Pasture in B89.
113. Enter Road Length (feet) for Forest in B90.
114. Enter Road Length (feet) for Wetlands in B91.
115. Enter Road Length (feet) for Water (bridges) in B92.
116. Enter Road Length (feet) for Recreation in B93.

Note: Average road widths, shown in Appendix A, can be changed if more accurate information is available. These values are located in FecaLOAD as follows:

Low Density Residential:	cell V70 (hidden)
High Density Residential:	cell V71 (hidden)
Major Roads/Highways:	cell V72 (hidden)
Commercial/Industrial	cell V73 (hidden)
Open Land:	cell V74 (hidden)
Agriculture/Pasture/Forest:	cell V75 (hidden)

The acreage of road surface is automatically calculated by FecaLOAD and incorporated into the runoff calculations from roads.

After the Land Use and Road Length Data have been entered, columns A-F should be hidden so that the only part of the model showing is the summary table (shown in Appendix B). Changes to the land use data can still be made by unhiding those columns if the model user desires.

Summary Table Inputs:

117. Enter the rainfall (in inches) of the known or predicted storm event to be modeled in AY5.
118. Enter the time (as number of days) since previous rainfall in AY6.
119. Enter the total rainfall (in inches) for the previous 5 days in AY7.
120. Enter the time of year of the rainfall event (season) in AY8.
121. Enter the number of days since manure was last applied in AY9.

Note1: 90% of all storm events that occur in coastal communities in Maine are approximately 0.5 inches.

Note2: Input numbers 118 and 119 above will be used by FecaLOAD to determine Antecedent Moisture Conditions (or AMC). Antecedent Moisture Conditions control the fraction of a given rainfall event that will become stormwater runoff.

Note3: The default rate of manure application is 10 tons/acre/year (cell B75). The default value can be changed if more accurate information is available.

There are no further model inputs to be made.

Evaluating FecaLOAD Output

FecaLOAD's user-friendly design enables land use and environmental managers to assess the impact of current and future land use conditions on downgradient surface waters without the burden of complex data management.

The summary table is designed to provide model output for runoff and fecal coliform loading by simply changing the hydrologic inputs and the time of year of the rainfall event.

FecaLOAD output for watershed runoff, total fecal coliform loading, and average fecal coliform concentration in the runoff can be compared to historical water quality and runoff data if such data are available. The model user can recreate the hydrologic conditions at the time of sampling by entering in the hydrologic data into the summary table, and comparing actual field data with the model output. If no historical data is available, communities can initiate a storm water sampling program to determine the extent of bacterial contamination in watershed runoff.

The U.S. Environmental Protection Agency and the State of Maine have established thresholds for number of fecal coliform organisms for shellfishing and swimming. These are:

Shellfishing:	14 fecal coliforms/100 ml
Swimming:	200 fecal coliforms/100 ml

If water quality testing of coastal areas determines that these thresholds have been exceeded, shellfish beds and/or beaches may be closed as a result. Land use and environmental managers may therefore evaluate FecaLOAD output in terms of these standards when formulating strategies to control or mitigate loadings of potentially harmful pathogens to coastal waters via non-point source pollution.

Footnotes

1 U.S. Environmental Protection Agency, 1988, Bacteriological Monitoring in Buttermilk Bay, EPA 503/4-88-001, Washington, D.C.

2 Converse et al., 1991.

3 Koppelman, et al., 1982, Long Island Segment of the National Urban Runoff Program, Long Island Regional Planning Board, Hauppauge, NY.

4 Koppelman, et al., 1982, Long Island Segment of the National Urban Runoff Program, Long Island Regional Planning Board, Hauppauge, NY.

5 Novotny and Olem, 1994, Water Quality: Prevention, Identification and Management of Diffuse Pollution, New York, Van Nostrand Reinhold.

6 Yates and Yates, 1988, Modeling Microbial Fate in the Subsurface Environment, Critical Reviews in Environmental Control, vol. 17, issue 4, CRC Press.

7 Reddy, et al., 1981, Behavior and Transport of Microbial Pathogens and Indicator Organisms in Soils Treated with Organic Wastes, Journal of Environmental Quality, vol. 10, no. 3.

8 Moore, et al, 1982, Evaluating Dairy Waste Management Systems' Influence on Fecal Coliform Concentration in Runoff, Department of Agricultural Engineering, Agricultural Experiment Station Bulletin 658, Oregon State University, Corvallis.

9 Reddy, et al., 1981, Behavior and Transport of Microbial Pathogens and Indicator Organisms in Soils Treated with Organic Wastes, Journal of Environmental Quality, vol. 10, no. 3.

10 Yates and Yates, 1988, Modeling Microbial Fate in the Subsurface Environment, Critical Reviews in Environmental Control, vol. 17, issue 4, CRC Press.

11 Teutsch, et al., 1991, Transport of Microorganisms in the Underground-Processes, Experiments and Simulation Models, Water Science Technology, vol. 24, no. 2.

12 Reddy, et al., 1981, Behavior and Transport of Microbial Pathogens and Indicator Organisms in Soils Treated with Organic Wastes, Journal of Environmental Quality, vol. 10, no. 3.

13 Moore, et al, 1982, Evaluating Dairy Waste Management Systems' Influence on Fecal Coliform Concentration in Runoff, Department of Agricultural Engineering, Agricultural Experiment Station Bulletin 658, Oregon State University, Corvallis.

14 United States Environmental Protection Agency, 1987, Septic Tank Siting to Minimize the Contamination of Ground Water by Microorganisms, Washington, D.C., Government Printing Office.

15 United States Environmental Protection Agency, 1987, Septic Tank Siting to Minimize the Contamination of Ground Water by Microorganisms, Washington, D.C., Government Printing

Office.

16 Reddy, et al., 1981, Behavior and Transport of Microbial Pathogens and Indicator Organisms in Soils Treated with Organic Wastes, Journal of Environmental Quality, vol. 10, no. 3.

17 Loehr, et al., 1979, Land Application of Wastes, Van Nostrand Reinhold, New York.

18 Yates and Yates, 1988, Modeling Microbial Fate in the Subsurface Environment, Critical Reviews in Environmental Control, vol. 17, issue 4, CRC Press.

APPENDIX A. Values for Fecal Coliform Loading, Concentration, and Road Width Used in FecaLOAD

Average Daily Loading of Fecal Coliform

Human Sources	Range of Literature Values	Selected Model Input
Septic Effluent Concentration: Reference (1)	10^4 - 10^7 FC/100 ml	10^6/100 ml effluent
Average Daily Discharge: Typical Home: Reference (2), (3), (4), (5)	45 - 100 gallons /person /day	70 gallons /person /day

Agricultural Sources	Range of Literature Values	Selected Model Value
Agricultural Runoff with No Manure Application Reference (6)		10 FC/100 ml of runoff
Agricultural Runoff with Land Applied Manure: Reference (7)	10 to 20 tons /acre /year	10 tons/ac/yr
Average Daily Manure Loading Rate: Reference (8)	12 - 115 lbs/animal/day	53 lbs /animal /day
Livestock Fecal Coliform Concentration: Reference (9), (10)	10^4 - 10^7 FC/gram manure	10^6 FC/gram manure

Mediun Curbside Accumulation of Fecal Coliform

Road Runoff Reference (12)	Range of Values	Model Coefficient Value
Low Density Residential	10^5 -10^7 FC/ft curb	2.6 x 10^6 FC/ft. curb
High Density Residential	10^5 - 10^6 FC/ft curb	4 x 10^5 FC/ft. curb
Industrial/Commercial	10^5 - 10^6 FC/ft. curb	1.6 x 10^6 FC/ft. curb
Highways	10^5 - 10^7 FC/ft. curb	6.5 x 10^6 FC/ft curb

Average Road Width Values used in Runoff Calculations

Road Width (Reference 11)	Typical Values	Model CoefficientValue
Residential	22 ft.	22 ft.
Major roads and highways	56 ft.	56 ft.
Commercial/industrial	56 ft.	56 ft.

APPENDIX A (Continued)

Calculations Used in FecaLOAD

Volume of Road Runoff:

(Road width in feet) x (length in feet) x (2.3 x 10^{-5} acres/ft^2) = Acres of road surface.
(Acres of road surface) x (inches of rain) / (12 inches) = Acre-ft.
(Acre feet) x (325,851 gallons per acre-foot) = volume of road runoff (gallons).

Volume of Watershed Runoff: Reference (13), (14)

(Acres of land cover) x (CN-associated runoff inches for a given rainfall on that land cover) = Acre-ft.
(Acre-ft) x (325,851 gallons/acre-ft.) = Volume of Watershed Runoff (gallons).

Note: The watershed runoff calculations in the model were developed from empirical data by the Natural Resources Conservation Service (NRCS). NRCS data are applied in the model as composite "curve number" (CN) runoff values which are determined from hydrologic soil groups Reference (15).

Surface Die-Off: Reference (16)

The equation for determining fecal coliform die-off is:

$$N_t = N_0 (10^{-kt})$$

where:

N_t = Number of fecal coliforms at time t (this is the number of fecal coliforms available for entrainment in surface runoff)
N_0 = Number of fecal coliforms at time 0
t = Time in days
k = First order die-off rate constant. From Moore, et al. (Typical values used 0.51 in warm months 0.36 in cold months).

References for Appendix A

(1) Converse, et al. "Bacterial and Nutrient Removal in Wisconsin At-Grade On-Site Systems." *IN* On-Site Wastewater Treatment. Proceedings of the 6th National Symposium on Individual and Small Community Sewage Systems, 16-17 December 1991, Chicago, Illinois. American Society of Agricultural Engineers, 50.

(2) Metcalf & Eddy, Inc. 1991. Wastewater engineering: treatment disposal reuse. McGraw Hill, Inc. 1991 (Septic system effluent rates range 35-50 gal./per person/day and an average occupancy of 2.4-2.8 residents/home.)

(3) US EPA. 1980. On-site wastewater treatment and disposal systems design manual.

(4) Porter, K. S. 1978. Nitrates in the Long Island comprehensive waste treatment management plan: VII Summary Documentation, Long Island Regional Planning Board, Hauppauge, New York.

(5) Massachusetts Audubon Society. April, 1986. Protecting and maintaining private wells.

APPENDIX A (Continued)

(6) Background coefficients were derived from sample concentrations from four H&W rounds of sampling agricultural-land runoff in Maine from May 1994 through April 1995. These areas had observed manure application approximately 7 months before the sampling project began. Samples were collected once in May 1994, once in November 1994, and twice in April 1995. The sample FC concentrations exhibited a decrease over the course of the sampling. Therefore, geometric means of FC concentrations were determined from these samples and calibrated as background coefficients for the model.

(7) Maine Department of Agriculture, Personal communication with Russel Libby, Researcher, March 1994. (Manure application range of 10 - 20 tons/acre.)

(8) Moore, J.A., M.E. Grismer, S.R. Crane, and J.R. Miner. 1982. Evaluating Dairy Waste Management Systems' Influence on Fecal Coliform Concentration in Runoff. Department of Agricultural Engineering, Agricultural Experiment Station bulletin 658, Oregon State University, Corvallis, p 15. (Average of daily manure production from known cattle weights for dairy and beef cows and horses (range of 12 lbs to 115 lbs./day).

(9) Moore, J.A., M.E. Grismer, S.R. Crane, and J.R. Miner. 1982. "Evaluating Dairy Waste Management Systems' Influence on Fecal Coliform Concentration in Runoff." Agricultural Experiment Station Bulletin No. 658, Oregon State University, Corvallis, Oregon. 1982, Table 4.

(10) Koppelman, Lee ed. (1978). Animal Waste: Non-Point Pollution. Nausau-Suffolk (NY) Regional Planning Board. 32 pp.

(11) Massachusetts Executive Office of Transportation and Commerce, Engineering Department, (personal communication, 4 August 1995)

(12) Novotney, V. and H. Olem. 1994. Water Quality: Prevention, Identification and Management of Diffuse Pollution. New York: Van Nostrand Reinhold. Note: This source sites Ellis (1986) who incorporated roadside fecal coliform values from the Nationwide Urban Runoff Program (NURP) Study by US EPA in 1981.

(13) U.S. Department of Agriculture, 1972. Soil Conservation Service, SCS National Engineering Handbook, Section 4, Hydrology.

(14) U.S. Department of Agriculture/SCS, Amherst, MA. March 1974. Estimating Runoff: The Modified Soil Cover Complex Method,

(15) U.S. Department of Agriculture, Massachusetts Agricultural Experiment Station, May, 1984. "Soil Survey of Essex County, Massachusetts"

(16) Moore, J.A., M.E. Grismer, S.R. Crane, and J.R. Miner. 1982. "Evaluating Dairy Waste Management Systems' Influence on Fecal Coliform Concentration in Runoff." Agricultural Experiment Station Bulletin No. 658, Oregon State University, Corvallis, Oregon. 1982, Table 4.

(17) U.S. Department of Agriculture, Maine Agricultural Experiment Station, August 1974. "Soil Survey, Cumberland County, Maine"

	A	B	C	D	E	F
1	**FecaLOAD Model**					
2	**WATERSHED NAME:**					
3	**LAND USE CONDITIONS:**		**(Existing or Buildout)**			
4	**FecaLOAD Land Use Classification**	**Soil Suitability Rating**	**Proximity to Surface Water**	**Sewered**	**Acreage**	**Number of Dwellings ***(NO ENTRY FOR FecaLOAD AUTO-CALCULATE)*****
5	Commercial	N/A	N/A	N/A		N/A
6	Industrial	N/A	N/A	N/A		N/A
7	Open Land	N/A	N/A	N/A		N/A
8	Sewered Residential Land	N/A	N/A	Y		N/A
9	Forest Land	N/A	N/A	N/A		N/A
10	Low Density Residential on Septic	Severe	<100	N		
11	Low Density Residential on Septic	Severe	100-500	N		
12	Low Density Residential on Septic	Severe	>500	N		
13	Low Density Residential on Septic	Moderate	<100	N		
14	Low Density Residential on Septic	Moderate	100-500	N		
15	Low Density Residential on Septic	Moderate	>500	N		
16	Low Density Residential on Septic	Slight	<100	N		
17	Low Density Residential on Septic	Slight	100-500	N		
18	Low Density Residential on Septic	Slight	>500	N		
19	Medium Density Residential on Septic	Severe	<100	N		
20	Medium Density Residential on Septic	Severe	100-500	N		
21	Medium Density Residential on Septic	Severe	>500	N		
22	Medium Density Residential on Septic	Moderate	<100	N		
23	Medium Density Residential on Septic	Moderate	100-500	N		
24	Medium Density Residential on Septic	Moderate	>500	N		
25	Medium Density Residential on Septic	Slight	<100	N		
26	Medium Density Residential on Septic	Slight	100-500	N		
27	Medium Density Residential on Septic	Slight	>500	N		
28	High Density Residential on Septic	Severe	<100	N		
29	High Density Residential on Septic	Severe	100-500	N		
30	High Density Residential on Septic	Severe	>500	N		
31	High Density Residential on Septic	Moderate	<100	N		
32	High Density Residential on Septic	Moderate	100-500	N		
33	High Density Residential on Septic	Moderate	>500	N		
34	High Density Residential on Septic	Slight	<100	N		
35	High Density Residential on Septic	Slight	100-500	N		
36	High Density Residential on Septic	Slight	>500	N		
37	Multi-family Residential on Septic	Severe	<100	N		
38	Multi-family Residential on Septic	Severe	100-500	N		
39	Multi-family Residential on Septic	Severe	>500	N		
40	Multi-family Residential on Septic	Moderate	<100	N		
41	Multi-family Residential on Septic	Moderate	100-500	N		
42	Multi-family Residential on Septic	Moderate	>500	N		
43	Multi-family Residential on Septic	Slight	<100	N		
44	Multi-family Residential on Septic	Slight	100-500	N		
45	Multi-family Residential on Septic	Slight	>500	N		
46	Agricultural Land	Severe	<100	N/A		N/A

	A	B	C	D	E	F
47	Agricultural Land	Severe	100-500	N/A		N/A
48	Agricultural Land	Severe	>500	N/A		N/A
49	Agricultural Land	Moderate	<100	N/A		N/A
50	Agricultural Land	Moderate	100-500	N/A		N/A
51	Agricultural Land	Moderate	>500	N/A		N/A
52	Agricultural Land	Slight	<100	N/A		N/A
53	Agricultural Land	Slight	100-500	N/A		N/A
54	Agricultural Land	Slight	>500	N/A		N/A
55	Pasture Land	Severe	<100	N/A		N/A
56	Pasture Land	Severe	100-500	N/A		N/A
57	Pasture Land	Severe	>500	N/A		N/A
58	Pasture Land	Moderate	<100	N/A		N/A
59	Pasture Land	Moderate	100-500	N/A		N/A
60	Pasture Land	Moderate	>500	N/A		N/A
61	Pasture Land	Slight	<100	N/A		N/A
62	Pasture Land	Slight	100-500	N/A		N/A
63	Pasture Land	Slight	>500	N/A		N/A
64						
65	Land Uses Not Modeled					
66	Salt Wetland	N/A	N/A	N/A		N/A
67	Wetland	N/A	N/A	N/A		N/A
68	Water	N/A	N/A	N/A		N/A
69	Waste Disposal	N/A	N/A	N/A		N/A
70						
71	Enter Total Watershed Acreage:		(If the data has been entered correctly			
72	Auto-Calculated Watershed Acreage:		these numbers should equal eachother)			
73						
74						
75	DEFAULT: Tons of Applied Manure/Acre =	10	(Default can be changed if other information is available)			
76						
77	Average Number Livestock/Acre =					
78	DEFAULT: Days between Grazing =	1	(Default can be changed if other information is available)			
79						
80	Roads Length Summary	Road Length (feet)				
81	Low Density Residential					
82	Medium Density Residential					
83	High Density Residential					
84	Multi-family Residential					
85	Major Roads/Highways					
86	Commercial/Industrial					
87	Open Land					
88	Agriculture					
89	Pasture					
90	Forest					
91	Wetlands					
92	Water (bridges)					
93	Recreation					
94						
95	- END OF LAND USE INPUTS -					

	AV	AW	AX	AY
1		**WATERSHED NAME:**		
2		**LAND USE CONDITIONS:**		
3		**RAINFALL CONDTIONS:**		
4		**HYDROLOGIC INPUTS**		
5		Rain Event (inches)		
6		Time Since Last Rainfall (days)		
7		Total Rainfall in Previous Five Days (inches)		
8		Time of Year (season)		
9		Days since Manure Applied		
10				
11				
12		**MODEL OUTPUTS**		
13		Total Watershed Runoff (gallons)	Total fc Loading (millons)	Average fc Concentration in Runoff (fc/100 ml)
14				
15				
16				
17				
18		*HORSLEY & WITTEN, INC.*		

APPENDIX B

FecaLOAD Model Runs for Each Subwatershed

Existing Conditions with No Manure Application
Existing Conditions With Manure Application
Buildout Conditions with No Manure Application
Buildout Conditions with Manure Application

FecaLOAD Model: BUNGANUC POINT WATERSHED					
BUILDOUT CONDITIONS, NO MANURE APPLICATION					
1	2	3	4	5	6
SOURCES BY CATEGORY	UNITS BY CATEGORY	Default Values	Watershed Runoff by Land Use (gallons)	Fecal Coliform Loading by Land Use (Millions/storm)	Average Fecal Coliform Concentration in Runoff fc/100 ml
HYDROLOGIC INPUTS:					
Rain event (inches)	1.50				
Time since Last Rain (days)	3.00				
Amount Rainfall in previous 5 days (inches)	0.5				
LAND USE INPUTS:					
Commercial/Industrial Acreage			0	No Loading	
Meadows/Parks/Cemeteries	16		5,214	No Loading	
Forest/Woods	204		66,474	3	1
RESIDENTIAL					
No. Homes on Septic Systems:					
Category I					
Category II	5				
Category III	14				
Category IV	18		176,828	4,493	671
Average Residential acreage per house	2.20				
LAND USE ACREAGE:		Tons manure per acre			
Days Since Manure Applied	365.00	10			
If no manure in 1 year enter 365 for background concentrations					
Agricultural Acreage:					
Category I	3				
Category II	5				
Category III	5				
Category IV	15		12,165	138	300
Grazing Acres	5				
# Head of Livestock:					
Category I	0				
Category II	0	Days Between			
Category III	0	Animal Grazing			
Category IV	0	3.00	2,172	0	0
ROAD RUNOFF:	LENGTH (FT.)	Road Acres Auto.-calculated			
Low Density Resid.	1491	1.05	41,899	1,136	700
High Density Resid.		0.00	0	0	#DIV/0!
Major Roads/H'ways	2,957	4.16	166,192	5,796	900
Commercial/Industrial	2,957	4.16	166,192	3,874	602
Agricultural/Woods	1,765	1.24	49,599	0	0
			Total Watershed Runoff (Gallons)	Total fc Loading (Millions)	Average Runoff FC conc. (fc/100 ml)
			686,735	15,439	594

FecaLOAD Model: BUNGANUC POINT WATERSHED					
BUILDOUT CONDITIONS WITH MANURE APPLICATION					
1	2	3	4	5	6
SOURCES BY CATEGORY	UNITS BY CATEGORY	Default Values	Watershed Runoff by Land Use (gallons)	Fecal Coliform Loading by Land Use (Millions/storm)	Average Fecal Coliform Concentration in Runoff fc/100 ml
HYDROLOGIC INPUTS:					
Rain event (inches)	1.50				
Time since Last Rain (days)	3.00				
Amount Rainfall in previous 5 days (inches)	0.5				
LAND USE INPUTS:					
Commercial/Industrial Acreage			0	No Loading	
Meadows/Parks/Cemeteries	16		5,214	No Loading	
Forest/Woods	204		66,474	3	1
RESIDENTIAL					
No. Homes on Septic Systems:					
Category I					
Category II	5				
Category III	14				
Category IV	18		176,828	4,493	671
Average Residential acreage per house	2.20				
LAND USE ACREAGE:		Tons manure per acre:			
Days Since Manure Applied	8.00	10			
If no manure in 1 year enter 365 for background concentrations					
Agricultural Acreage:					
Category I	3				
Category II	5				
Category III	5				
Category IV	15		12,165	12,776	27,746
Grazing Acres	5				
# Head of Livestock:					
Category I	0				
Category II	0	Days Between			
Category III	0	Animal Grazing			
Category IV	0	3.00	2,172	0	0
ROAD RUNOFF:	LENGTH (FT.)	Road Acres Auto.-calculated			
Low Density Resid.	1491	1.05	41,899	1,136	700
High Density Resid.		0.00	0	0	#DIV/0!
Major Roads/H'ways	2,957	4.16	166,192	5,796	900
Commercial/Industrial	2,957	4.16	166,192	3,874	602
Agricultural/Woods	1,765	1.24	49,599	0	0
			Total Watershed Runoff (Gallons)	Total fc Loading (Millions)	Average Runoff FC conc. (fc/100 ml)
			686,735	28,077	1,080

