Project #94.5.10

STRATEGIES FOR ASSESSING NONPOINT SOURCE POLLUTION IMPACTS ON COASTAL WATERSHEDS

A Final Report to

The New Hampshire Office of State Planning, New Hampshire Coastal Program

Submitted by

Dr. Stephen H. Jones and Dr. Richard Langan
Jackson Estuarine Laboratory
University of New Hampshire

July 14, 1995

This Report was funded in part by a grant from the Office of State Planning, New Hampshire Coastal Program, as authorozed by the National Oceanic and Atmospheric Administration (NOAA), Grant Award Number NA47OZ0237.

NH OFFICE OF STATE PLANNING COASTAL PROGRAM

STRATEGIES FOR ASSESSING NONPOINT SOURCE POLLUTION IMPACTS ON COASTAL WATERSHEDS

A Final Report to

The New Hampshire Office of State Planning, New Hampshire Coastal Program

Submitted by

Dr. Stephen H. Jones and Dr. Richard Langan
Jackson Estuarine Laboratory
University of New Hampshire

July 14, 1995

This Report was funded in part by a grant from the Office of State Planning, New Hampshire Coastal Program, as authorozed by the National Oceanic and Atmospheric Administration (NOAA), Grant Award Number NA47OZ0237.

NH OFFICE OF STATE PLANNING COASTAL PROGRAM

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION · NOAA · U.S. DEPARTMENT OF COMMERCE

ACKNOWLEDGEMENTS

The authors wish to acknowledge the contributions of the following individuals to this project: Mr. Dave Ehnert of the Rockingham Planning Commission for providing GIS maps and RPC reports; Mr. Daniel Marquis and Mr. Ryan Davis on the Jacksoson Estuarine Laboratory (JEL) and the Department of Natural Resources, UNH, for their nonpoint source assessement using GIS; Ms. Deborah Lamson, Ms. Beata Summer-Brason, Ms. Andrea Tomlinson, Mr. Gregory Houle, Mr. Gaston Gingives and Mr. Daniel Boisvert (JEL) for asssisting in field and laboratory work; Ms. Jaimie Wolf for providing analytical services; and again Mr. Daniel Marquis for his report on levels of contaminants in a small tributary to the Squamscott River.

INTRODUCTION

The issue of nonpoint source pollution has become increasingly important in coastal areas. Pollution can directly affect valuable marine and estuarine resources and habitats, and indirectly limit use of economically important species and areas. In New Hampshire, the Great Bay Estuary is the dominant coastal area, and the Squamscott/Exeter River system is a major tributary to the estuary. Two years of study in the Oyster River watershed (Jones and Langan, 1993; 1994a) has provided guidance for designing a one year study for the Squamscott/Exeter watershed. Nonpoint source pollution in this watershed is of critical importance because of its proximity to the abundant shellfish waters of Great Bay. The Great Bay National Estuarine Research Reserve and the Pease Wildlife Refuge areas also have numerous protected areas that include critical habitats.

Numerous studies have focused on or included some scrutiny of pollutants in this watershed. A previous study by Jones (1990) showed that improvements in water quality resulted from the upgrade of the Exeter POTW that year, but also showed lingering problems in the river. Jones and Langan (1994b) assessed the impact of animal waste storage and downstream constructed wetlands at a farm located on the shore of the Squamscott River. An ongoing monitoring program at JEL since 1988 has assessed monthly levels of fecal-borne bacteria, suspended solids and nutrients at Chapmans Landing in the Squamscott River, and has found levels of contaminants to be decreasing (Langan and Jones, 1995). These data also raised some concerns a few years ago because of apparently increasing levels of suspended solids (TSS). This trend has not been borne out in the past two years. Finally, a two-year study of all of the major tributaries to the estuary included sites in the Exeter/Squamscott River system (Jones and Langan, 1995). The results suggested that the Exeter River probably has little impact on nutrients in the Squamscott River, and other sources are suspected along the tidal Squamscott River, including the two POTWs at Exeter and Newfields. Conversely, bacterial contaminants from the urbanized areas influencing the lower Exeter and upper Squamscott River areas are probably a major source for the system. The effect of storm events on contaminants suggests that urban runoff or other rainfall-related processes (seepage from sewage pipes) from the town of Exeter can especially impact the water quality of the upper and eventually the lower Squamscott River tidal waters.

A more detailed, updated study of the system was needed to address a number of questions. The goals of this study were to: 1) identify pollution sources and problem areas; 2) evaluate known critical factors for designing and assessing processes responsible for contamination of tributaries to the river; 3) develop and evaluate methods for determining mechanisms that control external loading of suspended solids to the watershed. The focus of the study was on nonpoint sources of pollution, and most of the study areas were non-urban. This approach can serve to focus future efforts on any identified problems associated with residential areas on septic systems, agricultural land practices, excavation, logging, road construction, etc., and at the same time weigh the relative contribution of the largely unevaluated urban areas.

METHODS

Sample Site Selection and Landuse Data

The same strategies used in previous studies to assess nonpoint source pollution in a New Hampshire coastal watershed (Jones and Langan, 1993; 1994) were used in this study. Sampling sites were chosen to allow for assessing contaminant concentrations in the main stem of the tidal river, in each tributary to the river, in the mouths of the tributaries, more detailed sites in major tributaries, and intensive study of one target small tributary. In this study, the Squamscott River sites, designated GB#, were located along a transect from Chapmans Landing to just above the Exeter POTW (Figures 1 and 2). The tributary sites, designated SR#, were located downstream of suspected contaminant sources (housing developments, farms, etc.) and numbered in order going clockwise from Newmarket along the eastern watershed to Exeter and back up the western watershed area. The suspected sources were identified initially by extensive review of available maps and groundtruthing. The tributary mouth sites were designated SR-M#. The intensive tributary site locations were the Exeter River and tributaries, designated ER# and #EXT (Figure 2), and a small stream out of Newmarket through Newfields, designated SR1.# (Figure 1). Sampling was coordinated in some instances to maximize comparisons between different areas and occasionally to follow rain events, which are summarized for all sampling dates in Table 1. Tidal water sampling occurred mostly at low tide.

Landuse was assessed by a number of strategies. We first looked at USGS maps to locate housing developments and farms near tributaries. We then used a GIS to identify and quantify landuse areas with high potential for nonpoint source pollution.Spatial analyses were conducted using the Environmental Systems research Institute Inc., ARC/INFO software. The data layers were obtained from the Rockingham Planning Commission, including the landuse data, hydrography, and the soils data from the NRCS. Sewered areas were excluded, and the soils and landuse coverages were combined. A 75 foot buffer was created around the Squamscott River and its tributaries using the hydrography coverage, which was then overlayed with the combined soils/landuse coverages. The resulting coverage did not include SR25, which falls within the sewered area, and the landuse upstream of SR1. The areas omitted around SR1 were in Newmarket, over the border from Newfields.

Analytical Methods

Measurements of temperature, salinity, dissolved oxygen, pH and observations of weather conditions were recorded at the sampling times. Separate containers were used for collection of water samples for microbial analyses, suspended solids and nutrient analyses. Sample collection and processing methods were conducted according to JEL SOP's 1.05 and 1.06 (Langan 1992 a & b). Nutrient analyses for JEL samples were done using Lachat Method 11-107-06-1-C for ammonium, method 30-107-04-1-A for nitrite/nitrate (Lachat Instruments, 1991) and the wet chemistry method of Strickland and Parsons (1968) for orthophosphate. Microbial analysis of JEL samples involved standard membrane filtration methods using mTEC agar for detection of fecal coliforms and *Escherichia coli,* and mE agar for detection of enterococci.

RESULTS AND DISCUSSION

Updated Database and Assessment of Nonpoint Source Pollution in the Watershed

Water Quality Along a Transect of the Squamscott River

Bacterial and nutrient contaminants were measured at sites in the Squamscott River along a transect from Chapmans Landing (GB7) to just above the Exeter POTW (GB13) (Table 2). Rainfall can have a negative impact on water quality in the Squamscott River (Jones and Langan, 1995), however, no rainfall occurred within 48 h of sampling on the two sample dates. Levels of contaminants generally increased going upstream (Figures 3 and 4). For bacteria, the gradient was most apparent for fecal coliforms and *E. coli*, which increased from GB7 to GB8, and again from GB8 to GB9, with upstream sites having relatively equal and variable levels (Figure 3). Overall, fecal coliforms increased from 18 to 231/100 ml from GB7 to GB10, and *E. coli* increased from 14 to 125/100 ml from GB7 to GB12. Enterococci and *C. perfringens* showed no obvious and consistent trends. For nutrients, nitrate concentrations were relatively high and exhibited the most obvious gradient, increasing gradually from GB7 to GB13 over a relatively small range (21 to 37μM). Ammonium concentrations were relatively constant from GB7 to GB12, then increased at GB13, while phosphates remained relatively constant throughout.

The Squamscott River transect data do not indicate that any tributary, along the stretch of the river sampled, had any obvious influence on water quality. Bacteria and nutrients are subject to biological and physico-chemical processes that could attenuate concentrations with time and space. The river is also influenced by tidal mixing, and dilution with mixing could serve to homogenize contaminants, thus hiding any peak concentrations associated with sources. The diluting effect of tidal water on low tide contamination levels is quite apparent at GB7, as illustrated in Figure 5A. The differences in indicator concentrations between high and low tide are large, with concentrations at high tide quite low. The relationship between fecal coliforms and salinity (conservative indicator of dilution) on 10/25/94 for this transect suggests loading was occurring along the transect between GB13 and GB7 (Figure 5B). This is apparent from the fecal coliform concentrations that are higher than predicted (above straight line) if fecal coliforms were diluted linearly with salinity. The site with the fecal coliform concentration in least agreement with predictions is site GB10, which is located near the mouth of the SR9 tributary. The site with lower than expected bacterial levels is GB12, which probably is a reflection of the less saline, disinfected effluent from the Exeter POTW at that site. The smaller width and volume of the river in the upstream portions probably would more easily reflect influences from sources like the POTW or a tributary.

The relationship between salinity and fecal coliforms was re-tested on 4/28/95, using sites at the mouths of the tributaries that were routinely sampled. The data include sites from SR-M1, downstream of GB7, upstream to SR-M19, at the Oxbow Cut just downstream from the Rt. 101

bridge and the Exeter POTW (Figure 5C). The salinity decreased in order of sites going upstream, and the relationship between salinity and fecal coliforms suggests a general attenuation of fecal coliforms between SR-M19 and SR-M1. Deviations from expected fecal coliform levels were not large and were probably a result of variability. However, loading may have occurred between sites SR-M10 and 21 (the two highest concentrations) with some dilution at site SR-M20 (the lowest value at salinity=0.5). The other site where fecal coliform concentration was greater than expected was SR-M4, but levels again decreased immediately downstream at SR-M5, suggesting that little loading was probably occurring.

Water Quality and Sources of Contamination in the Exeter River and its Tributaries

Bacterial and nutrient contaminants were measured at sites in the Exeter River and its tributaries from the dam (9 EXT) upstream to the Brentwood town line (14 EXT) (Table 4). The transect along the Exeter River goes from 9 EXT upstream to ER4, ER5, ER6 and 14 EXT (Figure 2). A transect up the Little River goes from ER1 upstream to ER7 and ER2, with another site upstream on Scamen Brook at ER 3. Fecal coliforms and *E. coli* decreased going upstream in the Exeter River (Figure 6). In the Little River, levels also decreased going upstream. ER3 is the cleanest site, while ER2', a pipe near ER2, appears to be a potential source of contaminants. Enterococci and *C. perfringens* concentrations were quite variable and exhibited no obvious spatial trends. Rainfall events of 0.3-0.4"/48 h occurred before two sample dates (3/22&4/4), but contaminant levels were not high (Table 4). Rainfall has significant impacts on bacterial contaminants in this area (Jones and Langan, 1995), as presented in Table 4 for 9 EXT and 14 EXT.

Nutrients were generally present at relatively low concentrations in the Exeter River area (Table 5). The sites with the highest levels of nitrate, ammonium and phosphate, though by small margins over other sites, were sites ER3 and 7, where bacterial contaminants were lowest (Figures 7 and 8). The data from Jones and Langan (1995) in Table 5 show that rainfall has little impact on nutrient concentrations in this area.

The Exeter River and tributaries near Exeter are probably a significant source of bacterial contaminants to the tidal river, based on somewhat high levels at 9 EXT and the flow rate of the river compared to other tributaries. Bacterial levels increase along the Exeter River and Little River transects, as well as between the mouth of the Little River and the dam at 9 EXT. It appears that sources of contaminants are associated with some of the residential areas between upstream, relatively clean sites (ER3 and 14 EXT) and downstream sites.

Water Quality and Sources of Contamination in the Tributaries of the Squamscott River

Almost all of the small tributaries that empty into the Squamscott River were sampled during the study at some point or points along their lengths (Figures 1 and 2). Samples could not be taken from the SR8 tributary, as a housing development has essentially incorporated the former stream bed into drainage ditches in yards. Geometric mean levels for bacterial contaminants are presented in Figure 9. Levels were relatively high in some tributaries: SR25, SR10, SR9 and SR21. Average levels of nitrate were also relatively high at some sites: SR9, SR5, SR6, SR25, and especially at SR1 (Figures 10). Nitrate at SR1 was always high at nearly a constant concentration (~220 μM). Significantly, it is located very close to and is apparently part of a drainage swale that originates at the Rockingham golf course across Rt. 108 in Newmarket. SR9, with the next highest levels, is located downstream of an extensive housing development that includes some more recent construction. Ammonium concentrations were not very high, except at SR19 (Figure 11), while phosphate levels were highest at SR11 and GB7 (Figure 12), which are sites in the Squamscott River. SR19 is downstream from a concentration of new (1990-91) residences on septic systems. Only a few samples were collected for sites SR10, SR21 and SR25, so the data from a date where most of the sites were sampled, including these three sites, are presented in Figure 13 for the bacterial contaminants. The three sites with the highest levels are the same three as for the overall mean levels in Figure 9: SR9, SR25 and SR10. For nitrate, SR1 and SR9 were still high, and SR5, SR6 and SR25 were again relatively high (Table 7). Thus, it is apparently valid to include these sites in comparisons with all other sites.

Rainfall events of >0.3"/48 h occurred on three occasions in spring, 1995 (4/19, 5/25 & 6/7/95) on sample dates for tributaries (Table 1). The 6/7/95 and some other individual samples suggest that rainfall could have an impact on some tributaries (Tables 6 and 7). However, it appears that temperature or some other warm season-related phenomenon also affects bacterial and nutrient concentrations. Obviously, 6/7/95 is a warm weather date, as were the July and August dates in 1994. These dates were not associated with rain events, yet had levels as high or higher than for 6/7/95 (Table 6). In between, samples had lower contaminants, even after some rainfall events earlier in the spring. Thus, rain events had no obvious, consistent impact on water quality in the tributaries. A study more focused on rainfall events would be needed to build enough data to discern effects.

Some of the tributaries have relatively high concentrations of contaminants. SR1 had constant high levels of nitrate, possibly associated with septic systems or some other non-apparent source (possibly seepage from old buried manure storage area), although more probably from the golf course. The constancy of high levels at this site, which is upstream of any obvious sources other than the golf course, suggests that it is coming from a strong, groundwater-borne source. Many of the sites with high nutrients, SRs 1,5,6, 9 and 19 are located at substantial distances upstream from the Squamscott River, often above marshes, and their impact may not be pronounced because of these attenuating factors. Other potential problem sites, SRs 4, 10, 11, 21, 25 and GB7 are either in the river or in close proximity, and may have bigger impacts on the river. The goal of this sampling and analysis is to determine whether tributaries are having negative impacts on the water quality of the Squamscott River. The following approaches help to provide evidence to make this determination.

Relationship Between Contamination Upstream and at the Mouths of Squamscott Tributaries

Samples were collected on two occasions at sites along the Squamscott River at the mouths of most of the tributaries (Tables 8 and 9). Many tributaries empty into the river after passing through fringing marshes in different small channels, making it difficult to locate the best sample sites. The data are presented in Figures 14 (bacteria) and 15 (nutrients) as sites in successive points along a transect from the mouth of SR1 up to the downtown Exeter site SR-M25. The fecal coliforms and *E. coli* again increase in concentration going up the river, with the end member, SR-M25 higher (Figure 14) than above the dam at 9 EXT/SR14 (Table 4). The enterococci are more variable with no obvious trend. *C. perfringens* levels were relatively high at some sites, probably a result of resuspended sediments in samples from these turbid tributaries at low tide. All of the sites where *C. perfringens* was >50/100 ml were small tributaries with low flow that flowed through the fringing marshes. *C. perfringens* cells in estuarine water are closely associated with particulate matter (S. Jones, unpublished).

Nutrient concentrations on 4/28/95 were relatively low, except for ammonium at SR-M3 (Figure 15). This site is downstream from some residences on septic systems and the fields of Stuart Farm, which have manure and inorganic nitrogenous fertilizers applied to corn and hay fields. The overall trend shows relatively higher nutrient levels at the mouths of downstream tributaries, especially ammonium at sites SR-M1, 5, 4 and 3. These higher levels may reflect farm influences (also potentially influencing SR-M 4 and 5) or even export from the extensive marshes at the mouths of these tributaries.

Both dates where tributary mouths were sampled had simultaneous sampling of the upstream tributary sites (Tables 6 and 7). Fecal coliform levels at mouths on 4/28/95 were relatively low, increasing going upstream, while enterococci were again more variable (Figure 16). Fecal coliforms levels were highest at SR3, but levels at SR-M3 were relatively low. Other sites had lower levels at upstream tributary sites, compared to mouth levels. Enterococci also did not have high tributary levels that corresponded with any elevated mouth levels. Nitrate levels were all higher in the tributaries than at the mouth sites (Figure 17), though there was little evidence of linkage/contamination of the river from the tributaries. Conversely, ammonium levels were relatively low in the tributaries and higher at every mouth site, and SR-M3 and SR3 had the highest levels for both site types (Figure 18). Thus, the tributaries appeared to have little influence downstream in the Squamscott River on 4/28/95.

Linked tributary and mouth sampling also occurred on 6/7/95 for bacterial contaminants. A rain event coincided with this date, and levels of bacteria were elevated compared to previous samples (see above discussion re: seasonal patterns). Again, the levels at mouth sites generally increased going upstream (Figure 19). The highest tributary levels were at sites SR9, SR20 and SR25. A definite linkage of high tributary to mouth levels is shown for SR25, a small linkage for SR20, and no relationship at SR9. SR25 upstream and downstream sites are in close proximity, and the tributary is near downtown Exeter, where major urban sources of bacterial contaminants appear to be concentrated.

In all cases, the linkage between tributary sites and mouth sites does not take into account the potential for contaminants to enter the tributary downstream of the upstream site. This is probably most significant for sites at greatest upstream distances and for contaminants that are mobile in the subsurface, i.e., nitrate.

<u>Contaminant Loading Estimation</u>

The best measure of potential influence of a tributary on the Squamscott River is the total loading potential from the tributary, relative to observed spatial trends in river water quality. Flow rates vary with season quite drastically in the tributaries of the Squamscott River. Flow rate measurements were made on 6/16/95 at a time when the tributaries were not almost dry, as seen in summer, or swollen with spring rains, but probably representing average flow conditions (Figure 20). Only flow at freshwater tributary sites was measured, excluding tidal sites SRs 3, 4, 11 and 16. SR14/9 EXT was also not measured. The highest flow rates were measured at SRs 25, 22, 24, 1, and 19, with substantially lower flow at SRs 5, 6, 10, 21, and especially 9 and 21. Some of the high flow sites correspond to some problem sites for contaminants, like SR1 and SR25. Low flows were measured at other potential problem sites, like SR9 and SR21.

Calculations of contaminant loading rates were made using flow rates and either overall mean contaminant levels or levels measured on the date closest to when flows were measured, i.e., 6/7/95. Loading rates calculated using 6/7/95 bacterial data showed SR25 to be the overwhelming most important potential source. Sites SR10 and SR24 were also higher loading rates for fecal coliforms and *E. coli* compared to the other sites. Sites SR6, SR10, SR 19 and SR22 also had relatively high loading rates for enterococci. In contrast, sites SR 9 and SR21 had high concentrations of contaminants at tributary sites but no significant loading. Using overall mean contaminant concentrations, the same three sites, SR25>>SR24 and SR10, appeared as potential problems (Figure 22).

Loading rates for nutrients showed SR25 to be a consistent potential problem site, although nitrate at SR1 was the worst apparent problem (Figure 23). Other relatively high loading rate sites were SR24 and SR22 for nitrate, SR24 and SR19 for ammonium, and SR22, SR24 and SR1 for phosphate.

The tributaries with the largest potential to influence river water quality are, not surprisingly, the tributaries withe the highest flow rates: SRs 25, 24, 22, 1 and 19. Other sites with elevated loading were SR10 for all bacteria and, to a lesser extent, SR6 for enterococci. The calculation of loading emphasizes the importance of not drawing conclusions based solely on contaminant concentrations. The most direct connection between tributary and river water quality is at SR25, which is also a tributary site very close to the river. SR10 is also quite close to the river, an area that corresponds with some evidence of loading (Figure 5B). Other sites with elevated loading rates may not have much influence on the river because of the proximity of the sampling site relatively far upstream and the potential for attenuation to occur before the water reaches the river. This is especially true in areas where the water flows through downstream marshes that can slow flow and promote plant uptake and microbial transformations of nutrients.

High Intensity Assessment of Contaminant Sources and Fate in a Small Tributary

The last approach taken to understanding the sources and fate of contaminants in the watershed was to focus more intensively at one site, both spatially and temporally. SR1 was chosen because of early measurements indicating elevated contamination with nitrate and bacteria (Tables 6 and 7). Sites were chosen along a transect from the upstream end (SR1.1) to the mouth at the Squamscott River (SR1.6), with SR1.2 corresponding to routine site SR1 and located downstream from a house. Bacterial contamination was apparent at SR1.2/SR1, with attenuation occurring downstream to the river, especially for enterococci (Figure 24). The geometric mean concentrations of bacteria at SR1.2 were dominated by extremely high counts on 10/18/95 (Table 10). Site 1.4, located downstream from another small stream, also exhibited elevated fecal coliforms and *E. coli*. The upstream site was much lower than SR1.2/SR1.

Nutrients exhibited unique trends (Figure 25). Both ammonium and phosphate were substantially higher downstream in the tidally-influenced water. Nitrate had very high concentrations along the whole transect, with some attenuation at 1.2 (where bacteria were highest). Nitrate concentrations at all sites remained consistently high on all sample dates (Table 11).

The observed bacterial levels are consistent with expectations, based on proximity to potential sources and downstream attenuation. There are a few houses in the area upstream of 1.2, and the stream entering above 1.4 has a small pond filled with ducks, geese, swans and other birds at its head. The observed ammonium and phosphate levels reflect relatively low level of contamination in the freshwater portion entering tidal water with higher levels. The ammonium could also be exported from the fringing marshes through which the stream flows. However, the constant high concentrations and the lack of downstream attenuation for nitrate, as well as the lack of high levels of any other contaminant, is not consistent with typical surface-borne contamination. The major potential source upstream is the golf course, which probably fertilizes turf at a high rate. Nitrate is a very mobile anion in groundwater and it is quite probable that the groundwater in the area is contaminated with nitrate from nitrogen fertilizer applied at the golf course. The nitrate does not have much apparent impact on the river, except that the highest level measured at GB7 occurred in October, 1994, at the same time as sampling for the SR1 sites.

Sources and Impacts of Suspended Sediments in the Squamscott River

Total suspended solids (TSS) were also measured at the same sites and times as nutrients and bacteria (Table 12). The TSS decreased going upstream from GB7 to GB13 (Figure 28). The levels in the Exeter River sites were substantially lower than downstream levels but near to levels at the upstream GB13 site observed in the river (Figure 27). The other tributaries around the watershed had varying TSS levels (Figure 26). The highest levels were observed at SR11, GB7 and SR3, which are all sites either in the river (SR11 and GB7) or heavily influenced by tidal waters (SR3). The average levels for the other sites all had TSS levels that were lower than average levels at downstream sites (Figure 28). In contrast to all other samples, TSS levels in tributary mouth samples were high (Figure 29). As previously mentioned, and as suggested by elevated levels of *C. perfringens* in the same samples, sampling at the tributary mouths is nearly impossible to accomplish by boat without disturbing the readily resuspendable sediments and contaminating the samples. Thus, the measured levels of TSS are probably not reflective of water concentrations upstream. However, all of the tributaries that flow through the fringing marshes and sampled by boat had obviously turbid water. Resuspension of sediments in the river, as well as at these sites with flowing water entering the river, is probably the governing mechanism causing high levels of TSS in the river. The SR1.1-1.6 samples further illustrate this, as upstream water had very low TSS levels and the sites in the mouth of the tributary had relatively high levels, probably even higher than what was occurring in the river (Figure 30).