FecaLOAD Model: BUNGANUC POINT WATERSHED

EXISTING CONDITIONS (1995), AND NO MANURE APPLICATION

1	2	3	4	5	6
SOURCES BY CATEGORY	UNITS BY CATEGORY	Default Values	Watershed Runoff by Land Use (gallons)	Fecal Coliform Loading by Land Use (Millions/storm)	Average Fecal Coliform Concentration in Runoff fc/100 ml
HYDROLOGIC INPUTS:					
Rain event (inches)	1.50				
Time since Last Rain (days)	3.00				
Amount Rainfall in previous 5 days (inches)	0.5				
LAND USE INPUTS:					
Commercial/Industrial Acreage			0	No Loading	
Meadows/Parks/Cemeteries	16		5,214	No Loading	
Forest/Woods	407		132,621	5	1
RESIDENTIAL					
No. Homes on Septic Systems:					
Category I	0				
Category II	3				
Category III	8				
Category IV	10		100,362	2,522	664
Average Residential acreage per house	2.20				
LAND USE ACREAGE:		Tons manure per acre:			
Days Since Manure Applied	365.00	10			
If no manure in 1 year enter 365 for background concentrations					
Agricultural Acreage:					
Category I	5				
Category II	10				
Category III	10				
Category IV	30		23,896	271	300
Grazing Acres	5				
# Head of Livestock:					
Category I	0				
Category II	0	Days Between			
Category III	0	Animal Grazing			
Category IV	0	3.00	2,172	0	0
ROAD RUNOFF:	LENGTH (FT.)	Road Acres Auto.-calculated			
Low Density Resid.	956	0.67	26,865	728	700
High Density Resid.	0	0.00	0	0	#DIV/0!
Major Roads/H'ways	1,896	2.67	106,560	3,716	900
Commercial/Industrial	1,896	2.67	106,560	2,484	602
Agricultural/Woods	1,765	1.24	49,599	0	0
			Total Watershed Runoff (Gallons)	Total fc Loading (Millions)	Average Runoff FC conc. (fc/100 ml)
			553,850	9,727	464

FecaLOAD Model: BUNGANUC POINT WATERSHED

EXISTING CONDITIONS (1995) WITH MANURE APPLICATION

1	2	3	4	5	6
SOURCES BY CATEGORY	UNITS BY CATEGORY	Default Values	Watershed Runoff by Land Use (gallons)	Fecal Coliform Loading by Land Use (Millions/storm)	Average Fecal Coliform Concentration in Runoff fc/100 ml
HYDROLOGIC INPUTS:					
Rain event (inches)	1.50				
Time since Last Rain (days)	3.00				
Amount Rainfall in previous 5 days (inches)	0.5				
LAND USE INPUTS:					
Commercial/Industrial Acreage			0	No Loading	
Meadows/Parks/Cemeteries	16		5,214	No Loading	
Forest/Woods	407		132,621	5	1
RESIDENTIAL					
No. Homes on Septic Systems:					
Category I	0				
Category II	3				
Category III	8				
Category IV	10		100,362	2,522	664
Average Residential acreage per house	2.20				
LAND USE ACREAGE:		Tons manure per acre			
Days Since Manure Applied	8.00	10			
If no manure in 1 year enter 365 for background concentrations					
Agricultural Acreage:					
Category I	5				
Category II	10				
Category III	10				
Category IV	30		23,896	25,547	28,245
Grazing Acres	5				
# Head of Livestock:					
Category I	0				
Category II	0	Days Between			
Category III	0	Animal Grazing			
Category IV	0	3.00	2,172	0	0
ROAD RUNOFF:	LENGTH (FT.)	Road Acres Auto.-calculated			
Low Density Resid.	956	0.67	26,865	728	700
High Density Resid.	0	0.00	0	0	#DIV/0!
Major Roads/H'ways	1,896	2.67	106,560	3,716	900
Commercial/Industrial	1,896	2.67	106,560	2,484	602
Agricultural/Woods	1,765	1.24	49,599	0	0
			Total Watershed Runoff (Gallons)	Total fc Loading (Millions)	Average Runoff FC conc. (fc/100 ml)
			553,850	35,002	1,670

FecaLOAD Model: BUNGANUC STREAM WATERSHED

EXISTING CONDITIONS (1995), AND NO MANURE APPLICATION

1	2	3	4	5	6
SOURCES BY CATEGORY	UNITS BY CATEGORY	Default Values	Watershed Runoff by Land Use (gallons)	Fecal Coliform Loading by Land Use (Millions/storm)	Average Fecal Coliform Concentration in Runoff fc/100 ml
HYDROLOGIC INPUTS:					
Rain event (inches)	1.50				
Time since Last Rain (days)	3.00				
Amount Rainfall in previous 5 days (inches)	0.5				
LAND USE INPUTS:					
Commercial/Industrial Acreage			0	No Loading	
Meadows/Parks/Cemeteries	163		53,114	No Loading	
Forest/Woods	2,221		723,715	27	1
RESIDENTIAL					
No. Homes on Septic Systems:					
Category I	85				
Category II	42				
Category III	15				
Category IV			493,556	1,773	95
Average Residential acreage per house	1.60				
LAND USE ACREAGE:		Tons manure per acre			
Days Since Manure Applied	365.00	10			
If no manure in 1 year enter 365 for background concentrations					
Agricultural Acreage:					
Category I	150				
Category II	86				
Category III	150				
Category IV	250		276,322	3,138	300
Grazing Acres	5				
# Head of Livestock:					
Category I	10				
Category II	10	Days Between			
Category III	10	Animal Grazing			
Category IV	10	3.00	2,172	0	5
ROAD RUNOFF:		Road Acres Auto.-calculated			
Low Density Resid.	4200	2.96	118,026	3,200	700
High Density Resid.	10	0.01	281	4	335
Major Roads/H'ways	6,350	8.94	356,888	12,446	900
Commercial/Industrial	6,350	8.94	356,888	8,319	602
Agricultural/Woods	48,600	34.21	1,365,728	7	0
			Total Watershed Runoff (Gallons)	Total fc Loading (Millions)	Average Runoff FC Conc. (fc/100 ml)
			3,746,688	28,915	204

FecaLOAD Model: BUNGANUC STREAM WATERSHED					
BUILDOUT CONDITIONS, 50% AGRICULTURE REDUCTION, NO MANURE APPLICATION					
1	2	3	4	5	6
SOURCES BY CATEGORY	UNITS BY CATEGORY	Default Values	Watershed Runoff by Land Use (gallons)	Fecal Coliform Loading by Land Use (Millions/storm)	Average Fecal Coliform Concentration in Runoff fc/100 ml
HYDROLOGIC INPUTS:					
Rain event (inches)	1.50				
Time since Last Rain (days)	3.00				
Amount Rainfall in previous 5 days (inches)	0.5				
LAND USE INPUTS:					
Commercial/Industrial Acreage			0	No Loading	
Meadows/Parks/Cemeteries	163		53,114	No Loading	
Forest/Woods	1,100		358,436	14	1
RESIDENTIAL					
No. Homes on Septic Systems:					
Category I	397				
Category II	198				
Category III	67				
Category IV			2,300,943	7,921	91
Average Residential acreage per house	1.60				
LAND USE ACREAGE:		Tons manure per acre			
Days Since Manure Applied	365.00	10			
If no manure in 1 year enter 365 for background concentrations					
Agricultural Acreage:					
Category I	75				
Category II	43				
Category III	75				
Category IV	125		138,161	1,569	300
Grazing Acres	5				
# Head of Livestock:					
Category I	10				
Category II	10	Days Between			
Category III	10	Animal Grazing			
Category IV	10	3.00	2,172	4	51
ROAD RUNOFF:		Road Acres Auto.-calculated			
Low Density Resid.	7266	5.12	204,185	5,537	700
High Density Resid.	17	0.01	478	6	335
Major Roads/H'ways	10,986	15.47	617,444	21,533	900
Commercial/Industrial	10,986	15.47	617,444	14,392	602
Agricultural/Woods	48,600	34.21	1,365,728	7	0
			Total Watershed Runoff (Gallons)	Total fc Loading conc. (Millions)	Average Runoff FC (fc/100 ml)
			5,658,103	50,982	238

FecaLOAD Model: BUNGANUC STREAM WATERSHED					
BUILDOUT CONDITIONS; WITH MANURE APPLICATION					
1	2	3	4	5	6
SOURCES BY CATEGORY	UNITS BY CATEGORY	Default Values	Watershed Runoff by Land Use (gallons)	Fecal Coliform Loading by Land Use (Millions/storm)	Average Fecal Coliform Concentration in Runoff fc/100 ml
HYDROLOGIC INPUTS:					
Rain event (inches)	1.50				
Time since Last Rain (days)	3.00				
Amount Rainfall in previous 5 days (inches)	0.5				
LAND USE INPUTS:					
Commercial/Industrial Acreage			0	No Loading	
Meadows/Parks/Cemeteries	163		53,114	No Loading	
Forest/Woods	1,100		358,436	14	1
RESIDENTIAL					
No. Homes on Septic Systems:					
Category I	397				
Category II	156				
Category III	52				
Category IV			2,102,825	6,148	77
Average Residential acreage per house	1.60				
LAND USE ACREAGE:		Tons manure per acre:			
Days Since Manure Applied	8.00	10			
If no manure in 1 year enter 365 for background concentrations					
Agricultural Acreage:					
Category I	75				
Category II	43				
Category III	75				
Category IV	125		138,161	121,681	23,269
Grazing Acres	5				
# Head of Livestock:					
Category I	10				
Category II	10	Days Between			
Category III	10	Animal Grazing			
Category IV	10	3.00	2,172	4	51
ROAD RUNOFF:		Road Acres Auto.-calculated			
Low Density Resid.	7266	5.12	204,185	5,537	700
High Density Resid.	17	0.01	478	6	335
Major Roads/H'ways	10,986	15.47	617,444	21,533	900
Commercial/Industrial	10,986	15.47	617,444	14,392	602
Agricultural/Woods	48,600	34.21	1,365,728	7	0
			Total Watershed Runoff (Gallons)	Total fc Loading (Millions)	Average Runoff FC conc. (fc/100 ml)
			5,459,986	169,321	819

FecaLOAD Model: FLYING POINT NECK WATERSHED					
EXISTING CONDITIONS (1995), AND NO MANURE APPLICATION					
1	2	3	4	5	6
SOURCES BY CATEGORY	UNITS BY CATEGORY	Default Values	Watershed Runoff by Land Use (gallons)	Fecal Coliform Loading by Land Use (Millions/storm)	Average Fecal Coliform Concentration in Runoff fc/100 ml
HYDROLOGIC INPUTS:					
Rain event (inches)	1.50				
Time since Last Rain (days)	3.00				
Amount Rainfall in previous 5 days (inches)	0.5				
LAND USE INPUTS:					
Commercial/Industrial Acreage			0	No Loading	
Meadows/Parks/Cemeteries	3		978	No Loading	
Forest/Woods	690		224,837	9	1
RESIDENTIAL					
No. Homes on Septic Systems:					
Category I	10				
Category II	15				
Category III	12				
Category IV	150		324,982	25,064	2038
Average Residential acreage per house	0.80				
LAND USE ACREAGE:		Tons manure per acre			
Days Since Manure Applied	365.00	10			
If no manure in 1 year enter 365 for background concentrations					
Agricultural Acreage:					
Category I	10				
Category II	20				
Category III	20				
Category IV	50		43,447	493	300
Grazing Acres	5				
# Head of Livestock:					
Category I	10				
Category II	10	Days Between			
Category III	10	Animal Grazing			
Category IV	10	3.00	2,172	4	51
ROAD RUNOFF:	LENGTH (FT.)	Road Acres Auto.-calculated			
Low Density Resid.	11,790	8.30	331,315	8,984	700
High Density Resid.	0	0.00	0	0	#DIV/0!
Major Roads/H'ways	0	0.00	0	0	#DIV/0!
Commercial/Industrial	0	0.00	0	0	#DIV/0!
Agricultural/Woods	22,590	15.90	634,810	3	0
			Total Watershed Runoff (Gallons) 1,562,542	Total fc Loading (Millions) 34,557	Average Runoff FC conc. (fc/100 ml) 584

FecaLOAD Model: FLYING POINT NECK WATERSHED

BUILDOUT CONDITIONS, AND NO MANURE APPLICATION

1	2	3	4	5	6
SOURCES BY CATEGORY	UNITS BY CATEGORY	Default Values	Watershed Runoff by Land Use (gallons)	Fecal Coliform Loading by Land Use (Millions/storm)	Average Fecal Coliform Concentration in Runoff fc/100 ml
HYDROLOGIC INPUTS:					
Rain event (inches)	1.50				
Time since Last Rain (days)	3.00				
Amount Rainfall In previous 5 days (inches)	0.5				
LAND USE INPUTS:					
Commercial/Industrial Acreage			0	No Loading	
Meadows/Parks/Cemeteries	3		978	No Loading	
Forest/Woods	345		112,419	4	1
RESIDENTIAL					
No. Homes on Septic Systems:					
Category I	17				
Category II	26				
Category III	20				
Category IV	259		559,595	43,192	2039
Average Residential acreage per house	0.80				
LAND USE ACREAGE:		Tons manure per acre			
Days Since Manure Applied	365.00	10			
If no manure in 1 year enter 365 for background concentrations					
Agricultural Acreage:					
Category I	5				
Category II	10				
Category III	10				
Category IV	25		21,723	247	300
Grazing Acres	5				
# Head of Livestock:					
Category I	5				
Category II	5	Days Between			
Category III	5	Animal Grazing			
Category IV	5	3.00	2,172	2	25
ROAD RUNOFF:	LENGTH (FT.)	Road Acres Auto.-calculated			
Low Density Resid.	18,510	13.03	520,157	14,105	700
High Density Resid.	0	0.00	0	0	#DIV/0!
Major Roads/H'ways	0	0.00	0	0	#DIV/0!
Commercial/Industrial	0	0.00	0	0	#DIV/0!
Agricultural/Woods	22,590	15.90	634,810	3	0
			Total Watershed Runoff (Gallons) 1,851,854	Total fc Loading (Millions) 57,553	Average Runoff FC conc. (fc/100 ml) 821

FecaLOAD Model: FLYING POINT NECK WATERSHED					
EXISTING CONDITIONS (1995) WITH MANURE APPLICATION					
1	2	3	4	5	6
SOURCES BY CATEGORY	UNITS BY CATEGORY	Default Values	Watershed Runoff by Land Use (gallons)	Fecal Coliform Loading by Land Use (Millions/storm)	Average Fecal Coliform Concentration in Runoff fc/100 ml
HYDROLOGIC INPUTS:					
Rain event (inches)	1.50				
Time since Last Rain (days)	3.00				
Amount Rainfall in previous 5 days (inches)	0.5				
LAND USE INPUTS:					
Commercial/Industrial Acreage			0	No Loading	
Meadows/Parks/Cemeteries	3		978	No Loading	
Forest/Woods	690		224,837	9	1
RESIDENTIAL					
No. Homes on Septic Systems:					
Category I	10				
Category II	15				
Category III	12				
Category IV	150		324,982	25,064	2038
Average Residential acreage per house	0.80				
LAND USE ACREAGE:		Tons manure per acre			
Days Since Manure Applied	8.00	10			
If no manure in 1 year enter 365 for background concentrations					
Agricultural Acreage:					
Category I	10				
Category II	20				
Category III	20				
Category IV	50		43,447	44,450	27,030
Grazing Acres	5				
# Head of Livestock:					
Category I	10				
Category II	10	Days Between			
Category III	10	Animal Grazing			
Category IV	10	3.00	2,172	4	51
ROAD RUNOFF:	LENGTH (FT.)	Road Acres Auto.-calculated			
Low Density Resid.	11790	8.30	331,315	8,984	700
High Density Resid.	0	0.00	0	0	#DIV/0!
Major Roads/H'ways	0	0.00	0	0	#DIV/0!
Commercial/Industrial	0	0.00	0	0	#DIV/0!
Agricultural/Woods	22,590	15.90	634,810	3	0
			Total Watershed Runoff (Gallons)	Total fc Loading (Millions)	Average Runoff FC conc. (fc/100 ml)
			1,562,542	78,514	1,328

FecaLOAD Model: FLYING POINT NECK WATERSHED					
BUILDOUT CONDITIONS WITH MANURE APPLICATION					
1	2	3	4	5	6
SOURCES BY CATEGORY	UNITS BY CATEGORY	Default Values	Watershed Runoff by Land Use (gallons)	Fecal Coliform Loading by Land Use (Millions/storm)	Average Fecal Coliform Concentration in Runoff fc/100 ml
HYDROLOGIC INPUTS:					
Rain event (inches)	1.50				
Time since Last Rain (days)	3.00				
Amount Rainfall in previous 5 days (inches)	0.5				
LAND USE INPUTS:					
Commercial/Industrial Acreage			0	No Loading	
Meadows/Parks/Cemeteries	3		978	No Loading	
Forest/Woods	345		112,419	4	1
RESIDENTIAL					
No. Homes on Septic Systems:					
Category I	17				
Category II	26				
Category III	20				
Category IV	259		559,595	43,192	2039
Average Residential acreage per house	0.80				
LAND USE ACREAGE:		Tons manure per acre:			
Days Since Manure Applied	8.00	10			
If no manure in 1 year enter 365 for background concentrations					
Agricultural Acreage:					
Category I	5				
Category II	10				
Category III	10				
Category IV	25		21,723	22,225	27,030
Grazing Acres	5				
# Head of Livestock:					
Category I	5				
Category II	5	Days Between			
Category III	5	Animal Grazing			
Category IV	5	3.00	2,172	2	25
ROAD RUNOFF:	LENGTH (FT.)	Road Acres Auto.-calculated			
Low Density Resid.	18,510	13.03	520,157	14,105	700
High Density Resid.	0	0.00	0	0	#DIV/0!
Major Roads/H'ways	0	0.00	0	0	#DIV/0!
Commercial/Industrial	0	0.00	0	0	#DIV/0!
Agricultural/Woods	22,590	15.90	634,810	3	0
			Total Watershed Runoff (Gallons) 1,851,854	Total fc Loading (Millions) 79,532	Average Runoff FC conc. (fc/100 ml) 1,135

FecaLOAD Model: MEREPOINT NECK WATERSHED					
EXISTING CONDITIONS (1995), AND NO MANURE APPLICATION					
1	2	3	4	5	6
SOURCES BY CATEGORY	UNITS BY CATEGORY	Default Values	Watershed Runoff by Land Use (gallons)	Fecal Coliform Loading by Land Use (Millions/storm)	Average Fecal Coliform Concentration in Runoff fc/100 ml
HYDROLOGIC INPUTS:					
Rain event (inches)	1.50				
Time since Last Rain (days)	3.00				
Amount Rainfall in previous 5 days (inches)	0.5				
LAND USE INPUTS:					
Commercial/Industrial Acreage			0	No Loading	
Meadows/Parks/Cemeteries	11		3,584	No Loading	
Forest/Woods	36		11,731	0	1
RESIDENTIAL					
No. Homes on Septic Systems:					
Category I	10				
Category II	11				
Category III	12				
Category IV	90		187,038	15,606	2204
Average Residential acreage per house	0.70				
LAND USE ACREAGE:		Tons manure per acre			
Days Since Manure Applied	365.00	10			
If no manure in 1 year enter 365 for background concentrations					
Agricultural Acreage:					
Category I	0				
Category II	0				
Category III	5				
Category IV	20		10,862	123	300
Grazing Acres	5				
# Head of Livestock:					
Category I	0				
Category II	0	Days Between			
Category III	0	Animal Grazing			
Category IV	0	3.00	2,172	0	0
ROAD RUNOFF:	LENGTH (FT.)	Road Acres Auto.-calculated			
Low Density Resid.	7,319	5.15	205,674	5,577	700
High Density Resid.	0	0.00	0	0	#DIV/0!
Major Roads/H'ways	0	0.00	0	0	#DIV/0!
Commercial/Industrial	4,071	5.73	228,802	5,333	602
Agricultural/Woods	2,975	2.09	83,602	0	0
			Total Watershed Runoff (Gallons) 733,465	Total fc Loading (Millions) 26,640	Average Runoff FC conc. (fc/100 ml) 960

FecaLOAD Model: MEREPOINT NECK WATERSHED					
BUILDOUT CONDITIONS, AND NO MANURE APPLICATION					
1	2	3	4	5	6
SOURCES BY CATEGORY	UNITS BY CATEGORY	Default Values	Watershed Runoff by Land Use (gallons)	Fecal Coliform Loading by Land Use (Millions/storm)	Average Fecal Coliform Concentration in Runoff fc/100 ml
HYDROLOGIC INPUTS:					
Rain event (inches)	1.50				
Time since Last Rain (days)	3.00				
Amount Rainfall in previous 5 days (inches)	0.5				
LAND USE INPUTS:					
Commercial/Industrial Acreage			0	No Loading	
Meadows/Parks/Cemeteries	11		3,584	No Loading	
Forest/Woods	18		5,865	0	1
RESIDENTIAL					
No. Homes on Septic Systems:					
Category I	11				
Category II	12				
Category III	13				
Category IV	96		200,724	16,670	2194
Average Residential acreage per house	0.70				
LAND USE ACREAGE:		Tons manure per acre			
Days Since Manure Applied	365.00	10			
If no manure in 1 year enter 365 for background concentrations					
Agricultural Acreage:					
Category I	0				
Category II	0				
Category III	3				
Category IV	10		5,648	64	300
Grazing Acres	5				
# Head of Livestock:					
Category I	0				
Category II	0	Days Between			
Category III	0	Animal Grazing			
Category IV	0	3.00	2,172	0	0
ROAD RUNOFF:	LENGTH (FT.)	Road Acres Auto.-calculated			
Low Density Resid.	13,906	9.79	390,778	10,596	700
High Density Resid.	0	0.00	0	0	#DIV/0!
Major Roads/H'ways	0	0.00	0	0	#DIV/0!
Commercial/Industrial	7,735	10.89	434,729	10,133	602
Agricultural/Woods	2,975	2.09	83,602	0	0
			Total Watershed Runoff (Gallons)	Total fc Loading (Millions)	Average Runoff FC conc. (fc/100 ml)
			1,127,102	37,464	878