Evaluation of Previously Identified Critical Factors and Landuse Interpretation

Landuse Data and Interpretation

The Squamscott River watershed comprises 11,940 acres within portions of Exeter, Stratham and Newfields. The focus of this study was directed at the areas that would most likely impact the Squamscott River, meaning areas between the river and Route 108 on the east and Route 85 on the west. The predominant landuses are forest, undeveloped land and open space. Other landuses include clusters of residential development in Stratham and Newfields, and numerous single family houses throughout the watershed. Agricultural areas include cropland and dairy farms, located primarily in the Stratham portion of the watershed (Figure 31). A large commercial areas exists along Route 108 in Stratham and Exeter. The majority of the watershed is unsewered, but two distinct areas are sewered: the commercial area of Stratham with Exeter, and a portion of Newfields, at the center of town. There are extensive tributaries to the Squamscott and Exeter rivers throughout the watershed.

A GIS was used to manipulate available spatial data to identify and quantify specific landuses with high potential for nonpoint source pollution. Many potential data layers were available. However, the soils and landuse data were most useful, and resulted in identification of agricultural areas that were on poorly drained soils (Figure 32) and nonsewered residential areas on soils poorly suited for septic systems (Figures 34 and 35). These data were useful, when combined with USGS maps that show residential areas, to determine changes in landuse that can help determine ages of septic systems and other information. The GIS data were limited in that the 1986 data did not have farming data, and the 1991 data did not cover Newfields.

The GIS also allowed for quantification of residential and agricultural areas with potential for nonpoint source pollution, based on soils and proximity to a calculated 75 foot buffer. The percentage of the watershed with residential homes on soils with low or very low suitability for septic systems increased from 1.9% in 1986 to 6.8% in 1991, even though the 1991 coverage only included half of the watershed. The percentage of these homes that fell within the 75 foot stream buffer decreased from 4.8% to 3.8%, suggesting that newer homes may have been built less frequently within the buffer. Agricultural land on poorly drained soils covered 2.1% of the watershed in 1991, and the percentage that fell within the 75 foot buffer was 3.5%, similar to the residential areas. However, because of the smaller area covered and the fact that pollution-generating activities are not necessarily located within these areas on farms, the potential for pollution is probably much less significant compared to residences on septic systems.

Additional work was necessary to fill data gaps and to update landuse information to the present. This was accomplished by quantifying building permits in the watershed during 1990 through 1994 (Figure 33), groundtruthing areas around tributaries to confirm the existence of houses, and to identify other potential contamination sources (Figure 36). No farms of concern were found in Newfields, which was not included in the 1991 farmland data. Using a combination of existing residences on USGS maps, the 1986 and 1991 GIS data, and the new construction information up to 1994, the ages and general types of septic systems could be assumed.

Assessment of Critical Factors

The critical factors identified in a previous report (Jones and Langan, 1994a) for this type of study were soils and their suitability for specific uses, proximity of potential sources to surface water, farms with animals or manure spreading on land, and to a lesser extent, age and type of septic systems. The most important potential sources in the Squamscott River are also residential homes with septic systems and farms. These factors were considered during the whole process of sample site selection and landuse data collection and interpretation.

Based on soils and landuse data, the areas in the watershed that are potential problem areas are near SR3, SR4, SR5, SR6, SR8 (not sampled; M8 and GB9 were), SR9, SR10, between SR9 and SR10, SR19, SR20 and SR21. The areas identified as having potential for problems using the soils and landuse data were sampled for water quality assessment, as previously described. The sites that had high levels of contaminants included most of the areas predicted to be problems, including SR3, SR5, SR6, SR9, SR10 and SR19. The GIS analysis did not include critical areas near two of the most important sites: SR1 and SR25 (see METHODS).

The areas that had elevated contaminant levels and were predicted to be problems that also were significant as far as loading potential to the river included sites SR9, SR10 and SR19. Most sites had septic systems of different ages. Sites SR1, SR22 and SR24, which had high loading rates, were not predicted to be problem areas, using the existing digitized data. It is quite possible given 1991 or newer landuse data that these sites could also be included. However, no new construction was apparent based on review of building permits in these areas (Figure 33). The sources of these contaminants, mostly nutrients, may be something other than residential homes or farms. For example, the golf course in Newmarket upstream of SR1 is a probable major source of nitrates at SR1, and would not have been included in this analysis.

Some of the loading from the potential problem areas would be attenuated as streams flowed through downstream marshes or ponds. This would be most important at SRs 3-6, where extensive salt marshes exist. SR9 flowed through a dense forested area and was quite a distance upstream from the river, while SRs 19-24 flowed through smaller downstream fringing salt marshes. There is not much detention of flow for the tributaries downstream from SR10 and SR25, and these are in fact major potential loading sources of contaminants.

This approach was useful for predicting sites with potential significant impacts on the river water quality. Added coverages, while probably not adding much new critical information, would be useful for presenting a comprehensive assessment of potential sources. However, the whole approach, including the landuse assessment, water quality analysis and flow rate measurements, are necessary to formulate a coherent assessment of nonpoint source pollution in any coastal watershed. The potential usefulness for modelling such areas is increasing as models are tested and modified for these applications. We are presently cooperating with NOAA/SEA Division in their modelling efforts that are focusing on the whole Piscataqua/Great Bay Estuary. They are applying the SWAT model to predict nonpoint source pollution.

Assessment of Suspended Sediment Loading to the Watershed

Data from previous studies has raised concerns about the levels of TSS in the Squamscott River (Langan and Jones, 1995). The trend for TSS at Chapmans Landing from 1989 to 1992 was of concern, because relatively high levels persisted over that time period (Figure 37). Levels dropped in 1993, an unusually dry year, but remained relatively low in 1994, a more normal year. The analyses done in this study suggest no obvious sources of TSS to the Squamscott River from any tributaries or shoreline sites. Thus, anthropogenic sources of TSS are probably not significant in this watershed, leaving natural processes as the source of turbidity and solids in the river. Further investigation of potential sources was done as part of this study.

Potential sources other than residential home construction are summarized in Table 13. Figure 38 relates to road construction and salting in the watershed. No obvious significant sources of solids is apparent from review of road construction (Table 13) and measured TSS levels at sampling sites. Road salting data were general and no information for specific sites was available. The total building permits in the three towns that were on file for 1990 through 1994 are summarized in Figure 39, and locations are presented in Figure 33. Numerous analyses of building permit numbers in different areas and TSS levels at GB7 were made with no evidence of any relationship between the permits and TSS levels. Comparing the TSS levels in Figure 37 with the building permits in Figure 39 shows a negative relationship with time: there were more building permits in 1993 and 1994 compared to previous years, while TSS levels were lowest in these two years.

There are no apparent problem areas for loading of TSS in the watershed. The elevated levels measured in the river are probably internally-driven processes, resulting in resuspension of bottom sediments on a consistent basis. This was illustrated by some of the results from this study, where high TSS levels were measured at the mouths of small tributaries at low tide. This conclusion was only made possible by the measurement of water quality in the tributaries, mouths, and along the river.

REFERENCES

Jones, S.H. 1990. Impact of Runoff Events on Water Quality in Great Bay. Final Report to the NH Office of State Planning, NH Coastal Program.

Jones, S.H. and R. Langan. 1993. Oyster River Nonpoint Source Pollution Assessment. Final Report to the NH Office of State Planning, NH Coastal Program.

Jones, S.H. and R. Langan. 1994a. Land Use Impacts on Nonpoint Source Pollution in Coastal New Hampshire Watersheds. Final Report to the NH Office of State Planning, NH Coastal Program.

Jones, S.H. and R. Langan. 1994b. Mitigation of Agricultural Contaminants of Estuarine Water Using Constructed Wetlands. Final Report to the NH Office of State Planning, NH Coastal Program.

Jones, S.H. and R. Langan. 1995. Assessment of Nonpoint Source Pollution in Tributaries Entering Great Bay. Final Report to the NH Office of State Planning, NH Coastal Program.

Lachat Instruments. 1991. Operating manual for the Quick Chem Autoanalyzer Lachat Instruments. Milwaukee, Wisconsin.

Langan, R. 1992 a. UNH JEL Standard operating procedure for water sampling for suspended solids, chlorophyll, and nutrients. JEL SOP 1.05. In: Standard operating procedures and field methods used for conducting ecological risk assessment case studies. Mueller et al. eds. 1992. USEPA, US Navy (NRaD) Technical Document 2296.

Langan, R. 1992 b. UNH JEL Standard operating procedure for water sample filtration and analysis of total suspended solids, chlorophyll and phaeopigments. JEL SOP 1.06. In: Standard operating procedures and field methods used for conducting ecological risk assessment case studies. Mueller et al. eds. 1992. USEPA, US Navy (NRaD) Technical Document 2296.

Langan, R. and S.H. Jones. 1995. A Monitoring Plan for the Great Bay Estuarine Research Reserve: Final Report for 1994. NOAA Technical Memorandum, NOS MEMD# NA170RO182-03.

Strickland, J.D.H. and T.R. Parsons. 1968. A Practical Handbook of Seawater Analysis. Fisheries Research Board Of Canada, Ottawa,1968.Strickland, J.D.H. and T.R. Parsons. 1968. A Practical Handbook of Seawater Analysis. Fisheries Research Board Of Canada, Ottawa,1968.

Table 1. Rainfall at Durham, NH gauging station on day prior to sampling and cumulative of two days on day of sampling in different areas.

	Rainfall (inches)			
Date	Day of (cumulative)	24 h previous	Total rainfall for month	Sampling area(s)
7/19/94	0	0	July=2.20	SR tribs
8/2/94	0	0	Aug.=4.05	SR tribs
8/16/94	0	0		SR tribs
9/12/94	0	0	Sept=7.26	SR tribs
9/27/94	0.14	0		SR1
10/6/94	0	0	Oct.=0.19	SR1
10/11/94	0	0		GB7-13
10/12/94	0	0		SR1
10/18/94	0	0		SR1
10/20/94	0.06	0.02		SR tribs
10/25/94	0	0	Nov.=2.88	GB7-13
11/8/94	0.09	0.09		ER
11/15/94	0	0		ER & SR tribs
12/6/94	1.16	1.12	Dec.=5.55	ER
3/22/95	0.31	0.12	Mar.=1.87	ER
4/4/95	0.37	0	Apr.=1.85	ER
4/19/95	0.31	0		SR tribs
4/26/95	0	0		ER & SR tribs
4/28/95	0	0		SR trib mouths
5/25/95	0.43	0.04	May =2.74	SR tribs
6/1/95	0	0	June=1.92	SR tribs
6/7/95	0.3	0		SR tribs & mouths
6/16/95	0.29	0.24		trib flow rates

Table 2. Concentrations (per 100 ml) of bacterial indicators at sites from Chapman's Landing (GB7) to just above the Exeter POTW (GB13).

Fecal coliforms

Sites	GB 7	GB8	GB9	GB10	GB11	GB12	GB13
10/11/94	9	26	43	68	63	81	70
10/25/94	37	370	640	785	645	405	620
Geo. Mean	**18**	**99**	**165**	**231**	**202**	**181**	**208**

E. coli

Sites	GB 7	GB8	GB9	GB10	GB11	GB12	GB13
10/11/94	9	24	41	30	64	78	52
10/25/94	21	220	335	465	240	200	280
Geo. Mean	**14**	**72**	**118**	**118**	**124**	**125**	**121**

Enterococci

Sites	GB 7	GB8	GB9	GB10	GB11	GB12	GB13
10/11/94	10	11	15	21	29	31	28
10/25/94	25	47	64	39	42	54	40
Geo. Mean	**16**	**23**	**31**	**28**	**35**	**41**	**33**

C. perfringens

Sites	GB 7	GB8	GB9	GB10	GB11	GB12	GB13
10/11/94	7.0	9.0	13	19	22	13	20
10/25/94	0.5	5.0	4.5	3.5	1.5	0.5	0.5
Geo. Mean	**1.9**	**6.7**	**7.7**	**8.2**	**5.7**	**2.5**	**3.2**

Table 3. Concentrations of nutrients at sites
from Chapman's Landing (GB7) to just above the Exeter POTW (GB13).

Ammonium (μm)

Sites	GB 7	GB8	GB9	GB10	GB11	GB12	GB13
10/11/94	4.89	4.59	2.55	1.24	0.80	1.47	
10/25/94	7.76	6.93	8.41	11.00	9.31	9.93	9.68
Average	**6.32**	**5.76**	**5.48**	**6.12**	**5.05**	**5.70**	**9.68**

Nitrate (μm)

Sites	GB 7	GB8	GB9	GB10	GB11	GB12	GB13
10/11/94	17.48	27.27	21.78	31.27	29.12	21.39	
10/25/94	24.99	18.86	24.88	20.61	24.11	38.42	36.87
Average	**21.24**	**23.06**	**23.33**	**25.94**	**26.61**	**29.91**	**36.87**

Phosphate (μm)

Sites	GB 7	GB8	GB9	GB10	GB11	GB12	GB13
10/11/94	2.98	2.96	3.09	2.84	2.93	2.18	
10/25/94	2.69	3.15	3.34	3.25	3.19	3.99	3.32
Average	**2.83**	**3.06**	**3.21**	**3.05**	**3.06**	**3.08**	**3.32**

Table 4. Bacterial indicator concentrations (per 100 ml) at sites in the Exeter River and its tributaries.

FECAL COLIFORMS

DATE	9-EXT	9-EXT*	ER-1	ER-2	ER-2'	ER-3	ER-4	ER-5	ER-6	ER-7	14-EXT	14-EXT*
11/8/94	57.5	wet/dry	208	97.5	65	1	113	40	20		22.5	wet/dry
11/15/94	32.5	condition	95	62.5	77.5	0.75	47.5	35	27.5		8.5	condition
12/6/94	357	levels	723	585		61	893	950	870		169	levels
3/22/95		from	65	15		0.4	25	25	50	15		from
4/4/95	290	other	10	20.5		3	37	22	22	17		other
4/26/95		study	16.5	10		1	24	11	37	8		study
Geo. mean	**118**	**149/31**	**73**	**47**	**71**	**2**	**69**	**45**	**52**	**13**	**32**	**42/16**

E. COLI

DATE	9-EXT	9-EXT*	ER-1	ER-2	ER-2'	ER-3	ER-4	ER-5	ER-6	ER-7	14-EXT	14-EXT*
11/8/94	40	wet/dry	208	82.5	47.5	1	113	35	20		22.5	wet/dry
11/15/94	32.5	condition	95	62.5	67.5	0.75	47.5	35	27.5		8.5	condition
12/6/94	320	levels	710	585		61	833	905	870		169	levels
3/22/95		from	25	12.5		0.45	25	25	37.5	10		from
4/4/95	97.5	other	5	16		0.8	33.5	22	18	15		other
4/26/95		study	15	8		1	23	9	36	7		study
Geo. mean	**80**	**111/24**	**55**	**41**	**57**	**2**	**66**	**42**	**48**	**10**	**32**	**33/9**

ENTEROCOCCI

DATE	9-EXT	9-EXT*	ER-1	ER-2	ER-2'	ER-3	ER-4	ER-5	ER-6	ER-7	14-EXT	14-EXT*
11/8/94	11.3	wet/dry	25	14	66	30.5	30	6.3	8.8		5	wet/dry
11/15/94	3	condition	21.3	48	16	34	56.3	24	21.5		14	condition
12/6/94	78	levels	296	254		223	205	192	468		418	levels
3/22/95		from	35	39		10	30	55	21	47.5		from
4/4/95		other	175	51.25		30	2.5	3	4	211.25		other
4/26/95		study	2.5	2		1	8.75	2.75	2	2.5		study
Geo. mean	**14**	**41/14**	**37**	**30**	**32**	**20**	**25**	**15**	**16**	**29**	**31**	**22/11**

C. PERFRINGENS

DATE	9-EXT	9-EXT*	ER-1	ER-2	ER-2'	ER-3	ER-4	ER-5	ER-6	ER-7	14-EXT	14-EXT*
11/8/94	8.5	wet/dry	11	<0.5	<0.5	14.5	19.5	1.5	2.5		1.5	wet/dry
11/15/94	10	condition	8.5	23.5	12	5	31	5	1.25		3.25	condition
12/6/94	41	levels	62.5	44.8		45.5	36.5	45	37.3		45.5	levels
3/22/95		from	0.45	0.5		0.45	0.45	0.2	0.5	0.45		from
4/4/95	10	other	20	13		15	10	10	6	45.5		other
4/26/95		study	5			8	7.5	5	2	12		study
Geo. mean	**14**	**NA**	**8**	**9**	**12**	**8**	**10**	**4**	**3**	**6**	**6**	**NA**

* Fecal coliforms, E. coli and enterococci also measured at 9&14 EXT as part of Jones and Langan (1995) study.

Table 5. Dissolved inorganic nutrient concentrations at sites in the Exeter River and its tributaries.

NH4 µM

DATE	9-EXT	9-EXT*	ER-1	ER-2	ER-3	ER-4	ER-5	ER-6	ER-7	14-EXT	14-EXT*
12/6/94	5.12	wet/dry	2.77	2.08	2.55	5.36	3.47	5.91		49.01	wet/dry
3/22/95		levels;	2.47	1.05	1.62	2.96	1.76	1.44	2.21		levels;
4/4/95	1.26	other	2.81	1.69	2.01	1.51	5.04	1.30	3.24		other
4/26/95		study	2.77	2.70	2.25	3.01	2.76	2.20	2.28		study
Average	**3.19**	**3.5/3.5**	**2.71**	**1.88**	**2.11**	**3.21**	**3.26**	**2.71**	**2.57**	**49.01**	**5.6/3.5**

NO3 µM

DATE	9-EXT	9-EXT*	ER-1	ER-2	ER-3	ER-4	ER-5	ER-6	ER-7	14-EXT	14-EXT*
12/6/95	19.94	wet/dry	6.32	10.57	11.61	14.89	9.73	15.86		33.13	wet/dry
3/22/95		levels;	2.88	1.05	7.10	4.33	4.95	5.32	3.92		levels;
4/4/95	5.70	other	6.85	5.70	14.38	7.51	4.89	6.98	20.96		other
4/26/95		study	5.71	0.86	3.23	3.01	6.24	4.36	6.06		study
Average	**12.82**	**6.3/4.2**	**5.44**	**4.54**	**9.08**	**7.44**	**6.45**	**8.13**	**10.31**	**33.13**	**6.3/4.2**

PO4 µM

DATE	9-EXT	9-EXT*	ER-1	ER-2	ER-3	ER-4	ER-5	ER-6	ER-7	14-EXT	14-EXT*
12/6/95	0.517	wet/dry	0.360	0.463	0.247	0.317	0.282	0.290		0.463	wet/dry
3/22/95		levels;	0.266	0.255	0.319	0.192	0.168	0.164	0.217		levels;
4/4/95	0.116	other	0.228	0.244	0.174	0.109	0.106	0.074	0.266		other
4/26/95		study	0.394	0.304	0.236	0.111	0.101	0.076	0.332		study
Average	**0.316**	**.31/.24**	**0.312**	**0.316**	**0.244**	**0.182**	**0.164**	**0.151**	**0.272**	**0.463**	**.16/.16**

Table 6. Concentrations (per 100 ml) of bacterial indicators at sites in tributaries to the Squamscott River.

Enteroccocci

Site	1	3	4	5	6	9	10	11	14	19	20	21	22	24	25	GB 7
7/19/94	109	231		148	660	1300			43		510		294			34
8/2/94	135	248		258	1100	6400		0	15		925		185			9
8/16/94	288			2015	610	7500			231		7400		485			
9/12/94		0		1100	210	1900		0	0		0		0			3
10/20/94	137	3		0	18	26		33	8		10		10			7
11/15/94	19	15		35	34	175		15	5		0		95			8
4/19/95	10	4		2	29	11		11			26		6			
4/26/95	2	17		2	4	3		8	5		3		10			
5/25/95	75	90	288	81	149	408	690		40	88	250	250	54	49	1390	
6/1/95	5	430		25	430	740	180	50	15	14	75	50		6	200	13
6/7/95	265	880		840	2350	3760	2540	88	140	612	1545	220	400	192	2960	59
Geo. Mean	**43**	**35**	**288**	**50**	**150**	**368**	**681**	**9**	**16**	**91**	**54**	**140**	**41**	**38**	**937**	**12**

C. Perfringens

Site	1	3	4	5	6	9	10	11	14	19	20	21	22	24	25	GB 7
7/19/94	0	9		31	0	193		0	5		12		2			12
8/2/94	16	6		22	40	1235		39	3		0		1			4
8/16/94	7	2		60	0	300		15	17		0		0			7
9/12/94		15		105	7	673		79	7		7		4			18
10/20/94	5	14		6	8	15		66	7		9		7			11
11/15/94	6	4		49	1	10		2	0		0		0			2
4/19/95	22	8		6	6	16		137	17		21		14			
4/26/95	3	3		4	2	3		98	4		2		4			
Geo. Mean	**5**	**6**		**20**	**3**	**65**		**20**	**5**		**2**		**2**			**7**

Table 6. Concentrations (per 100 ml) of bacterial indicators at sites in tributaries to the Squamscott River.

Fecal Coliforms

Site	1	3	4	5	6	9	10	11	14	19	20	21	22	24	25	GB 7
7/19/94	98	38		114	233	1300		303	93		685		456			33
8/2/94	123	18		165	110	7100		110	91		2490		75			25
8/16/94	50	0		300	103	400		65	268		1100		18			16
9/12/94		0		93	53	2100		65	105		355		9			38
10/20/94	34	43		8	74	0		230	124		20		28			28
11/15/94	80	61		9	11	545		30	28		15		40			37
4/19/95	26	166		31	9	27		72	116		20		56			
4/26/95	8	143		11	12	5		43	68		6		4			
5/25/95	19	1740	140	69	49				83	26			83			
6/1/95	5	1100		18	63	1150	300	335	110	9	15	50	10	70	600	41
6/7/95	165	540		280	235	6480	2100	220	140	283	1700	900	130	350	6100	98
Geo. Mean	**37**	**51**	**140**	**49**	**53**	**265**	**794**	**108**	**98**	**40**	**120**	**212**	**36**	**157**	**1913**	**35**

E. coli

Site	1	3	4	5	6	9	10	11	14	19	20	21	22	24	25	GB 7
7/19/94	85	27		105	161	4300		247	80		669		416			30
8/2/94	120	14		163	95	7100		105	86		2310		75			25
8/16/94	50	0		243	88	400		63	223		800		20			15
9/12/94		0		23	35	2100		18	53		145		23			4
10/20/94	32	43		2	32	0		190	108		20		27			26
11/15/94	80	57		8	11	540		28	28		15		40			37
4/19/95	16	159		30	6	27		45	75		20		55			
4/26/95	3	118		10	6	5		40	50		3		4			
5/25/95	19	1153	28	69	49				60	25			65			
6/1/95	0	1100		18	63	1040	250	190	70	6	5	0	10	30	100	15
6/7/95	165	540		270	225	6220	1900	220	110	259	1565	610	130	350	5740	84
Geo. Mean	**24**	**46**	**28**	**36**	**40**	**294**	**689**	**80**	**75**	**34**	**87**	**16**	**39**	**102**	**758**	**22**

Table 7. Concentrations of nutrients at sites in tributaries to the Squamscott River.

Ammonium (µm)

Site	1	3	4	5	6	9	10	11	14	19	20	21	22	24	25	GB 7
7/19/94	4.16	68.90		4.99	7.06	5.51		15.33	4.80		4.26		4.43			9.57
8/2/94	4.36	0.44		7.42	5.73	7.77		0.20	4.86		6.11		4.75			2.59
8/16/94	12.15	1.21		5.19	5.90	5.49		3.74	4.88		5.01		1.81			2.08
9/12/94	1.32	4.89		1.49	1.28	1.60		0.86	0.76		1.51		1.71			2.72
10/20/94	1.01	29.64		0.19	0.75	0.22		13.87	0.91		19.82		0.06			6.89
11/15/94	0.80	5.66		0.97	1.97	1.91		5.07	3.22		1.62		1.55			3.25
4/19/95	9.68	5.08		3.55	2.62	1.39		14.34	1.75		1.48		1.64			
4/26/95	1.81	7.57		1.77	2.29	1.98		9.33	3.84		1.58		2.00			
5/25/95	2.04	14.38	2.31	1.91	1.53	1.94	3.26		17.20	50.37	30.21	1.19	1.49	2.46	4.60	
6/1/95	1.41	7.50		1.69	7.81	4.65	4.23	5.88	14.01	43.68	1.75	1.94	3.64	4.51	5.66	8.47
6/7/95	10.93	25.84		1.60	3.21	13.17	8.42	17.92	130.94	35.35	18.89	50.74	5.86	24.17	28.33	
Average	**4.52**	**15.55**	**2.31**	**2.80**	**3.65**	**4.15**	**5.30**	**8.65**	**17.02**	**43.13**	**8.39**	**17.96**	**2.63**	**10.38**	**12.86**	**5.08**

Nitrate (µm)

Site	1	3	4	5	6	9	10	11	14	19	20	21	22	24	25	GB 7
7/19/94	215.93	8.03		50.38	56.05	206.13		4.87	0.28		9.79		4.36			3.62
8/2/94	235.36	0.30		48.09	61.17	35.98		1.54	0.00		12.77		5.81			0.40
8/16/94	228.17	2.74		41.24	75.72	220.78		1.35	0.14		9.18		5.91			1.31
9/12/94	244.21	4.09		48.03	69.61	122.92		1.71	0.51		10.23		4.11			1.98
10/20/94	231.71	14.40		69.46	25.78	146.14		22.08	8.91		8.29		6.02			20.03
11/15/94	259.11	10.74		75.45	35.09	162.34		20.34	4.59		7.23		8.17			4.76
4/19/95	179.01	12.43		37.84	25.72	95.29		7.65	3.66		16.30		5.32			
4/26/95	201.67	14.04		29.85	18.67	90.95		7.62	4.88		9.60		4.80			
5/25/95	222.26	19.91	6.38	14.79	10.13	59.89	4.37		5.58	2.50	5.31	1.14	2.48	4.05	14.20	
6/1/95	248.48	6.61		27.33	23.20	135.31	13.36	7.96	6.75	3.93	15.16	5.91	4.95	12.55	33.54	6.32
6/7/95	200.11	10.07		18.23	18.50	59.80	10.27	12.23	5.58	2.70	1.68	6.74	6.42	10.45	27.49	
Average	**224.18**	**9.40**	**6.38**	**41.88**	**38.15**	**121.41**	**9.34**	**8.73**	**3.72**	**3.04**	**9.59**	**4.60**	**5.30**	**9.02**	**25.08**	**5.49**

Table 7. Concentrations of nutrients at sites in tributaries to the Squamscott River.