FecaLOAD Model: MEREPOINT NECK WATERSHED					
EXISTING CONDITIONS WITH MANURE APPLICATION					
1	2	3	4	5	6
SOURCES BY CATEGORY	UNITS BY CATEGORY	Default Values	Watershed Runoff by Land Use (gallons)	Fecal Coliform Loading by Land Use (Millions/storm)	Average Fecal Coliform Concentration in Runoff fc/100 ml
HYDROLOGIC INPUTS:					
Rain event (inches)	1.50				
Time since Last Rain (days)	3.00				
Amount Rainfall in previous 5 days (inches)	0.5				
LAND USE INPUTS:					
Commercial/Industrial Acreage			0	No Loading	
Meadows/Parks/Cemeteries	11		3,584	No Loading	
Forest/Woods	36		11,731	0	1
RESIDENTIAL					
No. Homes on Septic Systems:					
Category I	10				
Category II	11				
Category III	12				
Category IV	90		187,038	15,606	2204
Average Residential acreage per house	0.70				
LAND USE ACREAGE:		Tons manure per acre			
Days Since Manure Applied	8.00	10			
If no manure in 1 year enter 365 for background concentrations					
Agricultural Acreage:					
Category I	0				
Category II	0				
Category III	3				
Category IV	10		5,648	7,976	37,311
Grazing Acres	5				
# Head of Livestock:					
Category I	0				
Category II	0	Days Between			
Category III	0	Animal Grazing			
Category IV	0	3.00	2,172	0	0
ROAD RUNOFF:	LENGTH (FT.)	Road Acres Auto.-calculated			
Low Density Resid.	7,319	5.15	205,674	5,577	700
High Density Resid.	0	0.00	0	0	#DIV/0!
Major Roads/H'ways	0	0.00	0	0	#DIV/0!
Commercial/Industrial	4,071	5.73	228,802	5,333	602
Agricultural/Woods	2,975	2.09	83,602	0	0
			Total Watershed Runoff (Gallons) 728,251	Total fc Loading (Millions) 34,493	Average Runoff FC conc. (fc/100 ml) 1,251

FecaLOAD Model: MEREPOINT NECK WATERSHED					
BUILDOUT CONDITIONS WITH MANURE APPLICATION					
1	2	3	4	5	6
SOURCES BY CATEGORY	UNITS BY CATEGORY	Default Values	Watershed Runoff by Land Use (gallons)	Fecal Coliform Loading by Land Use (Millions/storm)	Average Fecal Coliform Concentration in Runoff fc/100 ml
HYDROLOGIC INPUTS:					
Rain event (inches)	1.50				
Time since Last Rain (days)	3.00				
Amount Rainfall in previous 5 days (inches)	0.5				
LAND USE INPUTS:					
Commercial/Industrial Acreage			0	No Loading	
Meadows/Parks/Cemeteries	11		3,584	No Loading	
Forest/Woods	18		5,865	0	1
RESIDENTIAL					
No. Homes on Septic Systems:					
Category I	11				
Category II	12				
Category III	13				
Category IV	96		200,724	16,670	2194
Average Residential acreage per house	0.70				
LAND USE ACREAGE:		Tons manure per acre			
Days Since Manure Applied	8.00	10			
If no manure in 1 year enter 365 for background concentrations					
Agricultural Acreage:					
Category I	0				
Category II	0				
Category III	3				
Category IV	10		5,648	7,976	37,311
Grazing Acres	5				
# Head of Livestock:					
Category I	0				
Category II	0	Days Between			
Category III	0	Animal Grazing			
Category IV	0	3.00	2,172	0	0
ROAD RUNOFF:	LENGTH (FT.)	Road Acres Auto.-calculated			
Low Density Resid.	13,906	9.79	390,778	10,596	700
High Density Resid.	0	0.00	0	0	#DIV/0!
Major Roads/H'ways	0	0.00	0	0	#DIV/0!
Commercial/Industrial	7,735	10.89	434,729	10,133	602
Agricultural/Woods	2,975	2.09	83,602	0	0
			Total Watershed Runoff (Gallons) 1,127,102	Total fc Loading (Millions) 45,376	Average Runoff FC conc. (fc/100 ml) 1,064

FecaLOAD Model: ROSSMORE STREAM WATERSHED					
EXISTING CONDITIONS (1995), AND NO MANURE APPLICATION					
1	2	3	4	5	6
SOURCES BY CATEGORY	UNITS BY CATEGORY	Default Values	Watershed Runoff by Land Use (gallons)	Fecal Coliform Loading by Land Use (Millions/storm)	Average Fecal Coliform Concentration in Runoff fc/100 ml
HYDROLOGIC INPUTS:					
Rain event (inches)	1.50				
Time since Last Rain (days)	3.00				
Amount Rainfall in previous 5 days (inches)	0.5				
LAND USE INPUTS:					
Commercial/Industrial Acreage			0	No Loading	
Meadows/Parks/Cemeteries	39		12,708	No Loading	
Forest/Woods	601		195,836	7	1
RESIDENTIAL					
No. Homes on Septic Systems:					
Category I	50				
Category II	25				
Category III	12				
Category IV	13		391,021	3,468	234
Average Residential acreage per house	1.80				
LAND USE ACREAGE:		Tons manure per acre			
Days Since Manure Applied	365.00	10			
If no manure in 1 year enter 365 for background concentrations					
Agricultural Acreage:					
Category I	0				
Category II	10				
Category III	0				
Category IV	0		4,345	49	300
Grazing Acres	5				
# Head of Livestock:					
Category I	0				
Category II	0	Days Between			
Category III	0	Animal Grazing			
Category IV	0	3.00	2,172	0	0
ROAD RUNOFF:	LENGTH (FT.)	Road Acres Auto.-calculated			
Low Density Resid.	3670	2.58	103,132	2,797	700
High Density Resid.	10	0.01	281	4	335
Major Roads/H'ways	9,750	13.73	547,977	19,110	900
Commercial/Industrial	9,750	13.73	547,977	12,773	602
Agricultural/Woods	8,910	6.27	250,383	1	0
			Total Watershed Runoff (Gallons)	Total fc Loading (Millions)	Average Runoff FC conc. (fc/100 ml)
			2,055,834	38,209	491

FecaLOAD Model: ROSSMORE STREAM WATERSHED					
BUILDOUT CONDITIONS; NO MANURE APPLICATION					
1	2	3	4	5	6
SOURCES BY CATEGORY	UNITS BY CATEGORY	Default Values	Watershed Runoff by Land Use (gallons)	Fecal Coliform Loading by Land Use (Millions/storm)	Average Fecal Coliform Concentration in Runoff fc/100 ml
HYDROLOGIC INPUTS:					
Rain event (inches)	1.50				
Time since Last Rain (days)	3.00				
Amount Rainfall in previous 5 days (inches)	0.5				
LAND USE INPUTS:					
Commercial/Industrial Acreage			0	No Loading	
Meadows/Parks/Cemeteries	39		12,708	No Loading	
Forest/Woods	300		97,755	4	1
RESIDENTIAL					
No. Homes on Septic Systems:					
Category I	166				
Category II	82				
Category III	40				
Category IV	43		1,294,280	11,507	235
Average Residential acreage per house	1.80				
LAND USE ACREAGE:		Tons manure per acre			
Days Since Manure Applied	365.00	10			
If no manure in 1 year enter 365 for background concentrations					
Agricultural Acreage:					
Category I	0				
Category II	5				
Category III	0				
Category IV	0		2,172	25	300
Grazing Acres	5				
# Head of Livestock:					
Category I	0				
Category II	0	Days Between			
Category III	0	Animal Grazing			
Category IV	0	3.00	2,172	0	0
ROAD RUNOFF:	LENGTH (FT.)	Road Acres Auto.-calculated			
Low Density Resid.	5761	4.06	161,892	4,390	700
High Density Resid.	16	0.01	450	6	335
Major Roads/H'ways	15,308	21.55	860,352	30,004	900
Commercial/Industrial	15,308	21.55	860,352	20,053	602
Agricultural/Woods	8,910	6.27	250,383	1	0
			Total Watershed Runoff (Gallons)	Total fc Loading (Millions)	Average Runoff FC conc. (fc/100 ml)
			3,542,518	65,990	492

FecaLOAD Model: ROSSMORE STREAM WATERSHED

EXISTING CONDITIONS (1995) WITH MANURE APPLICATION

1	2	3	4	5	6
SOURCES BY CATEGORY	UNITS BY CATEGORY	Default Values	Watershed Runoff by Land Use (gallons)	Fecal Coliform Loading by Land Use (Millions/storm)	Average Fecal Coliform Concentration in Runoff fc/100 ml
HYDROLOGIC INPUTS:					
Rain event (inches)	1.50				
Time since Last Rain (days)	3.00				
Amount Rainfall in previous 5 days (inches)	0.5				
LAND USE INPUTS:					
Commercial/Industrial Acreage			0	No Loading	
Meadows/Parks/Cemeteries	39		12,708	No Loading	
Forest/Woods	601		195,836	7	1
RESIDENTIAL					
No. Homes on Septic Systems:					
Category I	50				
Category II	25				
Category III	12				
Category IV	13		391,021	3,468	234
Average Residential acreage per house	1.80				
LAND USE ACREAGE:		Tons manure per acre			
Days Since Manure Applied	8.00	10			
If no manure in 1 year enter 365 for background concentrations					
Agricultural Acreage:					
Category I	0				
Category II	10				
Category III	0				
Category IV	0		4,345	1,148	6,983
Grazing Acres	5				
# Head of Livestock:					
Category I	0				
Category II	0	Days Between			
Category III	0	Animal Grazing			
Category IV	0	3.00	2,172	0	0
ROAD RUNOFF:	LENGTH (FT.)	Road Acres Auto.-calculated			
Low Density Resid.	3670	2.58	103,132	2,797	700
High Density Resid.	10	0.01	281	4	335
Major Roads/H'ways	9,750	13.73	547,977	19,110	900
Commercial/Industrial	9,750	13.73	547,977	12,773	602
Agricultural/Woods	8,910	6.27	250,383	1	0
			Total Watershed Runoff (Gallons)	Total fc Loading (Millions)	Average Runoff FC conc. (fc/100 ml)
			2,055,834	39,308	505

FecaLOAD Model: ROSSMORE STREAM WATERSHED					
BUILDOUT CONDITIONS; WITH MANURE APPLICATION					
1	2	3	4	5	6
SOURCES BY CATEGORY	UNITS BY CATEGORY	Default Values	Watershed Runoff by Land Use (gallons)	Fecal Coliform Loading by Land Use (Millions/storm)	Average Fecal Coliform Concentration in Runoff fc/100 ml
HYDROLOGIC INPUTS:					
Rain event (inches)	1.50				
Time since Last Rain (days)	3.00				
Amount Rainfall in previous 5 days (inches)	0.5				
LAND USE INPUTS:					
Commercial/Industrial Acreage			0	No Loading	
Meadows/Parks/Cemeteries	39		12,708	No Loading	
Forest/Woods	300		97,755	4	1
RESIDENTIAL					
No. Homes on Septic Systems:					
Category I	116				
Category II	57				
Category III	28				
Category IV	30		903,259	8,039	235
Average Residential acreage per house	1.80				
LAND USE ACREAGE:		Tons manure per acre			
Days Since Manure Applied	8.00	10			
If no manure in 1 year enter 365 for background concentrations					
Agricultural Acreage:					
Category I	0				
Category II	5				
Category III	0				
Category IV	0		2,172	574	6,983
Grazing Acres	5				
# Head of Livestock:					
Category I	0				
Category II	0	Days Between			
Category III	0	Animal Grazing			
Category IV	0	3.00	2,172	0	0
ROAD RUNOFF:	LENGTH (FT.)	Road Acres Auto.-calculated			
Low Density Resid.	5761	4.06	161,892	4,390	700
High Density Resid.	16	0.01	450	6	335
Major Roads/H'ways	15,308	21.55	860,352	30,004	900
Commercial/Industrial	15,308	21.55	860,352	20,053	602
Agricultural/Woods	8,910	6.27	250,383	1	0
			Total Watershed Runoff (Gallons) 3,151,497	Total fc Loading (Millions) 63,071	Average Runoff FC conc. (fc/100 ml) 529

FecaLOAD Model: WHARTON POINT STREAM WATERSHED					
EXISTING CONDITIONS (1995), AND NO MANURE APPLICATION					
1	2	3	4	5	6
SOURCES BY CATEGORY	UNITS BY CATEGORY	Default Values	Watershed Runoff by Land Use (gallons)	Fecal Coliform Loading by Land Use (Millions/storm)	Average Fecal Coliform Concentration in Runoff fc/100 ml
HYDROLOGIC INPUTS:					
Rain event (inches)	1.50				
Time since Last Rain (days)	3.00				
Amount Rainfall in previous 5 days (inches)	0.5				
LAND USE INPUTS:					
Commercial/Industrial Acreage			0	No Loading	
Meadows/Parks/Cemeteries	13		4,236	No Loading	
Forest/Woods	719		234,287	9	1
RESIDENTIAL					
No. Homes on Septic Systems:					
Category I					
Category II	15				
Category III	10				
Category IV	28		633,237	5,596	233
Average Residential acreage per house	5.50				
LAND USE ACREAGE:		Tons manure per acre			
Days Since Manure Applied	365.00	10			
If no manure in 1 year enter 365 for background concentrations					
Agricultural Acreage:					
Category I	3				
Category II	5				
Category III	5				
Category IV	140		66,474	755	300
Grazing Acres	1				
# Head of Livestock:					
Category I					
Category II		Days Between			
Category III		Animal Grazing			
Category IV		3.00	434	0	0
ROAD RUNOFF:		Road Acres Auto.-calculated			
Low Density Resid.	771	0.54	21,666	588	700
High Density Resid.	5	0.00	141	2	335
Major Roads/H'ways	21,290	29.98	1,196,557	41,728	900
Commercial/Industrial	21,290	29.98	1,196,557	27,890	602
Agricultural/Woods	19,300	13.59	542,357	3	0
			Total Watershed Runoff (Gallons)	Total fc Loading (Millions)	Average Runoff FC conc. (fc/100 ml)
			3,895,946	76,570	519

FecaLOAD Model: WHARTON POINT STREAM WATERSHED

BUILDOUT CONDITIONS; NO MANURE APPLICATION

1	2	3	4	5	6
SOURCES BY CATEGORY	UNITS BY CATEGORY	Default Values	Watershed Runoff by Land Use (gallons)	Fecal Coliform Loading by Land Use (Millions/storm)	Average Fecal Coliform Concentration In Runoff fc/100 ml
HYDROLOGIC INPUTS:					
Rain event (inches)	1.50				
Time since Last Rain (days)	3.00				
Amount Rainfall in previous 5 days (inches)	0.5				
LAND USE INPUTS:					
Commercial/Industrial Acreage			0	No Loading	
Meadows/Parks/Cemeteries	13		4,236	No Loading	
Forest/Woods	360		117,306	4	1
RESIDENTIAL					
No. Homes on Septic Systems:					
Category I					
Category II	209				
Category III	141				
Category IV	395		8,901,163	78,936	234
Average Residential acreage per house	5.50				
LAND USE ACREAGE:		Tons manure per acre			
Days Since Manure Applied	365.00	10			
If no manure in 1 year enter 365 for background concentrations					
Agricultural Acreage:					
Category I	2				
Category II	3				
Category III	3				
Category IV	70		33,889	385	300
Grazing Acres	1				
# Head of Livestock:					
Category I					
Category II		Days Between			
Category III		Animal Grazing			
Category IV		3.00	434	0	0
ROAD RUNOFF:		Road Acres Auto.-calculated			
Low Density Resid.	1488	1.05	41,815	1,134	700
High Density Resid.	10	0.01	281	4	335
Major Roads/H'ways	41,100	57.87	2,309,934	80,556	900
Commercial/Industrial	41,100	57.87	2,309,934	53,841	602
Agricultural/Woods	19,300	13.59	542,357	3	0
			Total Watershed Runoff (Gallons)	Total fc Loading (Millions)	Average Runoff FC conc. (fc/100 ml)
			14,261,350	214,863	398

FecaLOAD Model: WHARTON POINT STREAM WATERSHED					
BUILDOUT CONDITIONS; WITH MANURE APPLICATION					
1	2	3	4	5	6
SOURCES BY CATEGORY	UNITS BY CATEGORY	Default Values	Watershed Runoff by Land Use (gallons)	Fecal Coliform Loading by Land Use (Millions/storm)	Average Fecal Coliform Concentration in Runoff fc/100 ml
HYDROLOGIC INPUTS:					
Rain event (inches)	1.50				
Time since Last Rain (days)	3.00				
Amount Rainfall in previous 5 days (inches)	0.5				
LAND USE INPUTS:					
Commercial/Industrial Acreage			0	No Loading	
Meadows/Parks/Cemeteries	13		4,236	No Loading	
Forest/Woods	360		117,306	4	1
RESIDENTIAL					
No. Homes on Septic Systems:					
Category I					
Category II	209				
Category III	141				
Category IV	367		8,566,623	74,522	230
Average Residential acreage per house	5.50				
LAND USE ACREAGE:		Tons manure per acre			
Days Since Manure Applied	8.00	10			
If no manure in 1 year enter 365 for background concentrations					
Agricultural Acreage:					
Category I	2				
Category II	3				
Category III	3				
Category IV	70		33,889	48,188	37,568
Grazing Acres	1				
# Head of Livestock:					
Category I					
Category II		Days Between Animal Grazing			
Category III					
Category IV		3.00	434	0	0
ROAD RUNOFF:		Road Acres Auto.-calculated			
Low Density Resid.	1488	1.05	41,815	1,134	700
High Density Resid.	10	0.01	281	4	335
Major Roads/H'ways	41,100	57.87	2,309,934	80,556	900
Commercial/Industrial	41,100	57.87	2,309,934	53,841	602
Agricultural/Woods	19,300	13.59	542,357	3	0
			Total Watershed Runoff (Gallons) 13,926,809	Total fc Loading (Millions) 258,252	Average Runoff FC conc. (fc/100 ml) 490

FecaLOAD Model: WHARTON POINT STREAM WATERSHED					
EXISTING CONDITIONS (1995) WITH MANURE APPLICATION					
1	2	3	4	5	6
SOURCES BY CATEGORY	UNITS BY CATEGORY	Default Values	Watershed Runoff by Land Use (gallons)	Fecal Coliform Loading by Land Use (Millions/storm)	Average Fecal Coliform Concentration in Runoff fc/100 ml
HYDROLOGIC INPUTS:					
Rain event (inches)	1.50				
Time since Last Rain (days)	3.00				
Amount Rainfall in previous 5 days (inches)	0.5				
LAND USE INPUTS:					
Commercial/Industrial Acreage			0	No Loading	
Meadows/Parks/Cemeteries	13		4,236	No Loading	
Forest/Woods	719		234,287	9	1
RESIDENTIAL					
No. Homes on Septic Systems:					
Category I					
Category II	15				
Category III	10				
Category IV	28		633,237	5,596	233
Average Residential acreage per house	5.50				
LAND USE ACREAGE:		Tons manure per acre			
Days Since Manure Applied	8.00	10			
If no manure in 1 year enter 365 for background concentrations					
Agricultural Acreage:					
Category I	3				
Category II	5				
Category III	5				
Category IV	140		66,474	95,811	38,080
Grazing Acres	1				
# Head of Livestock:					
Category I					
Category II		Days Between			
Category III		Animal Grazing			
Category IV		3.00	434	0	0
ROAD RUNOFF:		Road Acres Auto.-calculated			
Low Density Resid.	771	0.54	21,666	588	700
High Density Resid.	5	0.00	141	2	335
Major Roads/H'ways	21,290	29.98	1,196,557	41,728	900
Commercial/Industrial	21,290	29.98	1,196,557	27,890	602
Agricultural/Woods	19,300	13.59	542,357	3	0
			Total Watershed Runoff (Gallons)	Total fc Loading (Millions)	Average Runoff FC conc. (fc/100 ml)
			3,895,946	171,627	1,164

APPENDIX C

FecaLOAD Ranking Approaches For Each Subwatershed Under Existing and Buildout Conditions

QUALITATIVE RANKINGS OF FECAL COLIFORM SOURCES UNDER
BUILDOUT CONDITIONS (1,603 TOTAL NEW WATERSHED DWELLINGS APPORTIONED BY SUBWATERSHED)

BUNGANUC STREAM SUBWATERSHED
BUILDOUT CONDITIONS

	Number of Units (total)	average	Ranked Position in Model Category I	Caetgory II	Category III	Category IV
Dwellings w/septic systems	662		0	397	199	66
Average Residential Acreage per Dwelling (1)		1.6				
Total Agricultural Acres	636		150	86	150	250
Total Forest Acres	2,221	not ranked				
Total Open Space/Meadow Acres	163	not ranked				
Head of Livestock (2)			10	10	10	10
Road Length by Land Cover (not ranked)						
	Feet					
Agricultural	22,600					
Forest	26,000					
Residential	4,200					
Developed	12,700					

(1) Total residential acreage = 234/ number of watershed dwellings
(2) Estimate of livestock in subwatershed

ROSSMORE STREAM SUBWATERSHED
BUILDOUT CONDITIONS

	Number of Units (total)	average	Ranked Position in Model Category I	Caetgory II	Category III	Category IV
Dwellings w/septic systems	330		165	83	40	43
Average Residential Acreage per Dwelling (1)		1.8				
Total Agricultural Acres	10		0	10	0	0
Total Forest Acres	601	not ranked				
Total Open Space/Meadow Acres	39	not ranked				
Head of Livestock (2)	0					
Road Length by Land Cover (not ranked)						
	Feet					
Agricultural	640					
Forest	8,270					
Residential	3,670					
Developed	19,500					

(1) Total residential acreage / number of watershed dwellings
(2) Estimate of livestock in subwatershed

MEREPOINT NECK SUBWATERSHED
BUILDOUT CONDITIONS

	Number of Units (total)	average	Ranked Position in Model Category I	Caetgory II	Category III	Category IV
Dwellings w/septic systems	132		11	12	13	95
Average Residential Acreage per Dwelling (1)	1					
Total Agricultural Acres	54		4	5	5	10
Total Forest Acres	232	not ranked				
Total Open Space/Meadow Acres	12	not ranked				
Head of Livestock (2)	0					
Road Length by Land Cover (not ranked)						
	Feet					
Agricultural	2,975					
Forest	14,025					
Residential	7,320					
Developed	4,016					

(1) Total residential acreage / number of watershed dwellings
(2) Estimate of livestock in subwatershed

WHARTON PT. STREAM SUBWATERSHED
BUILDOUT CONDITIONS

	Number of Units (total)	average	Ranked Position in Model Category I	Caetgory II	Category III	Category IV
Dwellings w/septic systems	745		0	201	134	373
Average Residential Acreage per Dwelling (1)		5.5				
Total Agricultural Acres	153		3	5	5	140
Total Forest Acres	719	not ranked				
Total Open Space/Meadow Acres	13	not ranked				
Head of Livestock (2)	0					
Road Length by Land Cover (not ranked)						
	Feet					
Agricultural	12,000					
Forest	7,300					
Residential	771					
Developed	42,580					

(1) Total residential acreage / number of watershed dwellings
(2) Estimate of livestock in subwatershed