Phosphate (µm)

Site	1	3	4	5	6	9	10	11	14	19	20	21	22	24	25	GB 7
7/19/94	0.27	0.35		0.28	0.39	0.45		3.59	0.32		0.63		0.23			1.19
8/2/94	0.26	0.17		0.18	0.31	0.26		0.03	0.38		0.86		0.28			0.22
8/16/94	0.15	0.02		0.11	0.17	0.15		2.54	0.10		0.65		0.03			0.97
9/12/94	0.32	1.22		0.28	0.24	0.28		0.78	0.19		0.84		0.23			2.26
10/20/94	0.37	0.72		0.17	0.15	0.14		3.98	0.35		0.48		0.25			2.61
11/15/94	0.30	1.46		0.17	0.17	0.07		1.63	0.38		0.59		0.39			1.23
4/19/95	0.16	0.17		0.03	0.07	0.08		0.33	1.16		0.08		0.09			0.08
4/26/95	0.24	0.48		0.10	0.10	0.38		0.87	0.15		0.19		0.14			
5/25/95	0.47	0.73	0.95	0.26	0.22	0.56	0.78		0.38	0.41	0.50	0.47	0.47	0.24	0.46	
6/1/95	0.37	0.71		0.37	0.33	0.70	0.69	1.55	0.50	0.45	0.53	0.64	0.68	0.42	0.60	1.48
6/7/95	0.50	0.77		0.38	0.39	0.69	0.71	1.68	0.50	0.38	0.48	0.54	0.49	0.31	0.57	
Average	**0.31**	**0.62**	**0.95**	**0.21**	**0.23**	**0.34**	**0.72**	**1.70**	**0.40**	**0.41**	**0.53**	**0.55**	**0.30**	**0.32**	**0.54**	**1.26**

Table 8. Concentrations (per 100 ml) of bacterial indicators in the Squamscott River at the mouths of small tributaries.

Fecal coliforms

Sites	M1	M5	M4	M3	M24	M22	M8	M9	M21	M20	M10	M19	SR17	M16	M25
4/28/95	15	16	45	28	40	35	48	40	83	43	78	64		98	
6/7/95	366	386	98	510		745		588	370	885		850	2	1235	4310
Geo. mean	**74**	**79**	**66**	**118**	**40**	**161**	**48**	**153**	**175**	**195**	**78**	**233**	**2**	**348**	**4310**

E. coli

Sites	M1	M5	M4	M3	M24	M22	M8	M9	M21	M20	M10	M19	SR17	M16	M25
4/28/95	13	10	30	23	35	5	22	28	68	29	48	33		58	
6/7/95	344	350	84	480		610		570	325	868		825	2	1170	4215
Geo. mean	**66**	**59**	**50**	**104**	**35**	**55**	**22**	**126**	**149**	**159**	**48**	**166**	**2**	**260**	**4215**

Enterococci

Sites	M1	M5	M4	M3	M24	M22	M8	M9	M21	M20	M10	M19	SR17	M16	M25
4/28/95	4	14	8	4	32	5	8	6	13	20	14	19		18	
6/7/95	158	306	59	307		400		386	454	600		296	1	746	1615
Geo. mean	**24**	**64**	**22**	**35**	**32**	**42**	**8**	**48**	**77**	**108**	**14**	**74**	**1**	**114**	**1615**

C. perfringens

Sites	M1	M5	M4	M3	M24	M22	M8	M9	M21	M20	M10	M19	SR17	M16	M25
4/28/95		23	24	22	76	109	122	45	94	64	71	89		42	
6/7/95															
Geo. mean		**23**	**24**	**22**	**76**	**109**	**122**	**45**	**94**	**64**	**71**	**89**		**42**	

Table 9. Concentrations of nutrients in the Squamscott River at the mouths of small tributaries.

Ammonium (µm)

Sites	M1	M3	M4	M5	M8	M9	M10	M16	SR17	M19	M20	M21	M22	M24	M25
4/28/95	8.85	18.60	10.41	9.72	6.61	5.11	6.40			5.77	6.11	6.41	6.24	7.20	

Nitrate (µm)

Sites	M1	M3	M4	M5	M8	M9	M10	M16	SR17	M19	M20	M21	M22	M24	M25
4/28/95	5.39	8.36	9.55	9.33	8.37	6.67	7.25			5.24	5.89	6.92	8.57	9.98	

Phosphate (µm)

Sites	M1	M3	M4	M5	M8	M9	M10	M16	SR17	M19	M20	M21	M22	M24	M25
M	0.926	1.066	0.803	0.777	1.120	1.107	1.127			1.101	1.285	1.123	1.137	1.012	

Table 10. Concentrations (per 100 ml) of bacterial indicators along a small tributary in Newmarket and Newfields going downstream to the Squamscott River.

Fecal coliforms

Site	1.1	1.2	1.3	1.4	1.5	1.6
9/27/94	50	55	185	300	500	
10/6/94	13	33	45	100	55	25
10/12/94			45	50	23	33
10/18/94	76	3140	81	86	96	75
Geo. Mean	**36**	**177**	**74**	**107**	**88**	**40**

E. coli

Site	1.1	1.2	1.3	1.4	1.5	1.6
9/27/94	46	53	180	270	305	
10/6/94	8	28	45	90	50	20
10/12/94			40	50	23	31
10/18/94	72	2960	71	75	85	36
Geo. Mean	**29**	**163**	**69**	**98**	**74**	**28**

Enterococci

Site	1.1	1.2	1.3	1.4	1.5	1.6
9/27/94			70	40	105	
10/6/94	28	40	28	23	50	25
10/12/94			18	12	14	19
10/18/94	104	1245	74	92	80	101
Geo. Mean	**54**	**223**	**40**	**31**	**49**	**36**

C. perfringens

Site	1.1	1.2	1.3	1.4	1.5	1.6
9/27/94	7	10	15	15	25	
10/6/94	6	15	13	17	11	10
10/12/94			5	9	12	13
10/18/94	4	54	5	9	13	11
Geo. Mean	**5**	**20**	**8**	**12**	**14**	**11**

Table 11. Concentrations of nutrients along a small tributary in Newmarket and Newfields going downstream to the Squamscott River.

Ammonium (µm)

Site	1.1	1.2	1.3	1.4	1.5	1.6
9/27/94	0.54	2.29	3.84	3.19	5.90	4.42
10/6/94	3.18	2.17	2.66	4.47	9.72	11.57
10/12/94	1.98	2.35	1.89	3.17	5.68	6.64
10/18/94	1.42	0.64	3.47	1.99	6.63	6.28
Average	**1.78**	**1.86**	**2.96**	**3.21**	**6.98**	**7.23**

Nitrate (µm)

Site	1.1	1.2	1.3	1.4	1.5	1.6
9/27/94	183.4	49.9	122.3	119.4	97.4	117.9
10/6/94	216.5	53.6	165.5	161.2	76.3	14.3
10/12/94	220.6	56.8	182.9	172.9	137.4	145.6
10/18/94	237.6	63.5	183.4	180.5	125.4	122.6
Average	**214.5**	**55.9**	**163.5**	**158.5**	**109.1**	**100.1**

Phosphate (µm)

Site	1.1	1.2	1.3	1.4	1.5	1.6
9/27/94	0.455	0.400	0.661	0.752	1.157	1.048
10/6/94	0.318	0.238	0.469	0.568	1.271	1.811
10/12/94	0.326	0.215	0.449	0.496	0.856	1.125
10/18/94	0.297	0.210	0.376	0.462	1.005	1.442
Average	**0.349**	**0.266**	**0.489**	**0.570**	**1.072**	**1.356**

Table 12. Total suspended solids (mg/L) at all sample sites in the Exeter/Squamscott watershed: 1994-95

Total Suspended Solids (mg/L) in tributaries to the Squamscott River

DATE	SR-1	SR-3	SR-4	SR-5	SR-6	SR-9	SR-10	SR-11	SR-14	SR-19	SR-20	SR-21	SR-22	SR-24	SR-25	GB7
7/19/94	16.40	13.20		2.00	1.20	3.80		149.00	1.20		7.20					17.40
8/2/94	3.00	51.00		3.60	9.40	97.20		55.33	2.20		4.40		0.40			49.00
8/16/94	1.80	52.00		4.20	0.20	3.40		44.50	1.00		2.80		0.40			18.60
10/20/94	1.20	13.20		3.20	1.00	0.80		18.60	1.80		1.60		3.00			13.80
11/15/94	0.40	25.20		2.00	0.40	0.40		45.00	2.20		0.80		1.80			37.60
4/19/95	3.60	24.20		1.80	3.80	4.00		31.14	2.60		13.60		3.80			
4/26/95	1.00	6.20		1.40	0.80	5.80		33.70	1.60		2.20		3.20			
5/25/95	4.80	11.20	12.75	2.60	2.80	4.60	13.40		2.60	4.60	16.60	12.60	4.00	32.80	6.20	
6/1/95	2.60	8.20		1.60	1.40	2.20	3.60	32.20	1.40	5.40	5.60	15.00	2.00	3.80	3.20	12.60
6/7/95	5.40	11.60		5.40	15.60	12.60	27.80	31.00	3.40	22.20	10.80	8.80	5.60	5.60	10.00	
Mean	**4.02**	**21.60**	**12.75**	**2.78**	**3.66**	**13.48**	**14.93**	**48.94**	**2.00**	**10.73**	**6.56**	**12.13**	**2.69**	**14.07**	**6.47**	**24.83**

Total Suspended Solids (mg/L) on the Exeter River and tributaries

DATE	ER1	ER2	ER3	ER4	ER5	ER6	ER7	EXT9	ER14
11/16/94	2.80	4.22	4.67	2.30	4.30	5.20		5.10	3.10
12/6/94	5.89	4.20	7.70	8.30	5.11	4.56		18.00	4.44
3/22/95	2.60	2.60	7.00	2.20	3.40	2.00	5.20		
4/4/95	3.00	2.00	20.17	1.44	2.00	1.33	3.67	1.56	
4/26/95	2.40	4.40	26.60	2.80	1.80	2.20	3.20		
Mean	**3.34**	**3.48**	**13.23**	**3.41**	**3.32**	**3.06**	**4.02**	**8.22**	**3.77**

Table 12. Total suspended solids (mg/L) at all sample sites in the Exeter/Squamscott watershed: 1994-95

TSS in a transect from Chapmans Landing to the Exeter POTW

DATE	GB7	GB8	GB9	GB10	GB11	GB12	GB13
10/11/94	20.40	17.60	18.00	23.00	21.33	20.00	
10/25/94	16.20	11.40	11.60	11.40	10.00	9.60	12.80
Mean	**18.30**	**14.50**	**14.80**	**17.20**	**15.67**	**14.80**	**6.40**

TSS at the mouths of tributaries Entering the Squamscott River

DATE	SRM1	SRM3	SRM4	SRM5	SRM8	SRM9	SRM10	SRM19	SRM20	SRM21	SRM22	SRM24
4/28/95	87.33	60.67	76.00	137.50	47.00	47.60	61.00	36.00	36.33	34.80	123.00	37.20

TSS concentration along a small tributary in Newmarket and Newfields going downstream to the Squamscott River

DATE	SR1-1	SR1-2	SR1-3	SR1-4	SR1-5	SR1-6
9/27/94	0.80	0.20	12.80	15.20	26.60	32.33
10/6/94	1.62	3.50	5.40	5.80	17.80	24.60
10/12/94	1.20	0.40	4.40	8.20	22.80	45.00
10/18/94	2.60	1.40	4.40	4.20	11.80	22.60
Mean	**1.56**	**1.38**	**6.75**	**8.35**	**19.75**	**31.13**

Table 13. All suspected sources of suspended solids loading to the Squamscott River watershed.

Road Construction Within the Squamscott Watershed 1988-94.			
Town	**Road**	**Year**	**Map #**
Stratham	Peninsula Drive/Winding Brook	Started 1985, done in phases until fall 1994	3
Stratham	Parsonage Hill Development/Turnberry	Started 1990 to present	3
Stratham	Linda Lane	Started spring 1990, finished 1992	5
Stratham	Morning Star Drive/Tucker's Trail	Started spring 1992, finished summer 1992	5
Stratham	Greta' Way	Started summer 1993, finished summer 1994	1
Stratham	Boat Club Drive (end of River Rd)	Started July 1994 to present	1
Exeter	Captain' Meadows roads	Started 1988, finished Oct. 1993	06-01
Exeter	High Street, downtown area	Started and finished 1990	
Exeter	Glenerin Ln.	Started spring 1991, finished fall 1992	
Exeter	Prentice Way	Started 1985, sporadic until done in 1991	
Exeter	Henderson Swasey Forest road	Built 1993-logging road	06-03
Exeter	Oaklands Forest road	Built December 1993-logging road	06-03
Newfields			
Logging Areas Within the Watershed			
Town	**Forest Name/Owner**	**Map**	
Exeter	Henderson-Swasey/town owned	06-03	
Exeter	Oaklands/town owned	06-03	
Exeter	Privately owned	06-03	
Farms Within the Watershed			
Town	**Farm Type/Owner**	**Map/RPC Farm #**	
Stratham	Stuart Cow Farm/John Merrill	Map 3	
Stratham	Bittersweet Dairy Farm/Doug Scammen	Map 1	
Stratham	Small fruit	RPC 2	
Stratham	Veggies	RPC 3	
Stratham	Veggies	RPC 5	
Stratham	Small fruit	RPC 7	
Stratham	Equestrian	RPC 9	
Exeter	Greenhouse/Nursery	RPC 6	
Exeter	Greenhouse/Nursery	RPC 12	
Newfields	Tree farm/small fruit/ Hayden	RPC 1/Map 201	
Newfields	Corn/Hayden	Map 201	
Newfields	Grains and veggies/Goldsmith	Map 203	
Newfields	Grains and veggies/Finn	Map 204	

Town	**Storage location**		
Stratham	Leave in piles where removed		
Exeter	Next to lagoons at WWTP		
Newfields	No snow removal		
Salt storage sites			
Stratham	Public works, Bunker Hill Ave		
Exeter	Public works at WWTP-covered		
Newfields	Next to WWTP-Harvey Rd. -covered		
State	Route 108 in Newfields-covered		
Salt /sand applications			
Town	**Roads affected**	**Rate of application**	
Stratham	All roads in watershed except Squamscott	200 tons salt:264 tons sand for 94 and 95	
	and Rt101/108	333 tons salt:200 tons sand for 88-93	
Exeter	All roads except Newfields Rd and Rt 101	4000 tons salt/yr, 8 tons sand:1 ton salt 88-94	
Newfields	All roads except Rt 85		
State maintained			
Stratham	Squamscott Rd and Rt 101/108	12.8 tons salt /lane mile for 95	
		24.2 tons salt/lane mile 88-94	
		24 yds. sand:6 yds salt (1yd3 sand=2 tons)	
Exeter	Newfields Rd/Rt 101	same as above	
Newfields	Route 85 (Newfields Rd)	same as above	
Contaminated sites			
Town	**Site Name**	**Site address,Town map/lot**	**Description/RPC Reference #**
Stratham	Labbe's Beauty Salon	255 Portsmouth Ave, Map14/1-1	Underground Injection Control (UIC)/1
Stratham	Stratham Condos	Route 108, Map 3/11	Malfunctioning septic system/5
Stratham	Stratham Highway Garage	Bunker Hill Ave., Map 1/19	Leaking underground storage tank (LUST)/6
Stratham	Gil's Jeep Eagle Peugeot	50 Portsmouth Ave., Map 9/20	Non-hazardous holding tank permit/7
Stratham	Sullivan Tire	33 Portsmouth Road, Map 9/1	Non-hazardous holding tank/8
Stratham	Saef Lincoln Mercury/Goss	Portsmouth Ave, Map 7/12	LUST/9
Stratham	Antique Repair Company	23 Portsmouth Ave, Map 1/6	Hazardous waste/10
Stratham	King's Highway Plaza	Portsmouth Ave, Map 7/13	LUST/11
Stratham	Labonte Sunoco	Portsmouth Ave, Map 1/5-2	LUST/12
Stratham	Charter Gas Station	Portsmouth Ave, Map 7/7	LUST/14
Exeter	Brockhouse Corp.	Epping Rd, Map 5-4/18-24	UIC/13

Exeter	Dreher-Holloway	156 Epping Rd, Map 5-4/14	LUST/15		
Exeter	Adams Russell Inc	Lot 1 Exeter Ind. Park, Map 05-04/018.028	Hazardous waste/16		
Exeter	Exeter Ind. Park	Industrial Park Rd, Map 05-041/19.1,19.3	Hazardous waste/17		
Exeter	Texaco Service Station	84 Portsmouth Ave, Map 9-2/6	LUST/21		
Exeter	Globe Shopping Ctr	Portsmouth Ave, Map 09-02/10	LUST/22		
Exeter	Mobil	54 Portsmouth Ave, Map 09-01/9	LUST/23		
Exeter	Exeter Gas Works	277 Water St, Map 09-09/04-05	Oil spill or release (1992)/25		
Exeter	Petrol storage	42 Portsmouth Ave, Map 9,10/7-14	Hazardous waste/26		
Exeter	Exeter Hospital	10 Buzell Ave, Map 9-11/2	LUST/27		
Newfields	Stratham Veterinary Clinic	Route 108, Map 201/24	UIC/2		
Newfields	Newfields Country Store	66 Main Street, Map 102/16	LUST/4		

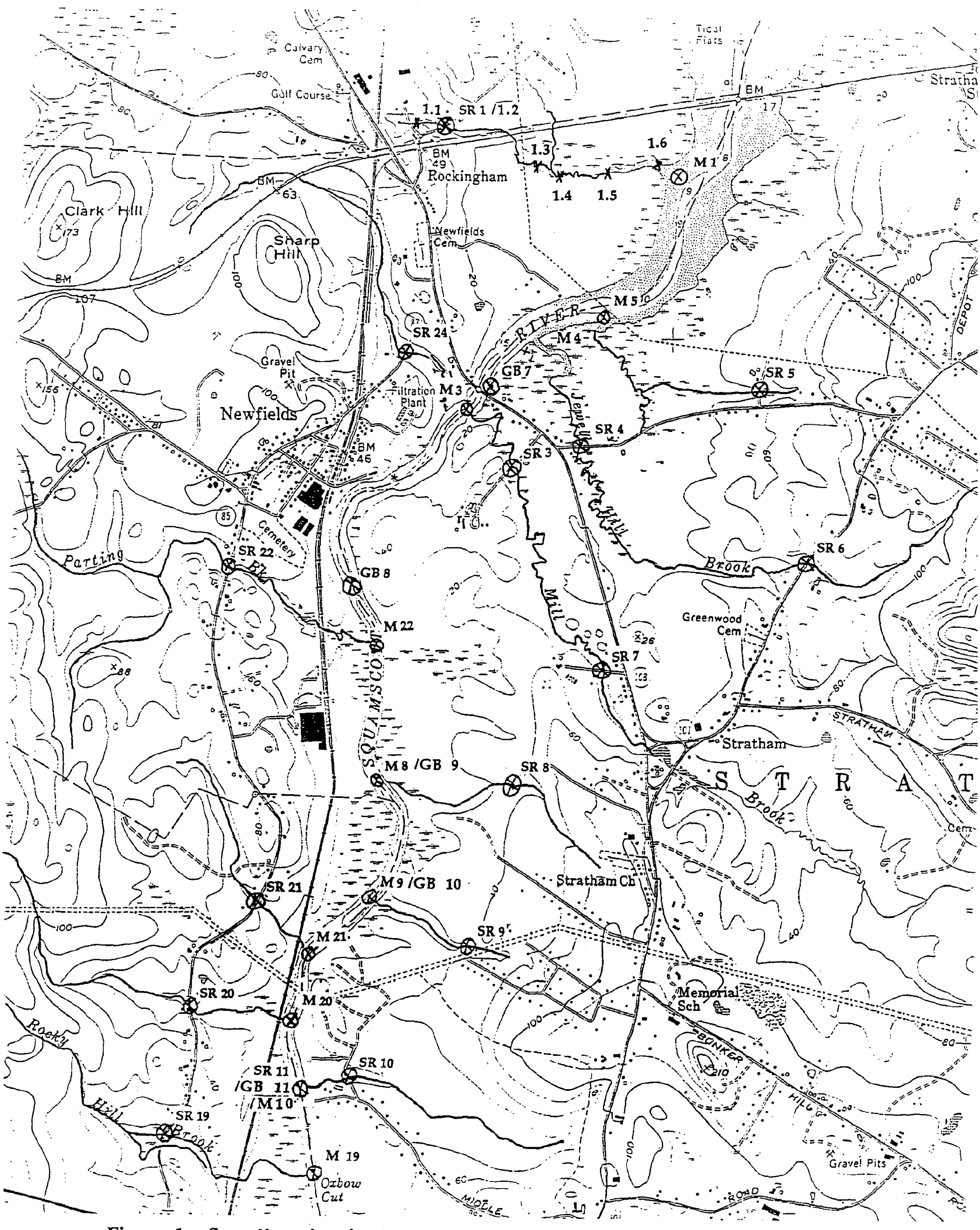


Figure 1. Sampling sites in the northern portion of the study area.

Figure 2. Sampling sites in the southern portion of the study area.

Figure 3. Geometric mean bacterial indicator levels in the Squamscott River going upstream from Chapmans Landing to the Exeter POTW: 1994-95.

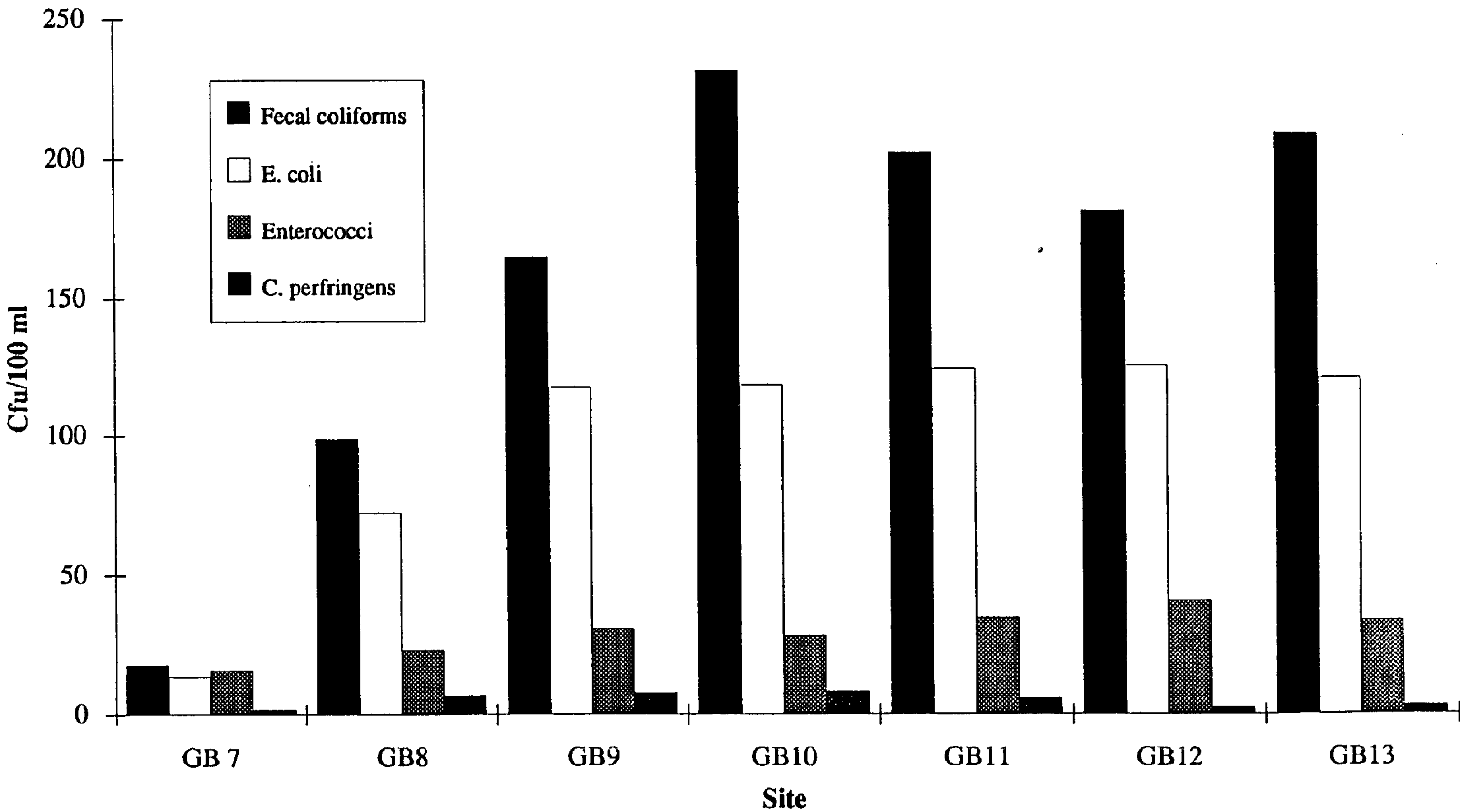


Figure 4. Mean amonium, nitrate and orthophosphate concentrations in the Squamscott River going upstream from Chapmans Landing to the Exeter POTW: 1994-1995