FLYING PT. NECK SUBWATERSHED
BUILDOUT CONDITIONS

	Number of Units (total)	average	Ranked Position in Model Category I	Caetgory II	Category III	Category IV
Dwellings w/septic systems	288		20	43	23	216
Average Residential Acreage per Dwelling (1)		0.8				
Total Agricultural Acres	100		10	20	20	50
Total Forest Acres	690	not ranked				
Total Open Space/Meadow Acres	3	not ranked				
Head of Livestock (2)	40		10	10	10	10
Road Length by Land Cover (not ranked)						
	Feet					
Agricultural	5,080					
Forest	17,510					
Residential	11,790					
Developed	0					

(1) Total residential acreage / number of watershed dwellings
(2) Estimate of livestock in subwatershed

BUNGANUC PT. SUBWATERSHED
BUILDOUT CONDITIONS

	Number of Units (total)	average	Ranked Position in Model Category I	Caetgory II	Category III	Category IV
Dwellings w/septic systems	37		0	5	14	17
Average Residential Acreage						
per Dwelling (1)		2.2				
Total Agricultural Acres	56		3	10	10	30
Total Forest Acres	407	not ranked				
Total Open Space/Meadow Acres	16	not ranked				
Head of Livestock (2)	0					
Road Length by Land Cover (not ranked)						
	Feet					
Agricultural	1,736					
Forest	6,500					
Residential	956					
Developed	3,793					

(1) Total residential acreage / number of watershed dwellings
(2) Estimate of livestock in subwatershed

QUALITATIVE RANKINGS OF FECAL COLIFORM SOURCES UNDER EXISITNG DEVELOPED CONDITIONS

BUNGANUC STREAM SUBWATERSHED
EXISTING CONDITIONS

	Number of Units (total)	average	Ranked Position in Model Category I	Caetgory II	Category III	Category IV
Dwellings w/septic systems	142		0	85	42	15
Average Residential Acreage per Dwelling (1)		1.6				
Total Agricultural Acres	636		150	86	150	250
Total Forest Acres	2,221	not ranked				
Total Open Space/Meadow Acres	163	not ranked				
Head of Livestock (2)			10	10	10	10
Road Length by Land Cover (not ranked)						
	Feet					
Agricultural	22,600					
Forest	26,000					
Residential	4,200					
Developed	12,700					

(1) Total residential acreage = 234/ number of watershed dwellings
(2) Estimate of livestock in subwatershed

ROSSMORE STREAM SUBWATERSHED
EXISTING CONDITIONS

	Number of Units (total)	average	Ranked Position in Model Category I	Caetgory II	Category III	Category IV
Dwellings w/septic systems	100		50	25	12	13
Average Residential Acreage per Dwelling (1)		1.8				
Total Agricultural Acres	10		0	10	0	0
Total Forest Acres	601	not ranked				
Total Open Space/Meadow Acres	39	not ranked				
Head of Livestock (2)	0					
Road Length by Land Cover (not ranked)						
	Feet					
Agricultural	640					
Forest	8,270					
Residential	3,670					
Developed	19,500					

(1) Total residential acreage / number of watershed dwellings
(2) Estimate of livestock in subwatershed

MEREPOINT NECK SUBWATERSHED
EXISTING CONDITIONS

	Number of Units (total)	average	Ranked Position in Model Category I	Caetgory II	Category III	Category IV
Dwellings w/septic systems	123		10	11	12	90
Average Residential Acreage per Dwelling (1)	1					
Total Agricultural Acres	54		4	5	5	10
Total Forest Acres	232	not ranked				
Total Open Space/Meadow Acres	12	not ranked				
Head of Livestock (2)	0					
Road Length by Land Cover (not ranked)						
	Feet					
Agricultural	2,975					
Forest	14,025					
Residential	7,320					
Developed	4,016					

(1) Total residential acreage / number of watershed dwellings
(2) Estimate of livestock in subwatershed

WHARTON PT. STREAM SUBWATERSHED
EXISTING CONDITIONS

	Number of Units (total)	average	Ranked Position in Model Category I	Caetgory II	Category III	Category IV
Dwellings w/septic systems	53		0	15	10	28
Average Residential Acreage per Dwelling (1)		5.5				
Total Agricultural Acres	153		3	5	5	140
Total Forest Acres	719	not ranked				
Total Open Space/Meadow Acres	13	not ranked				
Head of Livestock (2)	0					
Road Length by Land Cover (not ranked)						
	Feet					
Agricultural	12,000					
Forest	7,300					
Residential	776					
Developed	42,580					

(1) Total residential acreage / number of watershed dwellings
(2) Estimate of livestock in subwatershed

FLYING PT. SUBWATERSHED
EXISTING CONDITIONS

	Number of Units (total)	average	Ranked Position in Model Category I	Caetgory II	Category III	Category IV
Dwellings w/septic systems	152		10	15	12	115
Average Residential Acreage per Dwelling (1)		0.8				
Total Agricultural Acres	100		10	20	20	50
Total Forest Acres	690	not ranked				
Total Open Space/Meadow Acres	3	not ranked				
Head of Livestock (2)	40		10	10	10	10
Road Length by Land Cover (not ranked)	Feet					
Agricultural	5,080					
Forest	17,510					
Residential	11,790					
Developed	0					

(1) Total residential acreage / number of watershed dwellings
(2) Estimate of livestock in subwatershed

BUNGANUC PT. SUBWATERSHED
EXISTING CONDITIONS

	Number of Units (total)	average	Ranked Position in Model Category I	Caetgory II	Category III	Category IV
Dwellings w/septic systems	21		0	3	8	10
Average Residential Acreage per Dwelling (1)		2.2				
Total Agricultural Acres	56		3	10	10	30
Total Forest Acres	407	not ranked				
Total Open Space/Meadow Acres	16	not ranked				
Head of Livestock (2)	0					
Road Length by Land Cover (not ranked)						
	Feet					
Agricultural	1,736					
Forest	6,500					
Residential	956					
Developed	3,793					

(1) Total residential acreage / number of watershed dwellings
(2) Estimate of livestock in subwatershed

APPENDIX D

Nitrogen Model Runs Under Existing and Buildout Scenarios

MAQUOIT BAY								
SCENARIO 1 - EXISTING LAND USES WITH MANURE APPLICATIONS								
BUNGANUC STREAM			SOURCE		REFER-	PERSIS-	LOADING	
	INPUT		LOADING		ENCE	TENCE	lbs/yr	
GROUND WATER								
Septic Systems III/IV	57	systems	30	lbs/unit-yr	1	0.00	0	
Septic Systems I/II	85	systems	30	lbs/unit-yr	1	0.15	371	
Lawns	142	lawns	10	lbs/5000 sq ft-yr	1	0.15	207	
Agriculture Fields/ Manure	636	acres	17.25	lbs/acre-yr	2	0.19	2045	
Cows	40	cows	135	lbs/cow-yr	3	0.19	1007	
Forested	2221	acres	2.2	lbs/acre-yr	5	0.29	1423	
Sludge Disposal/Septage Dispos	160000	lbs	1	15 yrs	6	0.00	320	
road drainage	76	acres	0	lbs/acre-yr	1	0.00	0	
TOTAL (Loading to Stream)							5373	
STORMWATER FLOW								
Septic Systems III/IV	57	systems	30	lbs/unit-yr	1	0.35	606	
Septic Systems I/II	85	systems	30	lbs/unit-yr	1	0.00	0	
Lawns	142	lawns	10	lbs/5000 sq ft-yr	1	0.35	503	
Agriculture Fields/ Manure	636	acres	17.25	lbs/acre-yr	2	0.45	4976	
Cows	40	cows	135	lbs/cow-yr	3	0.45	2449	
Forested	2221	acres	2.2	lbs/acre-yr	5	0.71	3463	
Sludge Disposal/Septage Dispos	160000	lbs	1	15 yrs	6	0.00	0	
road drainage	76	acres	8.7	lbs/acre-yr	1	1.00	661	
TOTAL (Loading to Stream)							12659	
				TOTAL LOADING			18032	
						MG/L		
				baseflow	=	1.08		
				runoff	=	1.04		
				stormflow	=	1.05		
Runoff/Recharge Calculations:								
	Soils	Runoff	(M gal/	Recharge				
	(acres)	(ft/yr)	yr)	(ft/yr)	(M gal/yr)			
clayey soils	2852	1.5	1397.6	0.25	233			
sandy soils	748	0.25	61.093	1.50	367			
total	3600		1458.7	6.17	599			
	ave stormflow (cfs)			8.70	ave baseflow		2.53	

MAQUOIT BAY								
SCENARIO 1 - EXISTING LAND USES WITH MANURE APPLICATIONS								
ROSSMORE STREAM								
					ref	persist	lbs/yr	
GROUND WATER								
Septic Systems III/IV	25	systems	30	lbs/unit-yr	1	0.00	0	
Septic Systems I/II	75	systems	30	lbs/unit-yr	1	0.37	834	
Lawns	100	lawns	10	lbs/5000 sq ft-yr	1	0.37	371	
Agriculture Fields/ Manure	10	acres	17.25	lbs/acre-yr	2	0.47	82	
Cows	0	cows	135	lbs/cow-yr	3	0.47	0	
Forested	601	acres	2.2	lbs/acre-yr	5	0.74	980	
Sludge Disposal/Septage Dispo:	0	lbs	1	15 yrs	6	0.00	0	
road drainage	37	acres	0	lbs/acre-yr	1	0.00	0	
TOTAL (Loading to Stream)							2266	
STORMWATER FLOW								
Septic Systems III/IV	25	systems	30	lbs/unit-yr	1	0.13	97	
Septic Systems I/II	75	systems	30	lbs/unit-yr	1	0.00	0	
Lawns	100	lawns	10	lbs/5000 sq ft-yr	1	0.13	129	
Agriculture Fields/ Manure	10	acres	17.25	lbs/acre-yr	2	0.17	29	
Cows	0	cows	135	lbs/cow-yr	3	0.17	0	
Forested	601	acres	2.2	lbs/acre-yr	5	0.26	342	
Sludge Disposal/Septage Dispo:	0	lbs	1	15 yrs	6	0.07	0	
road drainage	37	acres	8.7	lbs/acre-yr	1	1.00	322	
TOTAL (Loading to Stream)							919	
				TOTAL LOADING			3185	
						MG/L		
				baseflow	=	0.73		
				runoff	=	0.85		
				stormflow	=	0.76		
Runoff/Recharge Calculations:								
	Soils	Runoff		Recharge				
	(acres)	(ft/yr)	(Mgal/yr)	(ft/yr)	(M gal/yr)			
clayey soils	142	1.5	69.587	0.25	12			
sandy soils	732	0.25	59.786	1.50	359			
total	874		129.37	0.55	370			
	ave stormflow (cfs)			2.11	ave baseflow		1.57	

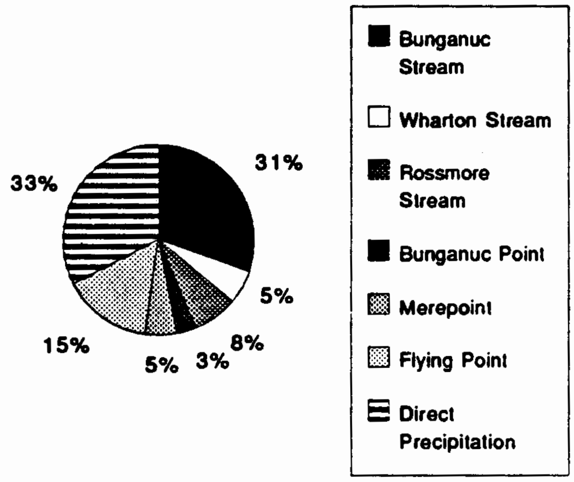
MAQUOIT BAY							
SCENARIO 1 - EXISTING LAND USES WITH MANURE APPLICATIONS							
WHARTON POINT STREAM							
					ref	persist	lbs/yr
GROUND WATER							
Septic Systems III/IV	38	systems	30	lbs/unit-yr	1	0.00	0
Septic Systems I/II	15	systems	30	lbs/unit-yr	1	0.33	148
Lawns	53	lawns	10	lbs/5000 sq ft-yr	1	0.33	174
Agriculture Fields/ Manure	153	acres	17.25	lbs/acre-yr	2	0.42	1109
Cows	0	cows	135	lbs/cow-yr	3	0.42	0
Forested	719	acres	2.2	lbs/acre-yr	5	0.66	1039
Sludge Disposal/Septage Dispo	0	lbs	1	15 yrs	6	0.00	0
road drainage	72	acres	0	lbs/acre-yr	1	0.00	0
TOTAL (Loading to Stream)							2470
STORMWATER FLOW							
Septic Systems III/IV	38	systems	30	lbs/unit-yr	1	0.17	196
Septic Systems I/II	15	systems	30	lbs/unit-yr	1	0.00	0
Lawns	53	lawns	10	lbs/5000 sq ft-yr	1	0.17	91
Agriculture Fields/ Manure	153	acres	17.25	lbs/acre-yr	2	0.22	580
Cows	0	cows	135	lbs/cow-yr	3	0.22	0
Forested	719	acres	2.2	lbs/acre-yr	5	0.34	543
Sludge Disposal/Septage Dispo	0	lbs	1	15 yrs	6	0.07	0
road drainage	72	acres	8.7	lbs/acre-yr	1	1.00	626
TOTAL (Loading to Stream)							2036
				TOTAL LOADING			4506
						MG/L	
				baseflow	=	0.54	
				runoff	=	0.85	
				stormflow	=	0.65	
Runoff/Recharge Calculations:							
	Soils	Runoff		Recharge			
	(acres)	(ft/yr)	(Mgal/yr)	(ft/yr)	(M gal/yr)		
clayey soils	409	1.5	200.43	0.25	33		
sandy soils	1048	0.25	85.595	1.50	514		
total	1457		286.03	1.21	547		
		ave stormflow (cfs)		3.52	ave baseflow		2.31

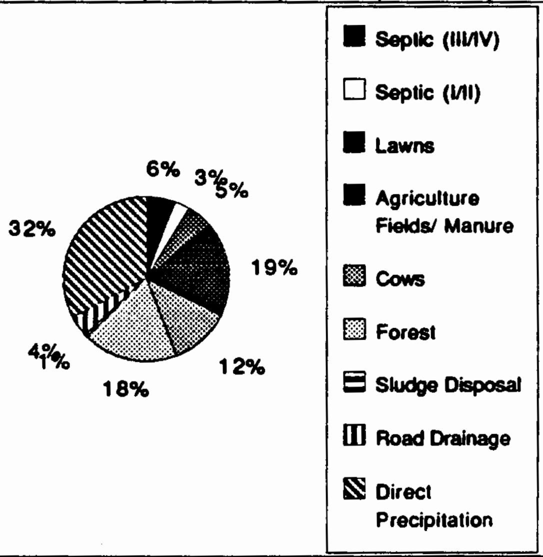
MAQUOIT BAY								
SCENARIO 1 - EXISTING LAND USES WITH MANURE APPLICATIONS								
BUNGANUC POINT								
					ref	persist	lbs/yr	
GROUND WATER								
Septic Systems III/IV	18	systems	30	lbs/unit-yr	1	0.00	0	
Septic Systems I/II	3	systems	30	lbs/unit-yr	1	0.13	12	
Lawns	21	lawns	10	lbs/5000 sq ft-yr	1	0.13	27	
Agriculture Fields/ Manure	56	acres	17.25	lbs/acre-yr	2	0.16	159	
Cows	0	cows	135	lbs/cow-yr	3	0.16	0	
Forested	407	acres	2.2	lbs/acre-yr	5	0.26	230	
Sludge Disposal/Septage Dispo:	0	lbs	1	15 yrs	6	0.00	0	
road drainage	15	acres	0	lbs/acre-yr	1	0.00	0	
TOTAL (Loading to Stream)							427	
STORMWATER FLOW								
Septic Systems III/IV	18	systems	30	lbs/unit-yr	1	0.37	201	
Septic Systems I/II	3	systems	30	lbs/unit-yr	1	0.00	0	
Lawns	21	lawns	10	lbs/5000 sq ft-yr	1	0.37	78	
Agriculture Fields/ Manure	56	acres	17.25	lbs/acre-yr	2	0.48	459	
Cows	0	cows	135	lbs/cow-yr	3	0.48	0	
Forested	407	acres	2.2	lbs/acre-yr	5	0.74	665	
Sludge Disposal/Septage Dispo:	0	lbs	1	15 yrs	6	0.07	0	
road drainage	15	acres	8.7	lbs/acre-yr	1	1.00	131	
TOTAL (Loading to Stream)							1534	
				TOTAL LOADING			1961	
						MG/L		
				baseflow	=	0.58		
				runoff	=	0.72		
				stormflow	=	0.68		
Runoff/Recharge Calculations:								
	Soils	Runoff		Recharge				
	(acres)	(ft/yr)	(Mgal/yr)	(ft/yr)	(M gal/yr)			
clayey soils	505	1.5	247.48	0.25	41			
sandy soils	96	0.25	7.8408	1.50	47			
total	601		255.32	1.08	88			
		ave stormflow (cfs)		1.45	ave baseflow		0.37	

MAQUOIT BAY								
SCENARIO 1 - EXISTING LAND USES WITH MANURE APPLICATIONS								
MEREPOINT NECK								
					ref	persist	lbs/yr	
GROUND WATER								
Septic Systems III/IV	102	systems	30	lbs/unit-yr	1	0.00	0	
Septic Systems I/II	21	systems	30	lbs/unit-yr	1	0.18	115	
Lawns	123	lawns	10	lbs/5000 sq ft-yr	1	0.18	224	
Agriculture Fields/ Manure	54	acres	17.25	lbs/acre-yr	2	0.23	218	
Cows	0	cows	135	lbs/cow-yr	3	0.23	0	
Forested	232	acres	2.2	lbs/acre-yr	5	0.36	186	
Sludge Disposal/Septage Dispo:	0	lbs	1	15 yrs	6	0.00	0	
road drainage	32.5	acres	0	lbs/acre-yr	1	0.00	0	
TOTAL (Loading to Stream)							743	
STORMWATER FLOW								
Septic Systems III/IV	102	systems	30	lbs/unit-yr	1	0.32	972	
Septic Systems I/II	21	systems	30	lbs/unit-yr	1	0.00	0	
Lawns	123	lawns	10	lbs/5000 sq ft-yr	1	0.32	391	
Agriculture Fields/ Manure	54	acres	17.25	lbs/acre-yr	2	0.41	379	
Cows	0	cows	135	lbs/cow-yr	3	0.41	0	
Forested	232	acres	2.2	lbs/acre-yr	5	0.64	324	
Sludge Disposal/Septage Dispo:	0	lbs	1	15 yrs	6	0.07	0	
road drainage	32.5	acres	8.7	lbs/acre-yr	1	1.00	283	
TOTAL (Loading to Stream)							2348	
				TOTAL LOADING			3091	
						MG/L		
				baseflow	=	1.11		
				runoff	=	2.01		
				stormflow	=	1.68		
Runoff/Recharge Calculations:								
	Soils	Runoff		Recharge				
	(acres)	(ft/yr)	(Mgal/yr)	(ft/yr)	(M gal/yr)			
clayey soils	266	1.5	130.35	0.25	22			
sandy soils	120	0.25	9.801	1.50	59			
total	386		140.15	0.59	81			
	ave stormflow (cfs)			0.93	ave baseflow		0.34	

MAQUOIT BAY								
SCENARIO 1 - EXISTING LAND USES WITH MANURE APPLICATIONS								
FLYING POINT								
					ref	persist	lbs/yr	
GROUND WATER								
Septic Systems III/IV	127	systems	30	lbs/unit-yr	1	0.00	0	
Septic Systems I/II	25	systems	30	lbs/unit-yr	1	0.13	99	
Lawns	152	lawns	10	lbs/5000 sq ft-yr	1	0.13	200	
Agriculture Fields/ Manure	100	acres	17.25	lbs/acre-yr	2	0.17	291	
Cows	40	cows	135	lbs/cow-yr	3	0.17	909	
Forested	690	acres	2.2	lbs/acre-yr	5	0.26	399	
Sludge Disposal/Septage Dispo:	0	lbs	1	15 yrs	6	0.00	0	
road drainage	39	acres	0	lbs/acre-yr	1	0.00	0	
TOTAL (Loading to Stream)							1898	
STORMWATER FLOW								
Septic Systems III/IV	127	systems	30	lbs/unit-yr	1	0.37	1404	
Septic Systems I/II	25	systems	30	lbs/unit-yr	1	0.00	0	
Lawns	152	lawns	10	lbs/5000 sq ft-yr	1	0.37	560	
Agriculture Fields/ Manure	100	acres	17.25	lbs/acre-yr	2	0.47	813	
Cows	40	cows	135	lbs/cow-yr	3	0.47	2547	
Forested	690	acres	2.2	lbs/acre-yr	5	0.74	1119	
Sludge Disposal/Septage Dispo:	0	lbs	1	15 yrs	6	0.07	0	
road drainage	39	acres	8.7	lbs/acre-yr	1	1.00	339	
TOTAL (Loading to Stream)							6782	
				TOTAL LOADING			8680	
						MG/L		
				baseflow	=	1.59		
				runoff	=	2.03		
				stormflow	=	1.92		
Runoff/Recharge Calculations:								
	Soils	Runoff		Recharge				
	(acres)	(ft/yr)	(Mgal/yr)	(ft/yr)	(M gal/yr)			
clayey soils	790	1.5	387.14	0.25	65			
sandy soils	160	0.25	13.068	1.50	78			
total	950		400.21	1.69	143			
	ave stormflow (cfs)			2.30	ave baseflow		0.60	

MAQUOIT BAY						
SCENARIO 1 - EXISTING LAND USES WITH MANURE APPLICATIONS						
SUMMARY OF NITROGEN LOADING TO BAY						
Bunganuc Stream	18032	31%	Septic (III/IV)		3475	6%
Wharton Stream	3185	5%	Septic (I/II)		1578	3%
Rossmore Stream	4506	8%	Lawns		2955	5%
Bunganuc Point	1961	3%	Agriculture Fields/ Manure		11139	19%
Merepoint	3091	5%	Cows		6912	12%
Flying Point	8680	15%	Forest		10714	18%
Direct Precipitation	19200	33%	Sludge Disposal		320	1%
			Road Drainage		2362	4%
			Direct Precipitation		19200	33%
TOTAL	58655		TOTAL		58655	