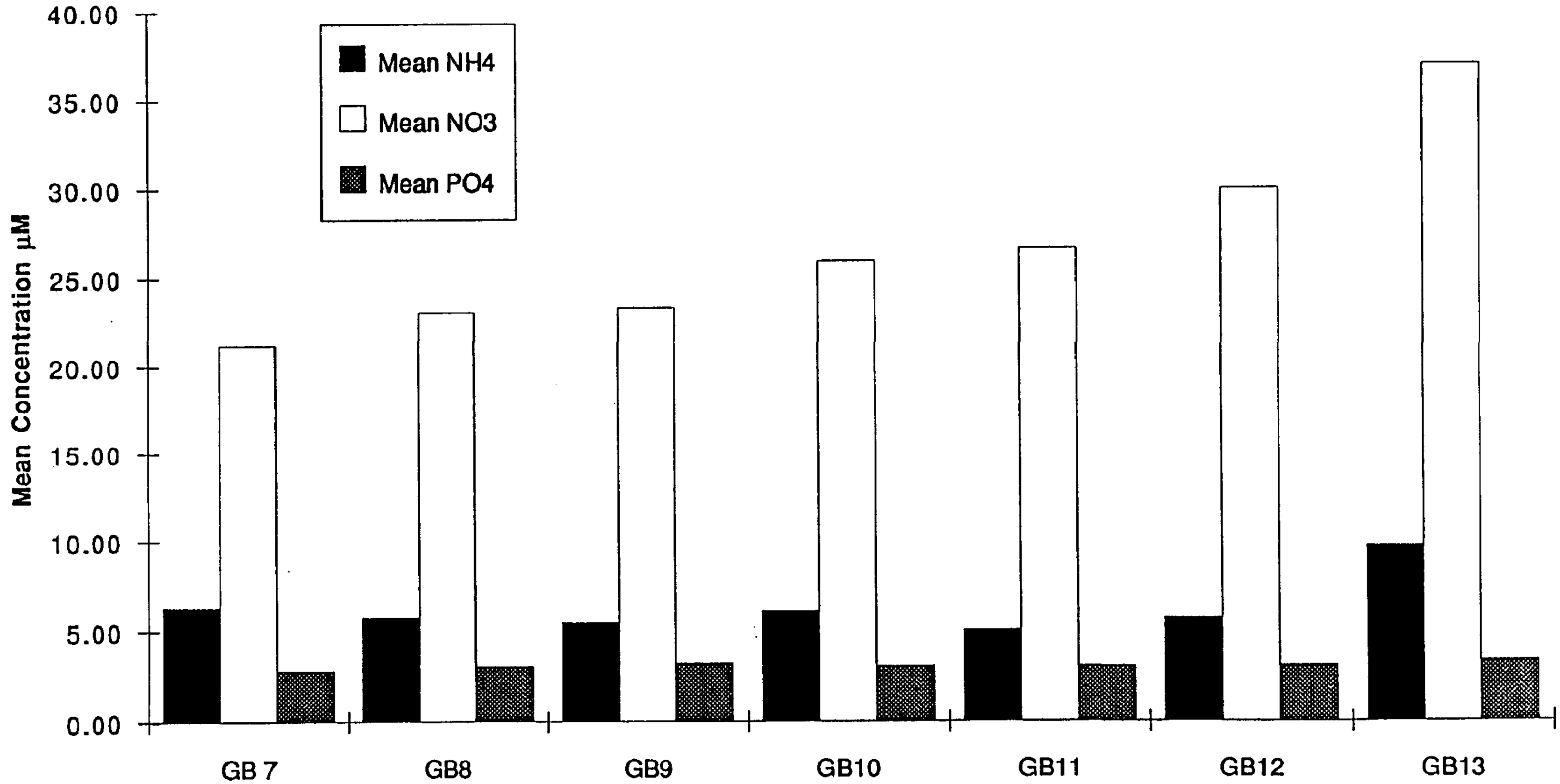


Figure 5A. Effect of tide stage on geometric mean bacterial indicator levels from monthly sampling at Chapmans Landing (GB7) in 1994.

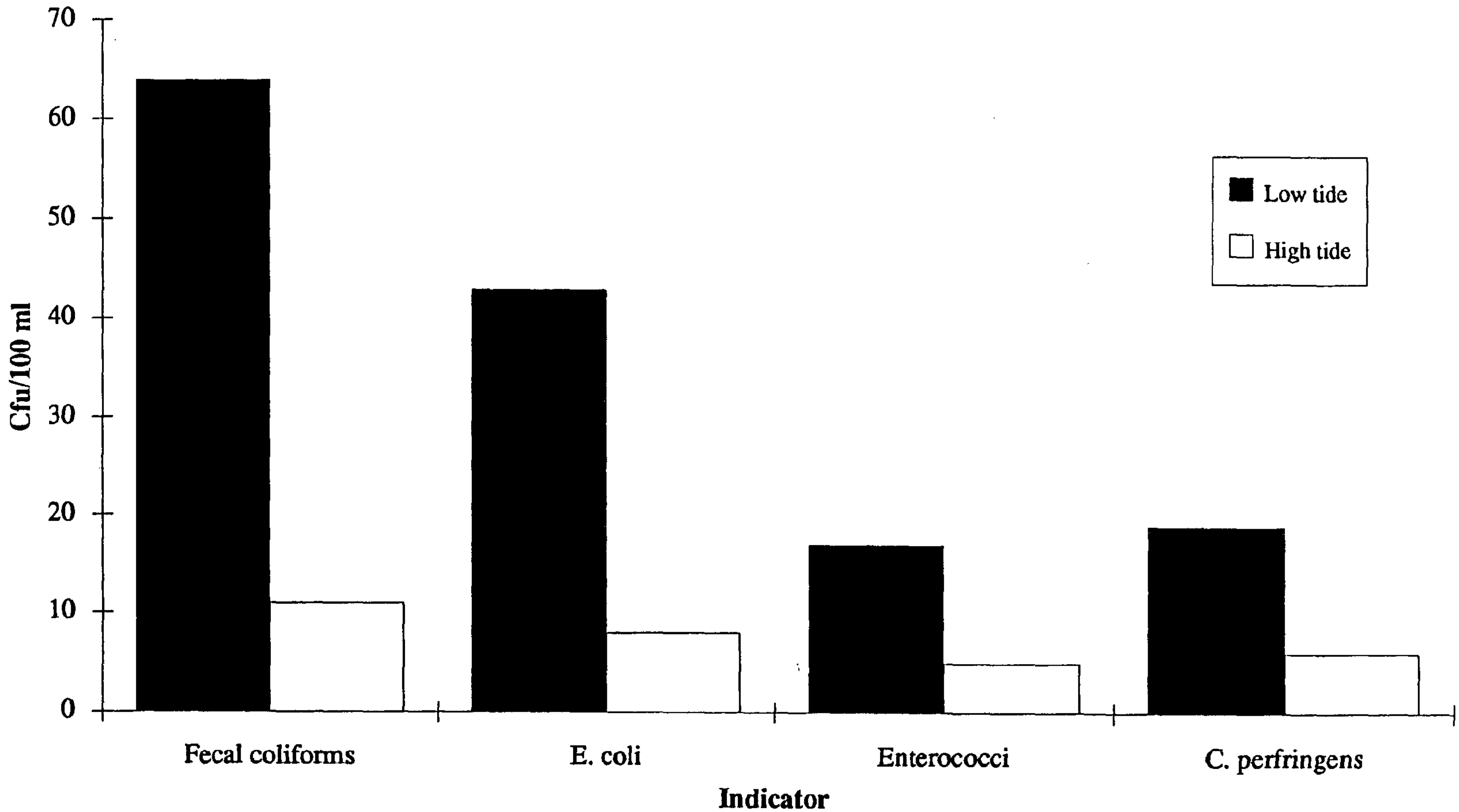


Figure 5B. Fecal coliform concentrations in the Squamscott River going upstream from Chapmans Landing to the Exeter POTW along a salinity gradient on 10/25/94.

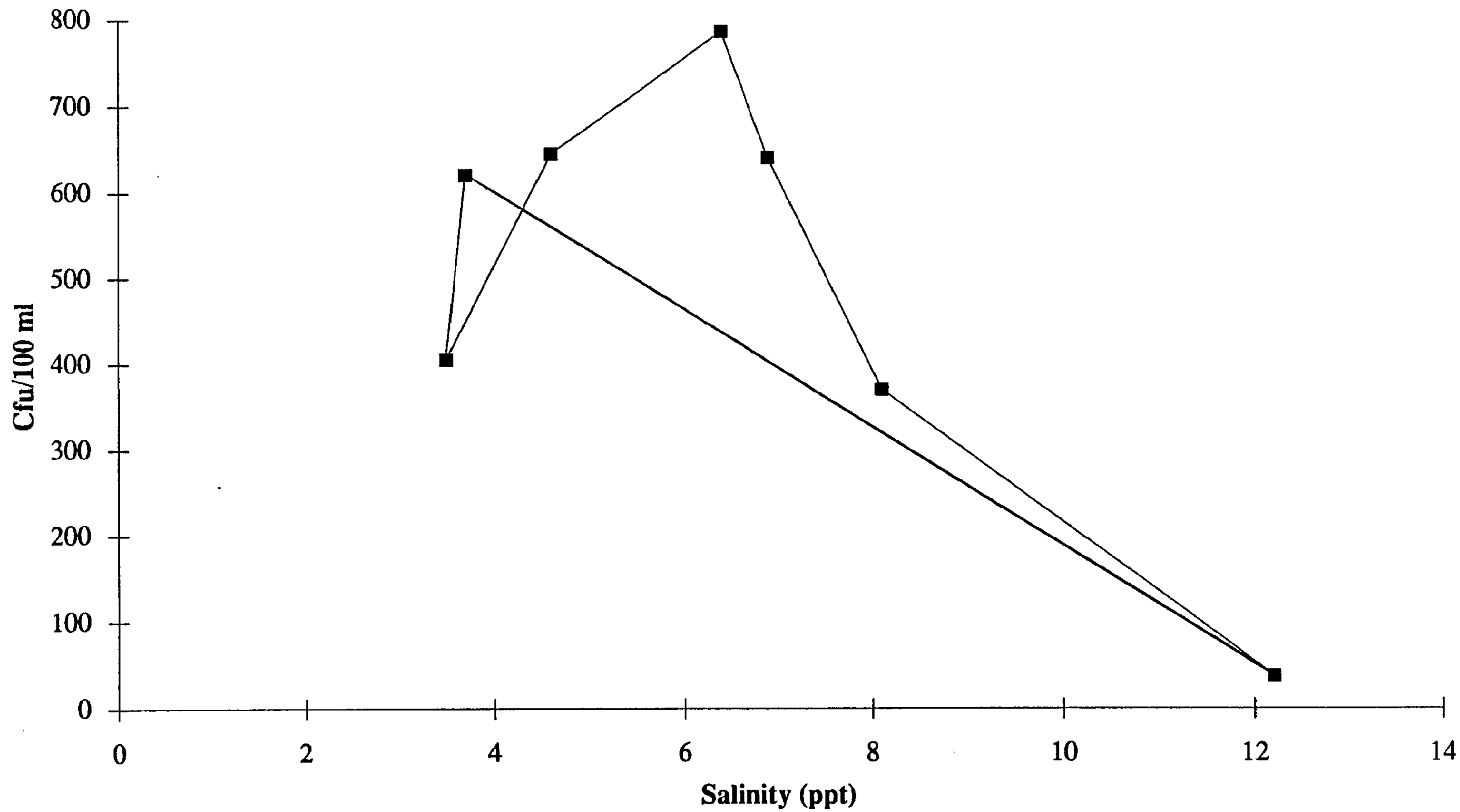


Figure 5C. Fecal coliform concentrations at tributary mouths in the Squamscott River going upstream from Chapmans Landing to below the Exeter POTW along a salinity gradient on 4/28/95.