MAQUOIT BAY								
SCENARIO 1 - EXISTING LAND USES WITH MANURE APPLICATIONS								
FLUSHING RATE OF EMBAYMENT								
Surface Area of Embayment		2470	acres					
Mean Depth of Embayment		10	feet					
Volume at Mean Tide		8048	million gallons					
Mean Salinity of Embayment		21	ppt					
Salinity of Offshore Water		33	ppt					
Area of Watershed		7878	acres					
Flushing Rate (Pilson, 1985) =			0.57	days				
NITROGEN LOADING STANDARDS/CARRYING CAPACITY								
				Critical N Loading Rate			**% of Critical**	
Shallow (less than 3 meters average) & Flushing Rate < 5 days					4299334		1	%
Shallow (less than 3 meters average) & Flushing Rate > 5 days					108811		54	%
Deep (greater than 3 meters average)					217621		27	%
REFERENCES								
1: Nelson et al. (1988) assuming 3 people/unit.								
2: This loading value is derived from an average concentration of 0.93 mg/L detected during								
H&W watershed sampling multiplied times an estimated 22 inches of runoff per year.								
3: Frimpter et al. (1988) 36% volatilization loss 7 days @ 68 degrees								
4: estimated at 20% of human loading								
5: Reckhow et al (1980) forest export = 2.2 lbs/acre-yr								
6: sludge 27000 cubic yds disposed 1967-1982 @ 2% N dry weight @ 55 lbs sludge/cubic foot								
7: NADP								

MAQUOIT BAY							
SCENARIO 2 - BUILDOUT CONDITIONS WITH NO MANURE							
BUNGANUC STREAM			SOURCE		REFER-	PERSIS-	LOADING
	INPUT		LOADING		ENCE	TENCE	lbs/yr
GROUND WATER							
Septic Systems III/IV	265	systems	30	lbs/unit-yr	1	0.00	0
Septic Systems I/II	397	systems	30	lbs/unit-yr	1	0.15	1735
Lawns	662	lawns	10	lbs/5000 sq ft-yr	1	0.15	964
Agriculture Fields/No Manure	636	acres	4.5	lbs/acre-yr	2	0.19	534
Cows	40	cows	135	lbs/cow-yr	3	0.19	1007
Forested	2221	acres	2.2	lbs/acre-yr	5	0.29	1423
Sludge Disposal/Septage Dispo:	160000	lbs	1	15 yrs	6	0.00	320
road drainage	87	acres	0	lbs/acre-yr	1	0.00	0
TOTAL (Loading to Stream)							5982
STORMWATER FLOW							
Septic Systems III/IV	265	systems	30	lbs/unit-yr	1	0.35	2817
Septic Systems I/II	397	systems	30	lbs/unit-yr	1	0.00	0
Lawns	662	lawns	10	lbs/5000 sq ft-yr	1	0.35	2346
Agriculture Fields/Manure	636	acres	4.5	lbs/acre-yr	2	0.45	1298
Cows	40	cows	135	lbs/cow-yr	3	0.45	2449
Forested	2221	acres	2.2	lbs/acre-yr	5	0.71	3463
Sludge Disposal/Septage Dispo:	160000	lbs	1	15 yrs	6	0.00	0
road drainage	87	acres	8.7	lbs/acre-yr	1	1.00	757
TOTAL (Loading to Stream)							13131
				TOTAL LOADING			19112
						MG/L	
				baseflow	=	1.20	
				runoff	=	1.08	
				stormflow	=	1.11	
Runoff/Recharge Calculations:							
	Soils	Runoff	(M gal/	Recharge			
	(acres)	(ft/yr)	yr)	(ft/yr)	(M gal/yr)		
clayey soils	2852	1.5	1397.6	0.25	233		
sandy soils	748	0.25	61.093	1.50	367		
total	3600		1458.7	6.17	599		
	ave stormflow (cfs)			8.70	ave baseflow		2.53

MAQUOIT BAY							
SCENARIO 2 - BUILDOUT CONDITIONS WITH NO MANURE							
ROSSMORE STREAM							
					ref	persist	lbs/yr
GROUND WATER							
Septic Systems III/IV	83	systems	30	lbs/unit-yr	1	0.00	0
Septic Systems I/II	248	systems	30	lbs/unit-yr	1	0.37	2757
Lawns	331	lawns	10	lbs/5000 sq ft-yr	1	0.37	1227
Agriculture Fields/Manure	10	acres	4.5	lbs/acre-yr	2	0.47	21
Cows	0	cows	135	lbs/cow-yr	3	0.47	0
Forested	601	acres	2.2	lbs/acre-yr	5	0.74	980
Sludge Disposal/Septage Dispo:	0	lbs	1	15 yrs	6	0.00	0
road drainage	43	acres	0	lbs/acre-yr	1	0.00	0
TOTAL (Loading to Stream)							4985
STORMWATER FLOW							
Septic Systems III/IV	83	systems	30	lbs/unit-yr	1	0.13	322
Septic Systems I/II	248	systems	30	lbs/unit-yr	1	0.00	0
Lawns	331	lawns	10	lbs/5000 sq ft-yr	1	0.13	428
Agriculture Fields/Manure	10	acres	4.5	lbs/acre-yr	2	0.17	7
Cows	0	cows	135	lbs/cow-yr	3	0.17	0
Forested	601	acres	2.2	lbs/acre-yr	5	0.26	342
Sludge Disposal/Septage Dispo:	0	lbs	1	15 yrs	6	0.07	0
road drainage	43	acres	8.7	lbs/acre-yr	1	1.00	374
TOTAL (Loading to Stream)							1475
				TOTAL LOADING			6459
						MG/L	
				baseflow	=	1.61	
				runoff	=	1.37	
				stormflow	=	1.55	
Runoff/Recharge Calculations:							
	Soils	Runoff		Recharge			
	(acres)	(ft/yr)	(Mgal/yr)	(ft/yr)	(M gal/yr)		
clayey soils	142	1.5	69.587	0.25	12		
sandy soils	732	0.25	59.786	1.50	359		
total	874		129.37	0.55	370		
	ave stormflow (cfs)			2.11	ave baseflow		1.57

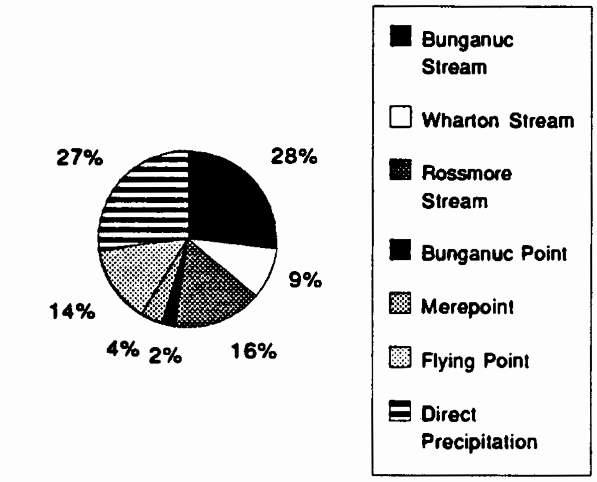
MAQUOIT BAY								
SCENARIO 2 - BUILDOUT CONDITIONS WITH NO MANURE								
WHARTON POINT STREAM								
					ref	persist	lbs/yr	
GROUND WATER								
Septic Systems III/IV	534	systems	30	lbs/unit-yr	1	0.00	0	
Septic Systems I/II	211	systems	30	lbs/unit-yr	1	0.33	2078	
Lawns	745	lawns	10	lbs/5000 sq ft-yr	1	0.33	2446	
Agriculture Fields/Manure	153	acres	4.5	lbs/acre-yr	2	0.42	289	
Cows	0	cows	135	lbs/cow-yr	3	0.42	0	
Forested	719	acres	2.2	lbs/acre-yr	5	0.66	1039	
Sludge Disposal/Septage Dispo:	0	lbs	1	15 yrs	6	0.00	0	
road drainage	83	acres	0	lbs/acre-yr	1	0.00	0	
TOTAL (Loading to Stream)							5852	
STORMWATER FLOW								
Septic Systems III/IV	534	systems	30	lbs/unit-yr	1	0.17	2750	
Septic Systems I/II	211	systems	30	lbs/unit-yr	1	0.00	0	
Lawns	745	lawns	10	lbs/5000 sq ft-yr	1	0.17	1279	
Agriculture Fields/Manure	153	acres	4.5	lbs/acre-yr	2	0.22	151	
Cows	0	cows	135	lbs/cow-yr	3	0.22	0	
Forested	719	acres	2.2	lbs/acre-yr	5	0.34	543	
Sludge Disposal/Septage Dispo:	0	lbs	1	15 yrs	6	0.07	0	
road drainage	83	acres	8.7	lbs/acre-yr	1	1.00	722	
TOTAL (Loading to Stream)							5446	
				TOTAL LOADING			11298	
						MG/L		
				baseflow	=	1.28		
				runoff	=	2.28		
				stormflow	=	1.63		
Runoff/Recharge Calculations:								
	Soils	Runoff		Recharge				
	(acres)	(ft/yr)	(Mgal/yr)	(ft/yr)	(M gal/yr)			
clayey soils	409	1.5	200.43	0.25	33			
sandy soils	1048	0.25	85.595	1.50	514			
total	1457		286.03	1.21	547			
	ave stormflow (cfs)			3.52	ave baseflow		2.31	

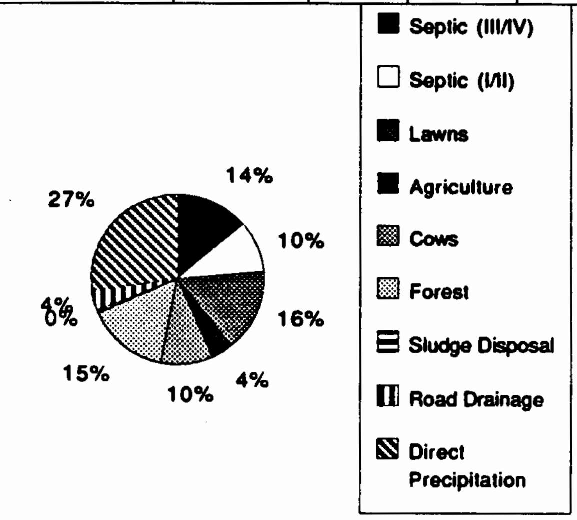
MAQUOIT BAY								
SCENARIO 2 - BUILDOUT CONDITIONS WITH NO MANURE								
BUNGANUC POINT								
					ref	persist	lbs/yr	
GROUND WATER								
Septic Systems III/IV	31	systems	30	lbs/unit-yr	1	0.00	0	
Septic Systems I/II	5	systems	30	lbs/unit-yr	1	0.13	19	
Lawns	36	lawns	10	lbs/5000 sq ft-yr	1	0.13	46	
Agriculture Fields/Manure	56	acres	4.5	lbs/acre-yr	2	0.16	41	
Cows	0	cows	135	lbs/cow-yr	3	0.16	0	
Forested	407	acres	2.2	lbs/acre-yr	5	0.26	230	
Sludge Disposal/Septage Dispo	0	lbs	1	15 yrs	6	0.00	0	
road drainage	17	acres	0	lbs/acre-yr	1	0.00	0	
TOTAL (Loading to Stream)							337	
STORMWATER FLOW								
Septic Systems III/IV	31	systems	30	lbs/unit-yr	1	0.37	346	
Septic Systems I/II	5	systems	30	lbs/unit-yr	1	0.00	0	
Lawns	36	lawns	10	lbs/5000 sq ft-yr	1	0.37	134	
Agriculture Fields/Manure	56	acres	4.5	lbs/acre-yr	2	0.48	120	
Cows	0	cows	135	lbs/cow-yr	3	0.48	0	
Forested	407	acres	2.2	lbs/acre-yr	5	0.74	665	
Sludge Disposal/Septage Dispo	0	lbs	1	15 yrs	6	0.07	0	
road drainage	17	acres	8.7	lbs/acre-yr	1	1.00	148	
TOTAL (Loading to Stream)							1412	
				TOTAL LOADING			1749	
						MG/L		
				baseflow	=	0.46		
				runoff	=	0.66		
				stormflow	=	0.61		
Runoff/Recharge Calculations:								
	Soils	Runoff		Recharge				
	(acres)	(ft/yr)	(Mgal/yr)	(ft/yr)	(M gal/yr)			
clayey soils	505	1.5	247.48	0.25	41			
sandy soils	96	0.25	7.8408	1.50	47			
total	601		255.32	1.08	88			
	ave stormflow (cfs)			1.45	ave baseflow		0.37	

MAQUOIT BAY								
SCENARIO 2 - BUILDOUT CONDITIONS WITH NO MANURE								
MEREPOINT NECK								
					ref	persist	lbs/yr	
GROUND WATER								
Septic Systems III/IV	108	systems	30	lbs/unit-yr	1	0.00	0	
Septic Systems I/II	23	systems	30	lbs/unit-yr	1	0.18	126	
Lawns	131	lawns	10	lbs/5000 sq ft-yr	1	0.18	239	
Agriculture Fields/Manure	54	acres	4.5	lbs/acre-yr	2	0.23	57	
Cows	0	cows	135	lbs/cow-yr	3	0.23	0	
Forested	232	acres	2.2	lbs/acre-yr	5	0.36	186	
Sludge Disposal/Septage Dispos	0	lbs	1	15 yrs	6	0.00	0	
road drainage	37	acres	0	lbs/acre-yr	1	0.00	0	
TOTAL (Loading to Stream)							608	
STORMWATER FLOW								
Septic Systems III/IV	108	systems	30	lbs/unit-yr	1	0.32	1029	
Septic Systems I/II	23	systems	30	lbs/unit-yr	1	0.00	0	
Lawns	131	lawns	10	lbs/5000 sq ft-yr	1	0.32	416	
Agriculture Fields/Manure	54	acres	4.5	lbs/acre-yr	2	0.41	99	
Cows	0	cows	135	lbs/cow-yr	3	0.41	0	
Forested	232	acres	2.2	lbs/acre-yr	5	0.64	324	
Sludge Disposal/Septage Dispos	0	lbs	1	15 yrs	6	0.07	0	
road drainage	37	acres	8.7	lbs/acre-yr	1	1.00	322	
TOTAL (Loading to Stream)							2190	
				TOTAL LOADING			2798	
						MG/L		
				baseflow	=	0.91		
				runoff	=	1.87		
				stormflow	=	1.52		
Runoff/Recharge Calculations:								
	Soils	Runoff		Recharge				
	(acres)	(ft/yr)	(Mgal/yr)	(ft/yr)	(M gal/yr)			
clayey soils	266	1.5	130.35	0.25	22			
sandy soils	120	0.25	9.801	1.50	59			
total	386		140.15	0.59	81			
	ave stormflow (cfs)			0.93	ave baseflow		0.34	

MAQUOIT BAY								
SCENARIO 2 - BUILDOUT CONDITIONS WITH NO MANURE								
FLYING POINT								
					ref	persist	lbs/yr	
GROUND WATER								
Septic Systems III/IV	241	systems	30	lbs/unit-yr	1	0.00	0	
Septic Systems I/II	47	systems	30	lbs/unit-yr	1	0.13	186	
Lawns	288	lawns	10	lbs/5000 sq ft-yr	1	0.13	379	
Agriculture Fields/Manure	100	acres	4.5	lbs/acre-yr	2	0.17	76	
Cows	40	cows	135	lbs/cow-yr	3	0.17	909	
Forested	690	acres	2.2	lbs/acre-yr	5	0.26	399	
Sludge Disposal/Septage Dispo:	0	lbs	1	15 yrs	6	0.00	0	
road drainage	45	acres	0	lbs/acre-yr	1	0.00	0	
TOTAL (Loading to Stream)							1949	
STORMWATER FLOW								
Septic Systems III/IV	241	systems	30	lbs/unit-yr	1	0.37	2664	
Septic Systems I/II	47	systems	30	lbs/unit-yr	1	0.00	0	
Lawns	288	lawns	10	lbs/5000 sq ft-yr	1	0.37	1061	
Agriculture Fields/Manure	100	acres	4.5	lbs/acre-yr	2	0.47	212	
Cows	40	cows	135	lbs/cow-yr	3	0.47	2547	
Forested	690	acres	2.2	lbs/acre-yr	5	0.74	1119	
Sludge Disposal/Septage Dispo:	0	lbs	1	15 yrs	6	0.07	0	
road drainage	45	acres	8.7	lbs/acre-yr	1	1.00	392	
TOTAL (Loading to Stream)							7994	
				TOTAL LOADING			9943	
						MG/L		
				baseflow	=	1.64		
				runoff	=	2.40		
				stormflow	=	2.20		
Runoff/Recharge Calculations:								
	Soils	Runoff		Recharge				
	(acres)	(ft/yr)	(Mgal/yr)	(ft/yr)	(M gal/yr)			
clayey soils	790	1.5	387.14	0.25	65			
sandy soils	160	0.25	13.068	1.50	78			
total	950		400.21	1.69	143			
	ave stormflow (cfs)			2.30	ave baseflow		0.60	

MAQUOIT BAY					
SCENARIO 2 - BUILDOUT CONDITIONS WITH NO MANURE					
SUMMARY OF NITROGEN LOADING TO BAY					
Bunganuc Stream	19112	27%	Septic (III/IV)	9928	14%
Wharton Stream	6459	9%	Septic (I/II)	6900	10%
Rossmore Stream	11298	16%	Lawns	10965	16%
Bunganuc Point	1749	2%	Agriculture	2906	4%
Merepoint	2798	4%	Cows	6912	10%
Flying Point	9943	14%	Forest	10714	15%
Direct Precipitation	19200	27%	Sludge Disposal	320	0%
			Road Drainage	2714	4%
			Direct Precipitation	19200	27%
TOTAL	70560		TOTAL	70560	





MAQUOIT BAY									
SCENARIO 2 - BUILDOUT CONDITIONS WITH NO MANURE									
FLUSHING RATE OF EMBAYMENT									
Surface Area of Embayment		2470	acres						
Mean Depth of Embayment		10	feet						
Volume at Mean Tide		8048	million gallons						
Mean Salinity of Embayment		21	ppt						
Salinity of Offshore Water		33	ppt						
Area of Watershed		7878	acres						
Flushing Rate (Pilson, 1985) =			0.57	days					
NITROGEN LOADING STANDARDS/CARRYING CAPACITY									
					Critical N Loading Rate		% of Critical		
Shallow (less than 3 meters average) & Flushing Rate < 5 days					4299334		2	%	
Shallow (less than 3 meters average) & Flushing Rate > 5 days					108811		65	%	
Deep (greater than 3 meters average)					217621		32	%	
REFERENCES									
1: Nelson et al. (1988) assuming 3 people/unit.									
2: This loading value is derived from an average concentration of 0.93 mg/L detected during									
H&W watershed sampling multiplied times an estimated 22 inches of runoff per year.									
3: Frimpter et al. (1988) 36% volatilization loss 7 days @ 68 degrees									
4: estimated at 20% of human loading									
5: Reckhow et al (1980) forest export = 2.2 lbs/acre-yr									
6: sludge 27000 cubic yds disposed 1967-1982 @ 2% N dry weight @ 55 lbs sludge/cubic foot									
7: NADP									

MAQUOIT BAY									
SCENARIO 3 - BUILDOUT CONDITIONS WITH MANURE APPLICATIONS (17.25 LBS/ACRE-YR)									
BUNGANUC STREAM			SOURCE		REFER-	PERSIS-	LOADING		
	INPUT		LOADING		ENCE	TENCE	lbs/yr		
GROUND WATER									
Septic Systems III/IV	265	systems	30	lbs/unit-yr	1	0.00	0		
Septic Systems I/II	397	systems	30	lbs/unit-yr	1	0.15	1735		
Lawns	662	lawns	10	lbs/5000 sq ft-yr	1	0.15	964		
Agriculture Fields/ Manure	636	acres	17.25	lbs/acre-yr	2	0.19	2045		
Cows	40	cows	135	lbs/cow-yr	3	0.19	1007		
Forested	2221	acres	2.2	lbs/acre-yr	5	0.29	1423		
Sludge Disposal/Septage Dispo	160000	lbs	1	15 yrs	6	0.00	320		
road drainage	87	acres	0	lbs/acre-yr	1	0.00	0		
TOTAL (Loading to Stream)							7494		
STORMWATER FLOW									
Septic Systems III/IV	265	systems	30	lbs/unit-yr	1	0.35	2817		
Septic Systems I/II	397	systems	30	lbs/unit-yr	1	0.00	0		
Lawns	662	lawns	10	lbs/5000 sq ft-yr	1	0.35	2346		
Agriculture Fields/ Manure	636	acres	17.25	lbs/acre-yr	2	0.45	4976		
Cows	40	cows	135	lbs/cow-yr	3	0.45	2449		
Forested	2221	acres	2.2	lbs/acre-yr	5	0.71	3463		
Sludge Disposal/Septage Dispo	160000	lbs	1	15 yrs	6	0.00	0		
road drainage	87	acres	8.7	lbs/acre-yr	1	1.00	757		
TOTAL (Loading to Stream)							16809		
				TOTAL LOADING			24302		
						MG/L			
				baseflow	=	1.50			
				runoff	=	1.38			
				stormflow	=	1.42			
Runoff/Recharge Calculations:									
	Soils	Runoff	(M gal/	Recharge					
	(acres)	(ft/yr)	yr)	(ft/yr)	(M gal/yr)				
clayey soils	2852	1.5	1397.6	0.25	233				
sandy soils	748	0.25	61.093	1.50	367				
total	3600		1458.7	6.17	599				
	ave stormflow (cfs)			8.70	ave baseflow		2.53		

MAQUOIT BAY								
SCENARIO 3 - BUILDOUT CONDITIONS WITH MANURE APPLICATIONS (17.25 LBS/ACRE-YR)								
ROSSMORE STREAM								
					ref	persist	lbs/yr	
GROUND WATER								
Septic Systems III/IV	83	systems	30	lbs/unit-yr	1	0.00	0	
Septic Systems I/II	248	systems	30	lbs/unit-yr	1	0.37	2757	
Lawns	331	lawns	10	lbs/5000 sq ft-yr	1	0.37	1227	
Agriculture Fields/ Manure	10	acres	17.25	lbs/acre-yr	2	0.47	82	
Cows	0	cows	135	lbs/cow-yr	3	0.47	0	
Forested	601	acres	2.2	lbs/acre-yr	5	0.74	980	
Sludge Disposal/Septage Dispo	0	lbs	1	15 yrs	6	0.00	0	
road drainage	43	acres	0	lbs/acre-yr	1	0.00	0	
TOTAL (Loading to Stream)							5045	
STORMWATER FLOW								
Septic Systems III/IV	83	systems	30	lbs/unit-yr	1	0.13	322	
Septic Systems I/II	248	systems	30	lbs/unit-yr	1	0.00	0	
Lawns	331	lawns	10	lbs/5000 sq ft-yr	1	0.13	428	
Agriculture Fields/ Manure	10	acres	17.25	lbs/acre-yr	2	0.17	29	
Cows	0	cows	135	lbs/cow-yr	3	0.17	0	
Forested	601	acres	2.2	lbs/acre-yr	5	0.26	342	
Sludge Disposal/Septage Dispo	0	lbs	1	15 yrs	6	0.07	0	
road drainage	43	acres	8.7	lbs/acre-yr	1	1.00	374	
TOTAL (Loading to Stream)							1496	
				TOTAL LOADING			6541	
						MG/L		
				baseflow	=	1.63		
				runoff	=	1.39		
				stormflow	=	1.57		
Runoff/Recharge Calculations:								
	Soils	Runoff		Recharge				
	(acres)	(ft/yr)	(Mgal/yr)	(ft/yr)	(M gal/yr)			
clayey soils	142	1.5	69.587	0.25	12			
sandy soils	732	0.25	59.786	1.50	359			
total	874		129.37	0.55	370			
		ave stormflow (cfs)		2.11	ave baseflow		1.57	

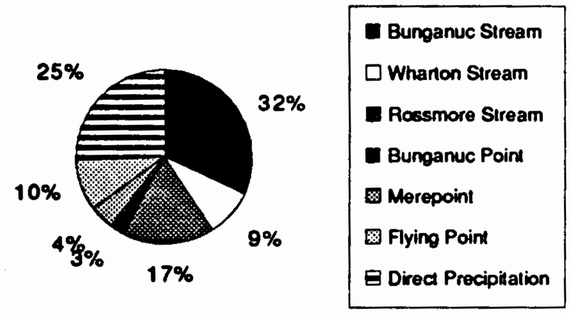
MAQUOIT BAY								
SCENARIO 3 - BUILDOUT CONDITIONS WITH MANURE APPLICATIONS (17.25 LBS/ACRE-YR)								
WHARTON POINT STREAM								
					ref	persist	lbs/yr	
GROUND WATER								
Septic Systems III/IV	534	systems	30	lbs/unit-yr	1	0.00	0	
Septic Systems I/II	211	systems	30	lbs/unit-yr	1	0.33	2078	
Lawns	745	lawns	10	lbs/5000 sq ft-yr	1	0.33	2446	
Agriculture Fields/ Manure	153	acres	17.25	lbs/acre-yr	2	0.42	1109	
Cows	0	cows	135	lbs/cow-yr	3	0.42	0	
Forested	719	acres	2.2	lbs/acre-yr	5	0.66	1039	
Sludge Disposal/Septage Dispo:	0	lbs	1	15 yrs	6	0.00	0	
road drainage	83	acres	0	lbs/acre-yr	1	0.00	0	
TOTAL (Loading to Stream)							6672	
STORMWATER FLOW								
Septic Systems III/IV	534	systems	30	lbs/unit-yr	1	0.17	2750	
Septic Systems I/II	211	systems	30	lbs/unit-yr	1	0.00	0	
Lawns	745	lawns	10	lbs/5000 sq ft-yr	1	0.17	1279	
Agriculture Fields/ Manure	153	acres	17.25	lbs/acre-yr	2	0.22	580	
Cows	0	cows	135	lbs/cow-yr	3	0.22	0	
Forested	719	acres	2.2	lbs/acre-yr	5	0.34	543	
Sludge Disposal/Septage Dispo:	0	lbs	1	15 yrs	6	0.07	0	
road drainage	83	acres	8.7	lbs/acre-yr	1	1.00	722	
TOTAL (Loading to Stream)							5875	
				TOTAL LOADING			12547	
						MG/L		
				baseflow	=	1.46		
				runoff	=	2.46		
				stormflow	=	1.81		
Runoff/Recharge Calculations:								
	Soils	Runoff		Recharge				
	(acres)	(ft/yr)	(Mgal/yr)	(ft/yr)	(M gal/yr)			
clayey soils	409	1.5	200.43	0.25	33			
sandy soils	1048	0.25	85.595	1.50	514			
total	1457		286.03	1.21	547			
	ave stormflow (cfs)			3.52	ave baseflow		2.31	

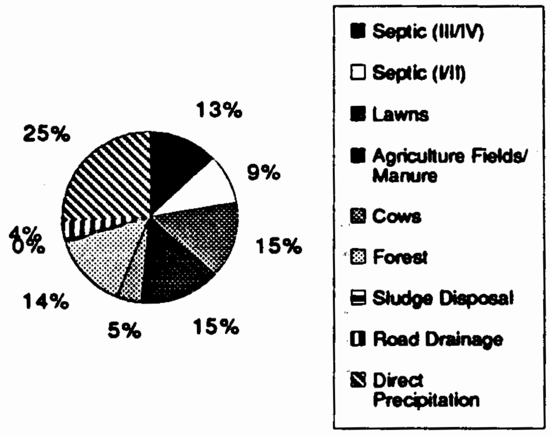
MAQUOIT BAY								
SCENARIO 3 - BUILDOUT CONDITIONS WITH MANURE APPLICATIONS (17.25 LBS/ACRE-YR)								
BUNGANUC POINT								
					ref	persist	lbs/yr	
GROUND WATER								
Septic Systems III/IV	31	systems	30	lbs/unit-yr	1	0.00	0	
Septic Systems I/II	5	systems	30	lbs/unit-yr	1	0.13	19	
Lawns	36	lawns	10	lbs/5000 sq ft-yr	1	0.13	46	
Agriculture Fields/ Manure	56	acres	17.25	lbs/acre-yr	2	0.16	159	
Cows	0	cows	135	lbs/cow-yr	3	0.16	0	
Forested	407	acres	2.2	lbs/acre-yr	5	0.26	230	
Sludge Disposal/Septage Dispo:	0	lbs	1	15 yrs	6	0.00	0	
road drainage	17	acres	0	lbs/acre-yr	1	0.00	0	
TOTAL (Loading to Stream)							454	
STORMWATER FLOW								
Septic Systems III/IV	31	systems	30	lbs/unit-yr	1	0.37	346	
Septic Systems I/II	5	systems	30	lbs/unit-yr	1	0.00	0	
Lawns	36	lawns	10	lbs/5000 sq ft-yr	1	0.37	134	
Agriculture Fields/ Manure	56	acres	17.25	lbs/acre-yr	2	0.48	459	
Cows	0	cows	135	lbs/cow-yr	3	0.48	0	
Forested	407	acres	2.2	lbs/acre-yr	5	0.74	665	
Sludge Disposal/Septage Dispo:	0	lbs	1	15 yrs	6	0.07	0	
road drainage	17	acres	8.7	lbs/acre-yr	1	1.00	148	
TOTAL (Loading to Stream)							1752	
				TOTAL LOADING			2206	
						MG/L		
				baseflow	=	0.62		
				runoff	=	0.82		
				stormflow	=	0.77		
Runoff/Recharge Calculations:								
	Soils	Runoff		Recharge				
	(acres)	(ft/yr)	(Mgal/yr)	(ft/yr)	(M gal/yr)			
clayey soils	505	1.5	247.48	0.25	41			
sandy soils	96	0.25	7.8408	1.50	47			
total	601		255.32	1.08	88			
	ave stormflow (cfs)			1.45	ave baseflow		0.37	

MAQUOIT BAY								
SCENARIO 3 - BUILDOUT CONDITIONS WITH MANURE APPLICATIONS (17.25 LBS/ACRE-YR)								
MEREPOINT NECK								
					ref	persist	lbs/yr	
GROUND WATER								
Septic Systems III/IV	108	systems	30	lbs/unit-yr	1	0.00	0	
Septic Systems I/II	23	systems	30	lbs/unit-yr	1	0.18	126	
Lawns	131	lawns	10	lbs/5000 sq ft-yr	1	0.18	239	
Agriculture Fields/ Manure	54	acres	17.25	lbs/acre-yr	2	0.23	218	
Cows	0	cows	135	lbs/cow-yr	3	0.23	0	
Forested	232	acres	2.2	lbs/acre-yr	5	0.36	186	
Sludge Disposal/Septage Dispo	0	lbs	1	15 yrs	6	0.00	0	
road drainage	37	acres	0	lbs/acre-yr	1	0.00	0	
TOTAL (Loading to Stream)							769	
STORMWATER FLOW								
Septic Systems III/IV	108	systems	30	lbs/unit-yr	1	0.32	1029	
Septic Systems I/II	23	systems	30	lbs/unit-yr	1	0.00	0	
Lawns	131	lawns	10	lbs/5000 sq ft-yr	1	0.32	416	
Agriculture Fields/ Manure	54	acres	17.25	lbs/acre-yr	2	0.41	379	
Cows	0	cows	135	lbs/cow-yr	3	0.41	0	
Forested	232	acres	2.2	lbs/acre-yr	5	0.64	324	
Sludge Disposal/Septage Dispo	0	lbs	1	15 yrs	6	0.07	0	
road drainage	37	acres	8.7	lbs/acre-yr	1	1.00	322	
TOTAL (Loading to Stream)							2469	
				TOTAL LOADING			3238	
						MG/L		
				baseflow	=	1.14		
				runoff	=	2.11		
				stormflow	=	1.76		
Runoff/Recharge Calculations:								
	Soils	Runoff		Recharge				
	(acres)	(ft/yr)	(Mgal/yr)	(ft/yr)	(M gal/yr)			
clayey soils	266	1.5	130.35	0.25	22			
sandy soils	120	0.25	9.801	1.50	59			
total	386		140.15	0.59	81			
	ave stormflow (cfs)			0.93	ave baseflow		0.34	

MAQUOIT BAY								
SCENARIO 3 - BUILDOUT CONDITIONS WITH MANURE APPLICATIONS (17.25 LBS/ACRE-YR)								
FLYING POINT								
					ref	persist	lbs/yr	
GROUND WATER								
Septic Systems III/IV	241	systems	30	lbs/unit-yr	1	0.00	0	
Septic Systems I/II	47	systems	30	lbs/unit-yr	1	0.13	186	
Lawns	288	lawns	10	lbs/5000 sq ft-yr	1	0.13	379	
Agriculture Fields/ Manure	100	acres	17.25	lbs/acre-yr	2	0.17	291	
Cows	0	cows	135	lbs/cow-yr	3	0.17	0	
Forested	690	acres	2.2	lbs/acre-yr	5	0.26	399	
Sludge Disposal/Septage Dispo	0	lbs	1	15 yrs	6	0.00	0	
road drainage	45	acres	0	lbs/acre-yr	1	0.00	0	
TOTAL (Loading to Stream)							1254	
STORMWATER FLOW								
Septic Systems III/IV	241	systems	30	lbs/unit-yr	1	0.37	2664	
Septic Systems I/II	47	systems	30	lbs/unit-yr	1	0.00	0	
Lawns	288	lawns	10	lbs/5000 sq ft-yr	1	0.37	1061	
Agriculture Fields/ Manure	100	acres	17.25	lbs/acre-yr	2	0.47	813	
Cows	0	cows	135	lbs/cow-yr	3	0.47	0	
Forested	690	acres	2.2	lbs/acre-yr	5	0.74	1119	
Sludge Disposal/Septage Dispo	0	lbs	1	15 yrs	6	0.07	0	
road drainage	45	acres	8.7	lbs/acre-yr	1	1.00	392	
TOTAL (Loading to Stream)							6048	
				TOTAL LOADING			7303	
						MG/L		
				baseflow	=	1.05		
				runoff	=	1.81		
				stormflow	=	1.61		
Runoff/Recharge Calculations:								
	Soils	Runoff		Recharge				
	(acres)	(ft/yr)	(Mgal/yr)	(ft/yr)	(M gal/yr)			
clayey soils	790	1.5	387.14	0.25	65			
sandy soils	160	0.25	13.068	1.50	78			
total	950		400.21	1.69	143			
	ave stormflow (cfs)			2.30	ave baseflow		0.60	

MAQUOIT BAY							
SCENARIO 3 - BUILDOUT CONDITIONS WITH MANURE APPLICATIONS (17.25 LBS/ACRE-YR)							
SUMMARY OF NITROGEN LOADING TO BAY							
Bunganuc Stream	24302	32%		Septic (III/IV)		9928	13%
Wharton Stream	6541	9%		Septic (I/II)		6900	9%
Rossmore Stream	12547	17%		Lawns		10965	15%
Bunganuc Point	2206	3%		Agriculture Fields/ Manure		11139	15%
Merepoint	3238	4%		Cows		3456	5%
Flying Point	7303	10%		Forest		10714	14%
Direct Precipitation	19200	25%		Sludge Disposal		320	0%
				Road Drainage		2714	4%
				Direct Precipitation		19200	25%
TOTAL	75337			TOTAL		75337	





MAQUOIT BAY								
SCENARIO 3 - BUILDOUT CONDITIONS WITH MANURE APPLICATIONS (17.25 LBS/ACRE-YR)								
FLUSHING RATE OF EMBAYMENT								
Surface Area of Embayment		2470	acres					
Mean Depth of Embayment		10	feet					
Volume at Mean Tide		8048	million gallons					
Mean Salinity of Embayment		21	ppt					
Salinity of Offshore Water		33	ppt					
Area of Watershed		7878	acres					
Flushing Rate (Pilson, 1985) =			0.57	days				
NITROGEN LOADING STANDARDS/CARRYING CAPACITY								
					Critical N Loading Rate		**% of Critical**	
Shallow (less than 3 meters average) & Flushing Rate < 5 days					4299334		2	%
Shallow (less than 3 meters average) & Flushing Rate > 5 days					108811		69	%
Deep (greater than 3 meters average)					217621		35	%
REFERENCES								
1: Nelson et al. (1988) assuming 3 people/unit.								
2: This loading value is derived from an average concentration of 0.93 mg/L detected during								
H&W watershed sampling multiplied times an estimated 22 inches of runoff per year.								
3: Frimpter et al. (1988) 36% volatilization loss 7 days @ 68 degrees								
4: estimated at 20% of human loading								
5: Reckhow et al (1980) forest export = 2.2 lbs/acre-yr								
6: sludge 27000 cubic yds disposed 1967-1982 @ 2% N dry weight @ 55 lbs sludge/cubic foot								
7: NADP								

MAQUOIT BAY								
SCENARIO 4 - BUILDOUT CONDITIONS WITH MANURE APPLICATIONS (50 LBS/ACRE-YR)								
BUNGANUC STREAM			SOURCE		REFER-	PERSIS-	LOADING	
	INPUT		LOADING		ENCE	TENCE	lbs/yr	
GROUND WATER								
Septic Systems III/IV	265	systems	30	lbs/unit-yr	1	0.00	0	
Septic Systems I/II	397	systems	30	lbs/unit-yr	1	0.15	1735	
Lawns	662	lawns	10	lbs/5000 sq ft-yr	1	0.15	964	
Agriculture Fields/ Manure	636	acres	50	lbs/acre-yr	2	0.19	5928	
Cows	40	cows	135	lbs/cow-yr	3	0.19	1007	
Forested	2221	acres	2.2	lbs/acre-yr	5	0.29	1423	
Sludge Disposal/Septage Dispo:	160000	lbs	1	15 yrs	6	0.00	320	
road drainage	76	acres	0	lbs/acre-yr	1	0.00	0	
TOTAL (Loading to Stream)							11376	
STORMWATER FLOW								
Septic Systems III/IV	265	systems	30	lbs/unit-yr	1	0.35	2817	
Septic Systems I/II	397	systems	30	lbs/unit-yr	1	0.00	0	
Lawns	662	lawns	10	lbs/5000 sq ft-yr	1	0.35	2346	
Agriculture Fields/ Manure	636	acres	50	lbs/acre-yr	2	0.45	14424	
Cows	40	cows	135	lbs/cow-yr	3	0.45	2449	
Forested	2221	acres	2.2	lbs/acre-yr	5	0.71	3463	
Sludge Disposal/Septage Dispo:	160000	lbs	1	15 yrs	6	0.00	0	
road drainage	87	acres	8.7	lbs/acre-yr	1	1.00	757	
TOTAL (Loading to Stream)							26256	
				TOTAL LOADING			37633	
						MG/L		
				baseflow	=	2.28		
				runoff	=	2.16		
				stormflow	=	2.19		
Runoff/Recharge Calculations:								
	Soils	Runoff	(M gal/	Recharge				
	(acres)	(ft/yr)	yr)	(ft/yr)	(M gal/yr)			
clayey soils	2852	1.5	1397.6	0.25	233			
sandy soils	748	0.25	61.093	1.50	367			
total	3600		1458.7	6.17	599			
	ave stormflow (cfs)			8.70	ave baseflow		2.53	

MAQUOIT BAY							
SCENARIO 4 - BUILDOUT CONDITIONS WITH MANURE APPLICATIONS (50 LBS/ACRE-YR)							
ROSSMORE STREAM							
					ref	persist	lbs/yr
GROUND WATER							
Septic Systems III/IV	83	systems	30	lbs/unit-yr	1	0.00	0
Septic Systems I/II	248	systems	30	lbs/unit-yr	1	0.37	2757
Lawns	331	lawns	10	lbs/5000 sq ft-yr	1	0.37	1227
Agriculture Fields/ Manure	10	acres	50	lbs/acre-yr	2	0.47	237
Cows	0	cows	135	lbs/cow-yr	3	0.47	0
Forested	601	acres	2.2	lbs/acre-yr	5	0.74	980
Sludge Disposal/Septage Dispo:	0	lbs	1	15 yrs	6	0.00	0
road drainage	43	acres	0	lbs/acre-yr	1	0.00	0
TOTAL (Loading to Stream)							5200
STORMWATER FLOW							
Septic Systems III/IV	83	systems	30	lbs/unit-yr	1	0.13	322
Septic Systems I/II	248	systems	30	lbs/unit-yr	1	0.00	0
Lawns	331	lawns	10	lbs/5000 sq ft-yr	1	0.13	428
Agriculture Fields/ Manure	10	acres	50	lbs/acre-yr	2	0.17	83
Cows	0	cows	135	lbs/cow-yr	3	0.17	0
Forested	601	acres	2.2	lbs/acre-yr	5	0.26	342
Sludge Disposal/Septage Dispo:	0	lbs	1	15 yrs	6	0.07	0
road drainage	43	acres	8.7	lbs/acre-yr	1	1.00	374
TOTAL (Loading to Stream)							1550
				TOTAL LOADING			6751
						MG/L	
				baseflow	=	1.68	
				runoff	=	1.44	
				stormflow	=	1.62	
Runoff/Recharge Calculations:							
	Soils	Runoff		Recharge			
	(acres)	(ft/yr)	(Mgal/yr)	(ft/yr)	(M gal/yr)		
clayey soils	142	1.5	69.587	0.25	12		
sandy soils	732	0.25	59.786	1.50	359		
total	874		129.37	0.55	370		
	ave stormflow (cfs)			2.11	ave baseflow		1.57

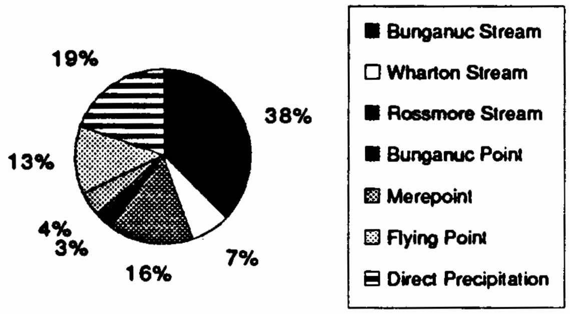
MAQUOIT BAY								
SCENARIO 4 - BUILDOUT CONDITIONS WITH MANURE APPLICATIONS (50 LBS/ACRE-YR)								
WHARTON POINT STREAM								
					ref	persist	lbs/yr	
GROUND WATER								
Septic Systems III/IV	534	systems	30	lbs/unit-yr	1	0.00	0	
Septic Systems I/II	211	systems	30	lbs/unit-yr	1	0.33	2078	
Lawns	745	lawns	10	lbs/5000 sq ft-yr	1	0.33	2446	
Agriculture Fields/ Manure	153	acres	50	lbs/acre-yr	2	0.42	3215	
Cows	0	cows	135	lbs/cow-yr	3	0.42	0	
Forested	719	acres	2.2	lbs/acre-yr	5	0.66	1039	
Sludge Disposal/Septage Dispo:	0	lbs	1	15 yrs	6	0.00	0	
road drainage	83	acres	0	lbs/acre-yr	1	0.00	0	
TOTAL (Loading to Stream)							8778	
STORMWATER FLOW								
Septic Systems III/IV	534	systems	30	lbs/unit-yr	1	0.17	2750	
Septic Systems I/II	211	systems	30	lbs/unit-yr	1	0.00	0	
Lawns	745	lawns	10	lbs/5000 sq ft-yr	1	0.17	1279	
Agriculture Fields/ Manure	153	acres	50	lbs/acre-yr	2	0.22	1681	
Cows	0	cows	135	lbs/cow-yr	3	0.22	0	
Forested	719	acres	2.2	lbs/acre-yr	5	0.34	543	
Sludge Disposal/Septage Dispo:	0	lbs	1	15 yrs	6	0.07	0	
road drainage	83	acres	8.7	lbs/acre-yr	1	1.00	722	
TOTAL (Loading to Stream)							6976	
				TOTAL LOADING			15754	
						MG/L		
				baseflow	=	1.92		
				runoff	=	2.93		
				stormflow	=	2.27		
Runoff/Recharge Calculations:								
	Soils	Runoff		Recharge				
	(acres)	(ft/yr)	(Mgal/yr)	(ft/yr)	(M gal/yr)			
clayey soils	409	1.5	200.43	0.25	33			
sandy soils	1048	0.25	85.595	1.50	514			
total	1457		286.03	1.21	547			
	ave stormflow (cfs)			3.52	ave baseflow		2.31	

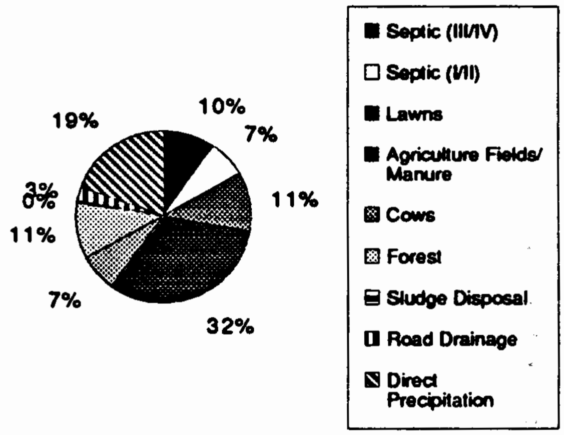
MAQUOIT BAY								
SCENARIO 4 - BUILDOUT CONDITIONS WITH MANURE APPLICATIONS (50 LBS/ACRE-YR)								
BUNGANUC POINT								
					ref	persist	lbs/yr	
GROUND WATER								
Septic Systems III/IV	31	systems	30	lbs/unit-yr	1	0.00	0	
Septic Systems I/II	5	systems	30	lbs/unit-yr	1	0.13	19	
Lawns	36	lawns	10	lbs/5000 sq ft-yr	1	0.13	46	
Agriculture Fields/ Manure	53	acres	50	lbs/acre-yr	2	0.16	436	
Cows	0	cows	135	lbs/cow-yr	3	0.16	0	
Forested	407	acres	2.2	lbs/acre-yr	5	0.26	230	
Sludge Disposal/Septage Dispo	0	lbs	1	15 yrs	6	0.00	0	
road drainage	17	acres	0	lbs/acre-yr	1	0.00	0	
TOTAL (Loading to Stream)							731	
STORMWATER FLOW								
Septic Systems III/IV	31	systems	30	lbs/unit-yr	1	0.37	346	
Septic Systems I/II	5	systems	30	lbs/unit-yr	1	0.00	0	
Lawns	36	lawns	10	lbs/5000 sq ft-yr	1	0.37	134	
Agriculture Fields/ Manure	53	acres	50	lbs/acre-yr	2	0.48	1260	
Cows	0	cows	135	lbs/cow-yr	3	0.48	0	
Forested	407	acres	2.2	lbs/acre-yr	5	0.74	665	
Sludge Disposal/Septage Dispo	0	lbs	1	15 yrs	6	0.07	0	
road drainage	17	acres	8.7	lbs/acre-yr	1	1.00	148	
TOTAL (Loading to Stream)							2553	
				TOTAL LOADING			3284	
						MG/L		
				baseflow	=	0.99		
				runoff	=	1.20		
				stormflow	=	1.15		
Runoff/Recharge Calculations:								
	Soils	Runoff		Recharge				
	(acres)	(ft/yr)	(Mgal/yr)	(ft/yr)	(M gal/yr)			
clayey soils	505	1.5	247.48	0.25	41			
sandy soils	96	0.25	7.8408	1.50	47			
total	601		255.32	1.08	88			
	ave stormflow (cfs)			1.45	ave baseflow		0.37	

MAQUOIT BAY								
SCENARIO 4 - BUILDOUT CONDITIONS WITH MANURE APPLICATIONS (50 LBS/ACRE-YR)								
MEREPOINT NECK								
					ref	persist	lbs/yr	
GROUND WATER								
Septic Systems III/IV	108	systems	30	lbs/unit-yr	1	0.00	0	
Septic Systems I/II	23	systems	30	lbs/unit-yr	1	0.18	126	
Lawns	131	lawns	10	lbs/5000 sq ft-yr	1	0.18	239	
Agriculture Fields/ Manure	54	acres	50	lbs/acre-yr	2	0.23	631	
Cows	0	cows	135	lbs/cow-yr	3	0.23	0	
Forested	232	acres	2.2	lbs/acre-yr	5	0.36	186	
Sludge Disposal/Septage Dispo:	0	lbs	1	15 yrs	6	0.00	0	
road drainage	37	acres	0	lbs/acre-yr	1	0.00	0	
TOTAL (Loading to Stream)							1182	
STORMWATER FLOW								
Septic Systems III/IV	108	systems	30	lbs/unit-yr	1	0.32	1029	
Septic Systems I/II	23	systems	30	lbs/unit-yr	1	0.00	0	
Lawns	131	lawns	10	lbs/5000 sq ft-yr	1	0.32	416	
Agriculture Fields/ Manure	54	acres	50	lbs/acre-yr	2	0.41	1097	
Cows	0	cows	135	lbs/cow-yr	3	0.41	0	
Forested	232	acres	2.2	lbs/acre-yr	5	0.64	324	
Sludge Disposal/Septage Dispo:	0	lbs	1	15 yrs	6	0.07	0	
road drainage	37	acres	8.7	lbs/acre-yr	1	1.00	322	
TOTAL (Loading to Stream)							3188	
				TOTAL LOADING			4370	
						MG/L		
				baseflow	=	1.76		
				runoff	=	2.73		
				stormflow	=	2.38		
Runoff/Recharge Calculations:								
	Soils	Runoff		Recharge				
	(acres)	(ft/yr)	(Mgal/yr)	(ft/yr)	(M gal/yr)			
clayey soils	266	1.5	130.35	0.25	22			
sandy soils	120	0.25	9.801	1.50	59			
total	386		140.15	0.59	81			
	ave stormflow (cfs)			0.93	ave baseflow		0.34	

MAQUOIT BAY								
SCENARIO 4 - BUILDOUT CONDITIONS WITH MANURE APPLICATIONS (50 LBS/ACRE-YR)								
FLYING POINT								
					ref	persist	lbs/yr	
GROUND WATER								
Septic Systems III/IV	241	systems	30	lbs/unit-yr	1	0.00	0	
Septic Systems I/II	47	systems	30	lbs/unit-yr	1	0.13	186	
Lawns	288	lawns	10	lbs/5000 sq ft-yr	1	0.13	379	
Agriculture Fields/ Manure	100	acres	50	lbs/acre-yr	2	0.17	842	
Cows	40	cows	135	lbs/cow-yr	3	0.17	909	
Forested	690	acres	2.2	lbs/acre-yr	5	0.26	399	
Sludge Disposal/Septage Dispo	0	lbs	1	15 yrs	6	0.00	0	
road drainage	45	acres	0	lbs/acre-yr	1	0.00	0	
TOTAL (Loading to Stream)							2716	
STORMWATER FLOW								
Septic Systems III/IV	241	systems	30	lbs/unit-yr	1	0.37	2664	
Septic Systems I/II	47	systems	30	lbs/unit-yr	1	0.00	0	
Lawns	288	lawns	10	lbs/5000 sq ft-yr	1	0.37	1061	
Agriculture Fields/ Manure	100	acres	50	lbs/acre-yr	2	0.47	2358	
Cows	40	cows	135	lbs/cow-yr	3	0.47	2547	
Forested	690	acres	2.2	lbs/acre-yr	5	0.74	1119	
Sludge Disposal/Septage Dispo	0	lbs	1	15 yrs	6	0.07	0	
road drainage	45	acres	8.7	lbs/acre-yr	1	1.00	392	
TOTAL (Loading to Stream)							10139	
				TOTAL LOADING			12855	
						MG/L		
				baseflow	=	2.28		
				runoff	=	3.04		
				stormflow	=	2.84		
Runoff/Recharge Calculations:								
	Soils	Runoff		Recharge				
	(acres)	(ft/yr)	(Mgal/yr)	(ft/yr)	(M gal/yr)			
clayey soils	790	1.5	387.14	0.25	65			
sandy soils	160	0.25	13.068	1.50	78			
total	950		400.21	1.69	143			
	ave stormflow (cfs)			2.30	ave baseflow		0.60	

MAQUOIT BAY						
SCENARIO 4 - BUILDOUT CONDITIONS WITH MANURE APPLICATIONS (50 LBS/ACRE-YR)						
SUMMARY OF NITROGEN LOADING TO BAY						
Bunganuc Stream	37633	38%	Septic (III/IV)		9928	10%
Wharton Stream	6751	7%	Septic (I/II)		6900	7%
Rossmore Stream	15754	16%	Lawns		10965	11%
Bunganuc Point	3284	3%	Agriculture Fields/ Manure		32192	32%
Merepoint	4370	4%	Cows		6912	7%
Flying Point	12855	13%	Forest		10714	11%
Direct Precipitation	19200	19%	Sludge Disposal		320	0%
			Road Drainage		2714	3%
			Direct Precipitation		19200	19%
TOTAL	99846		TOTAL		99846	





MAQUOIT BAY								
SCENARIO 4 - BUILDOUT CONDITIONS WITH MANURE APPLICATIONS (50 LBS/ACRE-YR)								
FLUSHING RATE OF EMBAYMENT								
Surface Area of Embayment		2470	acres					
Mean Depth of Embayment		10	feet					
Volume at Mean Tide		8048	million gallons					
Mean Salinity of Embayment		21	ppt					
Salinity of Offshore Water		33	ppt					
Area of Watershed		7878	acres					
Flushing Rate (Pilson, 1985) =			0.57	days				
NITROGEN LOADING STANDARDS/CARRYING CAPACITY								
					Critical N Loading Rate		**% of Critical**	
Shallow (less than 3 meters average) & Flushing Rate < 5 days					4299334		2	%
Shallow (less than 3 meters average) & Flushing Rate > 5 days					108811		92	%
Deep (greater than 3 meters average)					217621		46	%
REFERENCES								
1: Nelson et al. (1988) assuming 3 people/unit.								
2: This loading value is derived from an average concentration of 0.93 mg/L detected during								
H&W watershed sampling multiplied times an estimated 22 inches of runoff per year.								
3: Frimpter et al. (1988) 36% volatilization loss 7 days @ 68 degrees								
4: estimated at 20% of human loading								
5: Reckhow et al (1980) forest export = 2.2 lbs/acre-yr								
6: sludge 27000 cubic yds disposed 1967-1982 @ 2% N dry weight @ 55 lbs sludge/cubic foot								
7: NADP								

APPENDIX E

Shoreline Seepage Survey Water Quality Data

Merepoint Neck
Flying Point Neck

SHORELINE SEEPAGE SURVEY:

Sample Date: 6/21/1994

dl = detection limit in mg/l

SITE	Watershed	Fecal Coli. no./100 ml	Total P mg/l	PO4 - P mg/l	NH4 - N mg/l	NO3-N mg/l	Particulate N mg/l	TDN mg/l
			dl=0.002	dl=0.001	dl=0.001	dl=0.0007	dl=0.0005	dl=0.002
BSS-1	M	2,800	0.05	0.03	0.00	0.78	700.00*	1.71
BSS-2	M	26,800	0.23	0.04	3.75	0.11	9.26	4.26
BSS-3	M	10	0.08	0.00	0.01	0.02	9.31*	1.09
BSS-4**	M	700	1.97	0.00	0.00	0.00	926.34*	0.00
BSS-5	M	14	0.04	0.00	0.03	1.15	3.16	1.51
BSS-6	M	13	0.16	0.02	0.05	0.16	26.86	0.68
BSS-7	M	TNTC	0.02	0.00	0.02	0.01	0.26	0.43
BSS-8	M	TNTC	0.02	0.00	0.04	0.07	0.08	0.59
BSS-9	M	40	0.09	0.10	0.01	0.01	4.06	1.27
BSS-10	M	105	4.72***	4.72	3.39	0.00	2.17	5.70
BSS-11	M	1	0.09	0.01	0.01	2.75	2.25	3.15
BSS-11 Q (duplicate)	M	1	0.15					
BSS-12	M	0	0.03	0.03	0.00	4.16	3.80	5.40

Key:

Watershed: M = Merepoint Neck, F = Flying Point Neck

TNTC = Too Numerous To Count

* Data suspect. Due to exceptionally high suspended clay content, the sample was run as a sediment.

** Dissolved Nutrients sample not filtered/collected due to high clay content in sample.

***Data Suspect due to interference by high sulfide and iron concentrations present in sample

Note: Total Dissolved Nitrogen (TDN) = Dissolved Organic N + NH4-N + NO3-N

SHORELINE SEEPAGE SURVEY:

Sample Date: 8/3/1994
dl = detection limit in mg/l

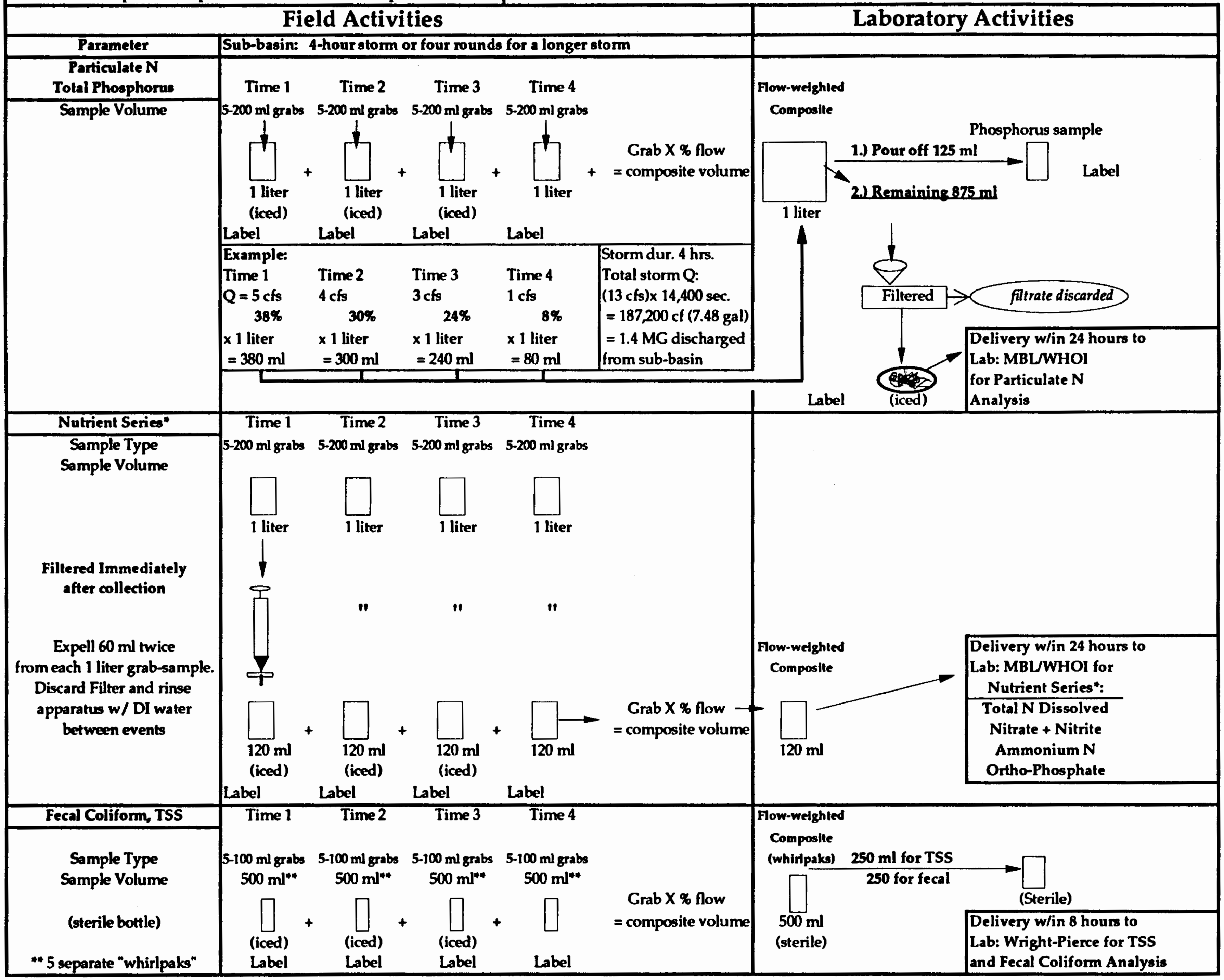
SITE	Watershed	Fecal Coli. no./100 ml	Total P mg/l	PO4 - P mg/l	NH4 - N mg/l	NO3-N mg/l	Particulate N mg/l	TDN mg/l
			dl=0.002	dl=0.001	dl=0.001	dl=0.0007	dl=0.0005	dl=0.002
BSS-2	M	>20,000	0.07	0.04	2.34	0.05	12.30	4.41
BSS-6	M	>20,000						
BSS-10	M	48	0.02	0.01	0.11	0.49	0.61	1.15
BSS-16	F	>1,000,000	1.73	0.26	0.55	0.03	54.74	2.06
BSS-17	F	196	0.15	0.01	0.03	0.02	6.68	0.91
BSS-18	F	5,100	0.08	0.01	0.01	0.01	0.30	0.76
BSS-19	F	8	0.12	0.12	1.11	0.01	0.25	1.89
BSS-19d	F	3						
BSS-20	F	4,600	0.45	0.02	0.03	0.03	3.34	0.80
BSS-21	F	20	0.11	0.01	0.02	0.10	0.69	0.81
BSS-22	F	>2,000	0.13	0.00	0.01	0.01	0.28	0.74
BSS-23b	F	0	0.01	0.00	0.00	0.00	0.03	0.01

d = duplicate fecal sample
b = nutrients field blank
Note: Total Dissolved Nitrogen = Dissolved Organic N + Ammonia-N + Nitrate-N

APPENDIX F

Composite Sampling Scheme for Test Sites

FIGURE 1. Composite Sample Flowchart for Each Sample Test Site



APPENDIX G

Daily Stage Measurements at Bunganuc Stream and Rossmore Stream

Maquoit Bay Project Daily Stream Stage Measurements

Stage Measurements
Bunganuc Stream

scale = 4ft.
datum = 0 ft.

Date:	Time:	Measurement Ft.	Stream Stage (ft.)
22-Jun	13:42	3.66	0.34
22-Jun	13:30	3.66	0.34
23-Jun	7:45	3.67	0.33
25-Jun	7:00	3.69	0.31
26-Jun	7:38	3.69	0.31
27-Jun	6:31	3.7	0.30
28-Jun	6:32	3.5	0.50
29-Jun	7:43	3.5	0.50
30-Jun	17:13	3.69	0.31
1-Jul	9:33	3.69	0.31
2-Jul	8:27	3.69	0.31
3-Jul	6:18	3.69	0.31
4-Jul	3:26	3.44	0.56
5-Jul	6:07	3.44	0.56
6-Jul	6:35	3.7	0.30
7-Jul	7:05	3.71	0.29
8-Jul	7:58	3.71	0.29
9-Jul	13:55	3.71	0.29
10-Jul	16:33	3.1	0.90
11-Jul	6:18	3.71	0.29
12-Jul	6:47	3.7	0.30
13-Jul	13:17	3.76	0.24
14-Jul	6:18	3.77	0.23
15-Jul	8:37	3.76	0.24
16-Jul	8:34	3.79	0.21
17-Jul	6:03	3.78	0.22
18-Jul	9:15	3.78	0.22
19-Jul	6:08	3.76	0.24
20-Jul	6:52	3.75	0.25
21-Jul	5:55	3.75	0.25
21-Jul	9:30	3.72	0.28
22-Jul	9:20	3.74	0.26
23-Jul	16:45	3.47	0.53

Maquoit Bay Project Daily Stream Stage Measurements

Date:	Time:	Measurement Ft.	Stream Stage (ft.)
24-Jul	9:53	3.45	0.55
25-Jul	6:11	3.47	0.53
26-Jul	7:09	3.67	0.33
27-Jul	6:57	3.67	0.33
28-Jul	15:32	3.69	0.31
29-Jul	7:03	3.68	0.32
29-Jul	8:15	3.72	0.28
30-Jul	8:08	3.68	0.32
31-Jul	16:20	3.69	0.31
1-Aug	6:54	3.68	0.32
2-Aug	6:14	3.76	0.24
3-Aug	6:03	3.75	0.25
4-Aug	6:16	3.75	0.25
5-Aug	8:20	3.74	0.26
6-Aug	15:51	3.71	0.29
7-Aug	9:56	3.69	0.31
8-Aug	6:20	3.7	0.30
9-Aug	11:15	3.7	0.30
10-Aug	6:20	3.72	0.28
11-Aug	7:05	3.81	0.19
12-Aug	6:57	3.86	0.14
13-Aug	11:12	3.86	0.14
14-Aug	17:15	3.87	0.13
15-Aug	6:30	3.85	0.15
16-Aug	7:40	3.86	0.14
17-Aug	6:15	3.86	0.14
18-Aug	10:18	3.68	0.32
18-Aug	10:45	3.68	0.32
19-Aug	7:57	3.86	0.14
20-Aug	14:22	3.84	0.16
21-Aug	13:46	3.85	0.15
22-Aug	6:35	3.85	0.15
23-Aug	13:56	3.8	0.20
24-Aug	15:03	3.76	0.24
25-Aug	16:36	3.74	0.26
26-Aug	14:20	3.74	0.26
27-Aug	6:17	3.75	0.25

Maquoit Bay Project Daily Stream Stage Measurements

Date:	Time:	Measurement Ft.	Stream Stage (ft.)
28-Aug	16:45	3.74	0.26
29-Aug	7:10	3.75	0.25
30-Aug	13:56	3.72	0.28
31-Aug	15:34	3.7	0.30
1-Sep	16:58	3.68	0.32
2-Sep	10:03	3.7	0.30
3-Sep	8:13	3.68	0.32
4-Sep	6:09	3.68	0.32
5-Sep	11:07	3.67	0.33
6-Sep	6:37	3.68	0.32
7-Sep	17:18	3.68	0.32
8-Sep	14:12	3.7	0.30
9-Sep	14:15	3.68	0.32
10-Sep	16:50	3.69	0.31
11-Sep	9:15	3.68	0.32
12-Sep	6:03	3.68	0.32
13-Sep	15:34	3.69	0.31
14-Sep	15:04	3.72	0.28
15-Sep	10:51	3.72	0.28
16-Sep	7:29	3.74	0.26
17-Sep	16:03	3.75	0.25
18-Sep	18:22	3.76	0.24
19-Sep	8:14	3.75	0.25
20-Sep	7:18	3.72	0.28
21-Sep	8:50	3.73	0.27
21-Sep	11:15	3.74	0.27
22-Sep	6:18	3.74	0.26
23-Sep	13:30	3.7	0.30
23-Sep	15:33	3.74	0.26
23-Sep	16:43	3.68	0.32
24-Sep	8:00	1.91	2.09
24-Sep	17:04	3.76	0.24
25-Sep	8:02	3.75	0.25
26-Sep	8:19	3.75	0.25
27-Sep	7:45	3.75	0.25
28-Sep	7:18	3.75	0.25
29-Sep	14:26	3.74	0.26

Maquoit Bay Project Daily Stream Stage Measurements

Date:	Time:	Measurement Ft.	Stream Stage (ft.)
30-Sep	16:15	3.74	0.26
1-Oct	11:03	3.73	0.27
2-Oct	17:15	3.74	0.26
3-Oct	7:43	3.75	0.25
4-Oct	16:46	3.76	0.24
5-Oct	15:14	3.73	0.27
6-Oct	8:20	3.74	0.26
7-Oct	7:02	3.72	0.28
8-Oct	17:48	3.68	0.32
9-Oct	16:03	3.66	0.34
10-Oct	9:26	3.66	0.34
11-Oct	6:53	3.67	0.33
12-Oct	15:16	3.68	0.32
13-Oct	15:13	3.66	0.34
14-Oct	15:43	3.67	0.33
15-Oct	16:43	3.67	0.33
16-Oct	16:15	3.68	0.32
17-Oct	8:14	3.67	0.33
18-Oct	14:44	3.69	0.31
19-Oct	14:14	3.69	0.31
20-Oct	14:58	3.7	0.30
21-Oct	13:58	3.69	0.31
22-Oct	15:39	3.68	0.32
23-Oct	7:03	3.69	0.31
24-Oct	7:51	3.7	0.30
25-Oct	14:16	3.69	0.31
26-Oct	10:00	3.6	0.40
26-Oct	16:01	3.67	0.33
27-Oct	16:08	3.66	0.34
28-Oct	11:09	3.66	0.34
29-Oct	12:19	15:21	0.36
30-Oct	9:19	3.63	0.37
31-Oct	7:32	3.64	0.36
1-Nov	16:41	3.64	0.36
2-Nov	13:02	2.66	1.34
3-Nov	7:14	3.63	0.37
4-Nov	12:52	3.64	0.36

Maquoit Bay Project Daily Stream Stage Measurements

Date:	Time:	Measurement Ft.	Stream Stage (ft.)
5-Nov	16:18	3.64	0.36
6-Nov	16:34	3.63	0.37
7-Nov	8:16	3.63	0.37
8-Nov	7:33	3.62	0.38
9-Nov	15:14	3.61	0.39
10-Nov	14:45	3.61	0.39
11-Nov	16:03	3.6	0.40
12-Nov	9:13	3.61	0.39
13-Nov	8:21	3.62	0.38
14-Nov	8:22	3.62	0.38
15-Nov	16:08	3.6	0.40
16-Nov	11:50	3.61	0.39
17-Nov	16:33	3.6	0.40
18-Nov	7:19	3.6	0.40
19-Nov	14:17	3.59	0.41
20-Nov	10:12	3.59	0.41
21-Nov	7:57	3.6	0.40
22-Nov	14:34	3.6	0.40
23-Nov	11:15	3.59	0.41
24-Nov	14:46	3.59	0.41
25-Nov	12:02	3.58	0.42
26-Nov	8:37	3.59	0.41
27-Nov	16:13	3.58	0.42
28-Nov	7:52	3.58	0.42
29-Nov	15:47	3.73	0.27
30-Nov	13:13	3.54	0.46
1-Dec	15:31	3.56	0.44
2-Dec	15:31	3.6	0.40
3-Dec	12:02	3.66	0.34
4-Dec	8:02	3.63	0.37
5-Dec	8:26	3.64	0.36
6-Dec	7:40	2.05	1.95
7-Dec	15:37	3.64	0.36
8-Dec	14:14	3.62	0.38
9-Dec	14:20	3.63	0.37
10-Dec	14:37	3.64	0.36
11-Dec	16:03	3.63	0.37

Maquoit Bay Project Daily Stream Stage Measurements

Date:	Time:	Measurement Ft.	Stream Stage (ft.)
12-Dec	8:16	3.63	0.37
13-Dec	15:53	3.63	0.37
14-Dec	14:14	3.63	0.37
15-Dec	13:52	3.63	0.37
16-Dec	11:13	3.61	0.39
17-Dec	9:45	3.62	0.38
18-Dec	11:34	3.61	0.39
19-Dec	8:22	3.61	0.39
20-Dec	7:03	3.61	0.39
21-Dec	12:47	3.62	0.38
22-Dec	14:19	3.61	0.39
23-Dec	15:16	3.61	0.39
24-Dec	14:02	3.6	0.40
25-Dec	16:15	3.61	0.39
26-Dec	10:16	3.61	0.39
27-Dec	10:40	3.62	0.38
28-Dec	14:17	3.6	0.40
29-Dec	14:19	3.61	0.39
30-Dec	15:49	3.61	0.39
31-Dec	8:04	3.61	0.39
1-Jan	10:13	3.62	0.38
2-Jan	9:22	3.62	0.38
3-Jan	9:38	3.61	0.39
4-Jan	15:40	3.61	0.39
5-Jan	12:47	3.59	0.41
6-Jan	14:36	ICE	
7-Jan	10:12	ICE	
8-Jan	10:13	ICE	
9-Jan	8:21	ICE	
10-Jan	9:38	ICE	
11-Jan	13:14	ICE	
12-Jan	13:37	ICE	
13-Jan	13:39	ICE	
14-Jan	8:03	3.57	0.43
15-Jan	15:51	3.55	0.45
16-Jan	7:43	3.54	0.46
17-Jan	15:35	3.56	0.44

Maquoit Bay Project Daily Stream Stage Measurements

Date:	Time:	Measurement Ft.	Stream Stage (ft.)
18-Jan	15:16	3.55	0.45
19-Jan	15:02	3.55	0.45
20-Jan	13:40	3.57	0.43
21-Jan	9:05	3.56	0.44
22-Jan	12:03	3.57	0.43
23-Jan	7:51	3.57	0.43
24-Jan	13:33	3.58	0.42
25-Jan	14:18	3.57	0.43
26-Jan	13:19	3.58	0.42
27-Jan	7:50	3.57	0.43
28-Jan	10:46	3.56	0.44
29-Jan	16:10	ICE	
30-Jan	9:17	ICE	
31-Jan	15:44	ICE	
1-Feb	15:14	ICE	
2-Feb	15:27	ICE	
3-Feb	13:25	ICE	
4-Feb	6:14	ICE	
5-Feb	9:13	ICE	
6-Feb	9:40	ICE	
7-Feb	13:14	ICE	
8-Feb	13:20	ICE	
9-Feb	16:16	ICE	
10-Feb	16:33	ICE	
11-Feb	9:02	ICE	
12-Feb	11:13	ICE	
13-Feb	9:19	ICE	
14-Feb	14:18	ICE	
15-Feb	12:14	ICE	
16-Feb	15:44	ICE	
17-Feb	16:20	ICE	
18-Feb	10:12	ICE	
19-Feb	10:36	ICE	
20-Feb	13:05	3.57	0.43
21-Feb	17:25	3.57	0.43
22-Feb	7:47	3.57	0.43
23-Feb	15:47	3.59	0.41

Maquoit Bay Project Daily Stream Stage Measurements

Date:	Time:	Measurement Ft.	Stream Stage (ft.)
24-Feb	15:10	3.56	0.44
25-Feb	10:25	ICE	
26-Feb	15:14	ICE	
27-Feb	9:52	ICE	
28-Feb	11:43	3.58	0.42
1-Mar	16:17	3.58	0.42
2-Mar	15:35	ICE	
3-Mar	16:30	ICE	
4-Mar	12:17	ICE	
5-Mar	8:20	ICE	
6-Mar	8:35	ICE	
7-Mar	14:36	ICE	
8-Mar	14:58	ICE	
9-Mar	15:14	ICE	
10-Mar	7:10	ICE	
11-Mar	8:37	ICE	
12-Mar	18:11	ICE	
13-Mar	7:47	ICE	
14-Mar	16:46	ICE	
15-Mar	12:14	ICE	
16-Mar	14:56	3.76	0.24
17-Mar	13:32	3.77	0.23
18-Mar	9:43	3.77	0.23
19-Mar	17:13	3.78	0.22
20-Mar	7:57	3.77	0.23
21-Mar	13:38	ICE	
22-Mar	15:35	ICE	
23-Mar	14:56	3.86	0.14
24-Mar	10:39	3.8	0.20
25-Mar	8:20	3.81	0.19
26-Mar	10:49	3.7	0.30
27-Mar	9:16	3.56	0.44
28-Mar	15:21	3.57	0.43
29-Mar	15:23	3.56	0.44
30-Mar	16:16	3.56	0.44
31-Mar	13:45	3.57	0.43
1-Apr	9:21	3.55	0.45

Maquoit Bay Project Daily Stream Stage Measurements

Date:	Time:	Measurement Ft.	Stream Stage (ft.)
2-Apr	17:42	3.55	0.45
3-Apr	16:16	3.56	0.44
4-Apr	8:02	3.56	0.44
5-Apr	13:34	3.56	0.44
6-Apr	14:14	3.56	0.44
7-Apr	16:02	3.56	0.44
8-Apr	9:25	3.55	0.45
9-Apr	10:52	3.55	0.45
10-Apr	8:57	3.55	0.45
11-Apr	15:35	3.55	0.45
12-Apr	15:06	3.55	0.45
13-Apr	14:46	1.7	2.30
14-Apr	11:13	3.55	0.45
15-Apr	14:56	3.55	0.45
16-Apr	10:39	3.55	0.45
17-Apr	8:20	3.55	0.45
18-Apr	16:43	3.57	0.43
19-Apr	14:02	3.56	0.44
20-Apr	9:33	3.56	0.44
21-Apr	15:35	3.57	0.43
22-Apr	9:11	3.57	0.43
23-Apr	16:36	3.57	0.43
24-Apr	8:32	3.57	0.43
25-Apr	15:35	3.57	0.43
26-Apr	17:13	3.57	0.43
27-Apr	16:06	3.56	0.44
28-Apr	13:45	3.55	0.45
29-Apr	7:12	3.55	0.45
30-Apr	17:16	3.56	0.44
1-May	7:55	3.55	0.45
2-May	13:56	3.55	0.45
3-May	8:32	3.56	0.44
4-May	16:46	3.56	0.44
5-May	17:14	3.57	0.43
6-May	9:05	3.57	0.43
7-May	11:34	3.58	0.42
8-May	8:36	3.58	0.42

Maquoit Bay Project Daily Stream Stage Measurements

Date:	Time:	Measurement Ft.	Stream Stage (ft.)
9-May	15:26	3.58	0.42
10-May	16:35	3.57	0.43
11-May	15:39	3.57	0.43
12-May	10:12	3.57	0.43
13-May	10:48	3.57	0.43
14-May	17:57	3.57	0.43
15-May	9:04	3.57	0.43
16-May	16:22	3.56	0.44
17-May	16:30	3.55	0.45
18-May	16:18	3.54	0.46
19-May	13:58	3.55	0.45

APPENDIX H

Specific Calibration Steps at The Test-Site Level

SPECIFIC TEST SITE CALIBRATION STEPS BY RAIN EVENT

The antecedent moisture condition (AMC) "multiplier" referred to herein is a step built into the model. It is applied to the runoff calculations when a set of user-input values for "Amount of rainfall in the previous five days" and "Time since last rain (days)" triggers the model to assume dry, normal and wet AMCs with multipliers for rainfall of 0.8, 1.0 and 1.2 respectively. The calibration entailed applying multiplier values incrementally until calculated runoff corresponded to actual data to arrive at these final multipliers.

Agricultural Modeling Calibration: Rain Event #1, May 16, 1994

Rainfall: 1.1 inches

Site BS-1 (Agricultural)

Input all units and ran the model with an input rainfall of 1.1 inches. The modeled runoff was lower than measured runoff.

Runoff Calibration: Adjusted agricultural curve number (CN) runoff percentage for this site (per inch of rain) to increase runoff. The adjustment was within the range of CNs used in the CN composite for this site. Result: The modeled runoff approximated actual runoff measurement. However, the fecal coliform loading was lower than loadings calculated from actual water quality data.

Fecal Coliform Calibration: Adjusted the background concentration up incrementally (from actual data-calculated geometric mean of 83 fecal coliforms/100 ml to 300 fecal coliforms/100 ml). Result: The fecal coliform concentration and loading approximated actual water quality data.

Site BS-6 (Agricultural)

Input all units and ran the model with an input rainfall of 1.1 inches. The modeled runoff was lower than measured runoff.

Runoff Calibration: Adjusted agricultural CN runoff percentage for this site (per inch of rain) to increase runoff. The adjustment was within the range of CNs used in the CN composite for this site. Result: The runoff approximated actual runoff measurement. The fecal coliform concentration and loading approximated actual water quality data.

Site GG-7 (Agricultural)

Input all units and ran the model with an input rainfall of 1.1 inches. The modeled runoff was lower than measured runoff.

Runoff Calibration: Adjusted the agricultural CN runoff percentage for this site (per inch of rain) to increase runoff. The adjustment was within the range of CNs used in the CN composite for this site. Result: The modeled runoff approximated actual runoff measurement.

The modeled fecal coliform concentration and loading were lower than actual water quality data. Fecal coliform calibration: Adjusted the background concentration up (from 300/100 ml to 400/100 ml). Result: The fecal coliform concentration and loading approximated actual water quality data.

Agricultural Modeling Calibration: Rain Event #2, November 28, 1994
Rainfall: 1.3 inches.
Site BS-1 (Agricultural)

Input all units and ran the model with an input rainfall of 1.3 inches. The modeled runoff was lower than measured runoff.

Runoff Calibration: Adjusted Ag. CN runoff to AMC III "wet" conditions to increase runoff. Adjustment was a 1.5 multiplier (built into the model calculations) to account for greater than 2 inches of rainfall in the previous 5 days. Result: Runoff approximated actual runoff measurement. Fecal concentration and loading approximated actual water quality data. Maintained adjusted background fecal coliform concentration from event #1.

Site BS-6 (Agricultural)

Input all units and ran the model with an input rainfall of 1.3 inches. The modeled runoff was lower than measured runoff. Runoff Calibration: Adjusted Ag. CN runoff to AMC III "wet" conditions to increase runoff. Adjustment was a 1.5 multiplier to account for greater than 2 inches of rainfall in the previous 5 days. Runoff still lower than measured runoff. Adjusted CN to reflect a slightly higher percentage of runoff by this 1.3-inch modeled event. Result: Runoff approximated actual runoff measurement. Fecal concentration and loading approximated actual water quality data. Maintained adjusted background fecal coliform concentration from event #1.

Site GG-7 (Agricultural)

Input all units and ran the model with an input rainfall of 1.3 inches. The model results approximated actual data for this rain event. Maintained adjustments from event #1.

Agricultural Modeling Calibration: Rain Event #3, April 4, 1995

Rainfall: 0.4 inches

Site BS-1 (Agricultural)

Input all units and ran the model with an input rainfall of .4 inches. The modeled runoff was lower than measured runoff.

Runoff Calibration: Adjusted the agricultural CN runoff to AMC III "wet" conditions to increase runoff to reflect the preceding observed rain events in the watershed and the resultant high water table conditions. Adjustment was in increments until a 1.2 multiplier achieved a runoff approximating actual measured volumes. Result: Runoff approximated actual runoff measurement. Fecal concentration and loading approximated actual water quality data.

Site BS-6 (Agricultural)

Input all units and ran the model with an input rainfall of 0.4 inches. The modeled runoff was lower than measured runoff.

Runoff Calibration: Adjusted the agricultural CN runoff to AMC III "wet" conditions to increase runoff. Adjustment was in increments until a 1.5 multiplier achieved a runoff approximating actual measured volumes. Result: Runoff approximated actual runoff measurement.
Fecal concentration and loading approximated actual water quality data.

Site GG-7 (Agricultural)

Input all units and ran the model with an input rainfall of 0.4 inches.

The modeled runoff was greater than measured runoff. Runoff Calibration: Reduced AMC incrementally from a multiplier of 1.5 to 1.2 to achieve a runoff approximating actual measured volumes. Result: Runoff approximated actual runoff measurement. Result: Fecal concentration and loading approximated actual water quality data.

Agricultural Modeling Calibration: Rain Event #4, April 13, 1995
Rainfall: 0.89 inches
Site BS-1 (Agricultural)

Input all units and ran the model with an input rainfall of 0.89 inches. The modeled runoff was lower than measured runoff. Runoff Calibration: Adjusted the agricultural CN runoff to AMC III "wet" conditions to increase runoff. The adjustment was in increments until a 1.2 multiplier achieved a runoff approximating actual measured volumes. Result: Runoff approximated actual runoff measurement.

The fecal coliform concentration and loading were greater than actual water quality data. Fecal coliform calibration: Reduced the background concentration from 300 fecal coliform/100 ml to 100 fecal coliform/100 ml. Rationale: Last observed manure application at this site was in October 1993. May 1994 sampling event represents background concentrations from the October 1993 application. April 1995 represents over 18 months since observed manure application. Result: Fecal coliform concentration and loadings approximated actual water quality data.

Site BS-6 (Agricultural)

Input all units and ran the model with an input rainfall of 0.89 inches. The modeled runoff was lower than measured runoff.

Runoff Calibration: Adjusted agricultural CN runoff to AMC III "wet" conditions to increase runoff. The adjustment was in increments until a 4.0 multiplier achieved a runoff approximating actual measured volumes. This is the only calibration situation where such a high AMC multiplier was applied. One explanation for the high runoff over this large watershed area may be that a heavy band of precipitation occurred over this area resulting in the high observed runoff. Communications with

Brunswick Naval Air Station Meteorological Center revealed that this phenomenon does occur in coastal Maine. Result: Only by using the AMC multiplier of 4 did modeled runoff approximate actual runoff measurement. Consequently, the fecal coliform concentration and loading approximated actual water quality data.

Note: This extreme multiplier value of 4 did not remain in the model as a permanent calibration. Its use here represents an isolated situation in the suite of monitoring data and model runs for this project and will thus be assumed to be an anomalous event.

Site GG-7 (Agricultural)

Input all units and ran the model with an input rainfall of 0.89 inches. The model results approximated actual water quality data for this rain event. Maintained adjustments from Event #3

Residential Modeling Calibration: Rain Event #1, May 16, 1994

Rainfall: 1.1 inches

Site BS-8 (Residential)

Input all units and ran the model with an input rainfall of 1.1 inches. The modeled runoff approximated actual runoff. However, the modeled fecal coliform was significantly lower than actual data.

Fecal coliform calibration 1: Placed 10% of the houses in Category III. Result 1: The modeled fecal coliform was still significantly lower than actual data. Fecal coliform calibration 2: Applied literature values for fecal coliforms associated with road runoff. Result 2: The modeled fecal coliform was significantly higher than actual data.

Fecal coliform calibration 3: Placed all houses in Category II (nonpolluting). Result 3: The modeled fecal coliform was still significantly higher than actual data; the change to Category II did not lower the fecal coliform appreciably.

Fecal coliform calibration 4: Reduced road runoff fecal coliform concentrations one order of magnitude within the range from the literature. Result 4: The modeled fecal coliform loadings and concentrations approximated actual data.

Final adjustment: Returned 10% of the houses to Category III. The 10% of the houses were placed in Category III to reflect the potential for episodic and seasonal surface breakout given the ranking of this test site based on depth to seasonal high water table, depth to bedrock and soils as described in the Cumberland County Soil Survey.

BS-13 (Residential)

Input all units and ran the model with an input rainfall of 1.1 inches. The modeled runoff approximated actual runoff.

The modeled fecal coliform loading was lower than actual data loading. Fecal coliform calibration: Placed 10% houses in Category III to reflect the potential for episodic and seasonal surface breakout. Result: Fecal coliform concentration and loading approximated actual water quality data.

Residential Modeling Calibration: Rain Event #2, November 28, 1994

Rainfall: 1.3 inches

Site BS-8 (Residential)

Input all units and ran the model with an input rainfall of 1.3 inches. Runoff greater than actual measurements. Reduced AMC wet conditions to average AMC conditions. Runoff still greater. Adjusted woods CN slightly to reduce the runoff.

Result: Runoff approximated actual runoff measurement.

Fecal concentration and loading approximated actual water quality data. Maintained adjusted background fecal coliform concentration from event #1.

BS-13 (Residential)

Input all units and ran the model with an input rainfall of 1.3 inches.

The modeled runoff was greater than actual measured runoff. Runoff Calibration: Reduced AMC from wet conditions to average AMC conditions. Result: Runoff approximated actual runoff measurement.

The modeled fecal coliform loading was greater than water quality data loading. Fecal coliform calibration: Increased the model die-off equation input "Days Since Last Rainfall" to up to 5 days in 1-day increments until the fecal coliform loadings were approximate. Result: Fecal concentration and loading approximated actual water quality data.

Residential Modeling Calibration: Rain Event #3, April 4, 1995

Rainfall: 0.4 inches

Site BS-8 (Residential)

Input all units and ran the model with an input rainfall of 0.4 inches. The modeled runoff approximated actual runoff.

Fecal coliform loading was significantly higher than actual water quality data. Fecal coliform calibration: Placed all houses in Category I to account for no fecal coliform pollution resulting from frozen ground conditions. Result: Fecal coliform concentration was within two orders of magnitude of actual water quality data.

BS-13 (Residential)

Input all units and ran the model with an input rainfall of 0.4 inches. The modeled runoff approximated actual runoff.

Fecal coliform loading was significantly higher than actual water quality data. Fecal coliform calibration: Placed all houses in Category I to account for no fecal coliform pollution resulting from frozen ground conditions. Result: Fecal coliform concentration was within two orders of magnitude of actual water quality data.

Residential Modeling Calibration: Rain Event #4, April 13, 1995
Rainfall: 0.89 inches
Site BS-8 (Residential)

Input all units and ran the model with an input rainfall of 0.89 inches. The model results approximated actual water quality data for this rain event. Maintained adjustments from rain events #1 and #2

BS-13 (Residential)

Input all units and ran the model with an input rainfall of 0.89 inches. The modeled results approximated actual water quality data for this rain event. Maintained adjustments from rain events #1 and #2.

Forest Modeling Calibration: Rain Event #1, May 16, 1994
Rainfall: 1.1 inches
BS-14 (Forest)

Input all units and ran the model with an input rainfall of 1.1 inches. The modeled runoff was higher than measured runoff.

Runoff Calibration: Adjusted the CN runoff percentage for this site (per inch of rain) to decrease runoff. Adjustment was within range of CNs used in the CN composite for the site. The runoff was still too high. Removed road length from the input.

Rationale 1: From field observations during storms and topographic map review, it was determined that a significant portion of the road lies at the base of the test site, and downgradient from the sample "pour point." Road runoff then joins the sample point area runoff via drainage swale.

Rationale 2: Sample concentrations from the pour point routinely exhibited low concentrations of fecal coliform. Therefore, inclusion of road runoff in the calibration is not justified.

The modeled fecal coliform loading was greater than water quality data. Fecal coliform calibration: Placed the 3 residential acres from this test site in Residential Category "II" for adequately functioning septic systems resulting in no fecal coliform from these as a source.

Result: The fecal coliform concentration and loading approximated actual water quality data.

Forest Modeling Calibration: Rain Event #2, November 28, 1994
Rainfall: 1.3 inches
BS-14 (Forest)

Input all units and ran the model with an input rainfall of 1.3 inches. The modeled runoff was lower than measured runoff. Runoff Calibration: Adjusted the agricultural CN runoff to AMC III "wet" conditions to increase runoff. Adjustment was within range of CNs used in the CN composite for this site. Result: Runoff approximated actual runoff measurement.

The modeled fecal coliform loading was less than water quality data loading. Fecal coliform calibration: Increased the background concentrations incrementally from 1 fecal coliform/100 ml to 100 fecal coliform/100 ml until the modeled loadings approximated actual loadings. Result: Fecal concentration and loading approximated actual water quality data.

Forest Modeling Calibration: Rain Event #3, April 4, 1995
Rainfall: 0.4 inches
BS-14 (Forest)

Input all units and ran the model with an input rainfall of 0.4 inches. Runoff approximated actual data.

Fecal coliform concentration was higher than actual data.
Fecal coliform calibration: Changed the background fecal coliform concentration back from 100 fecal coliform/100 ml in event #2 to 1 fecal coliform/100 ml in event #1. Result: Fecal coliform approximated actual data for this rain event.

Forest Modeling Calibration: Rain Event #4, April 13, 1995
Rainfall: 0.89 inches
BS-14 (Forest)

Input all units and ran the model with an input rainfall of 0.89 inches.

The model results approximated actual water quality data for this rain event. No further adjustment was necessary. Maintained adjustments from rain event #1.