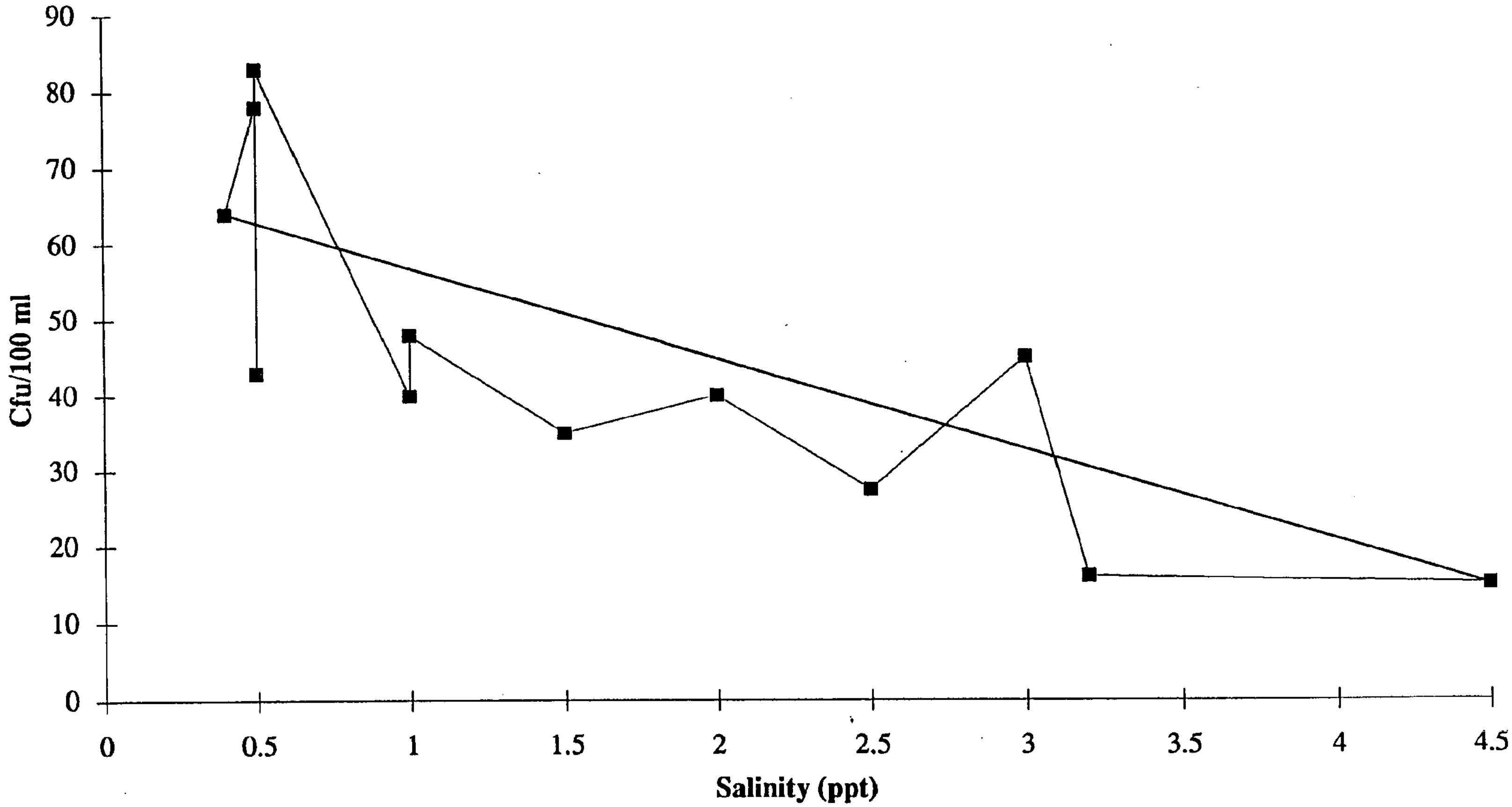


Figure 6. Geometric mean bacterial indicator levels in Exeter River tributaries going upstream from the dam: 1994-95.

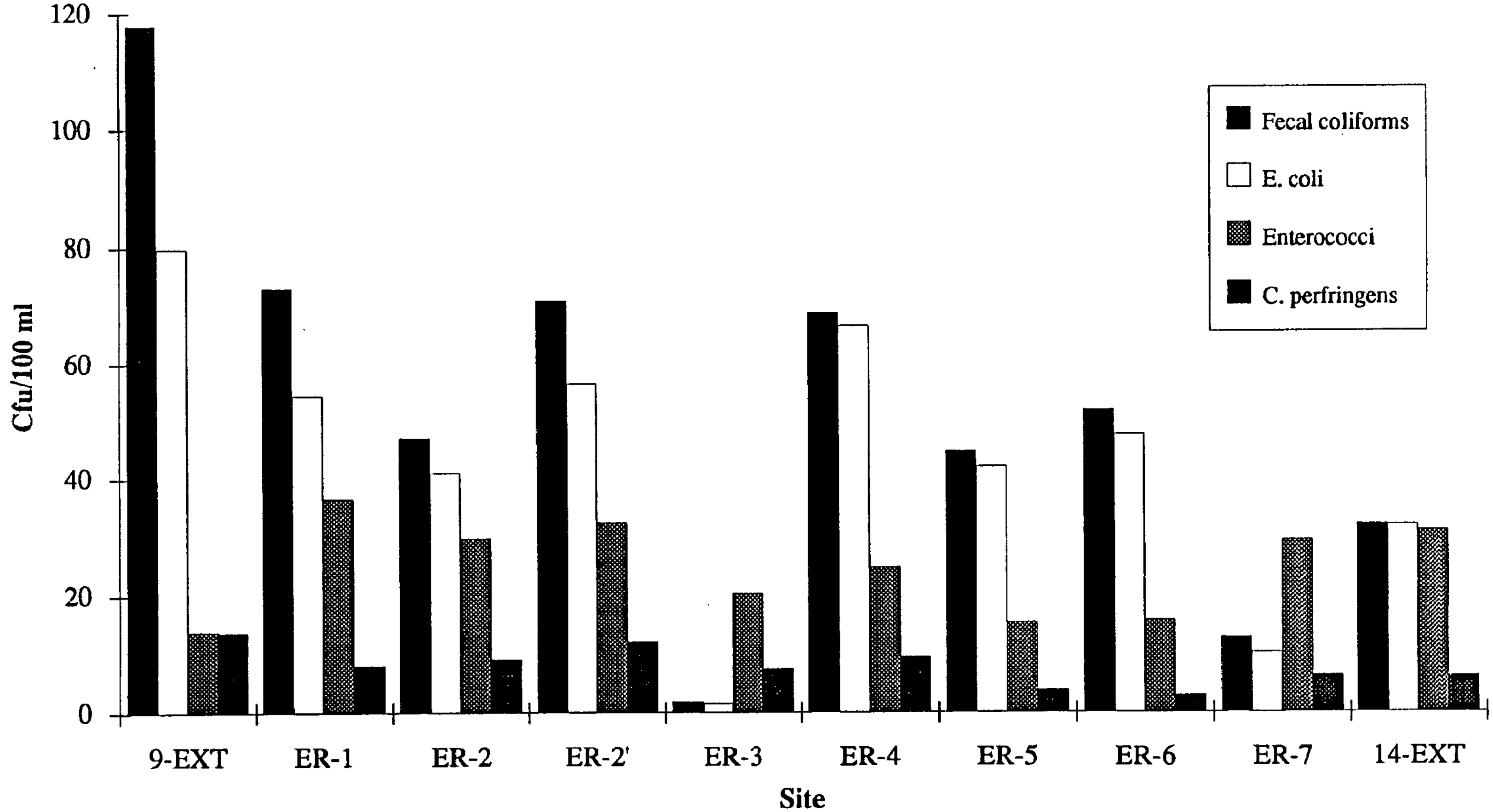


Figure 7. Mean ammonium and nitrate concentrations in Exeter River tributaries going upstream from the dam: 1994-95

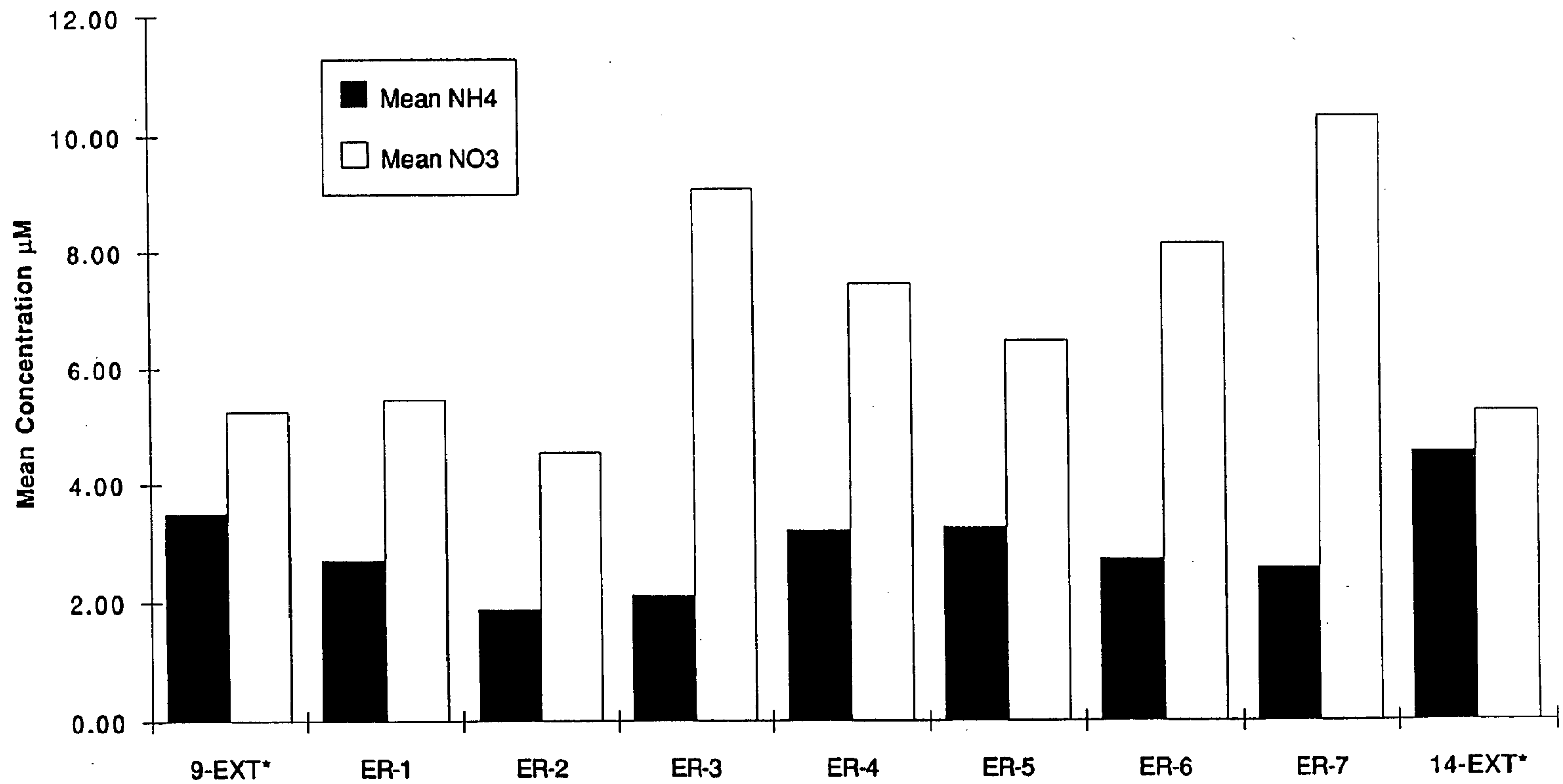


Figure 8. Mean orthophosphate concentrations in Exeter River tributaries going upstream from the dam: 1994-95

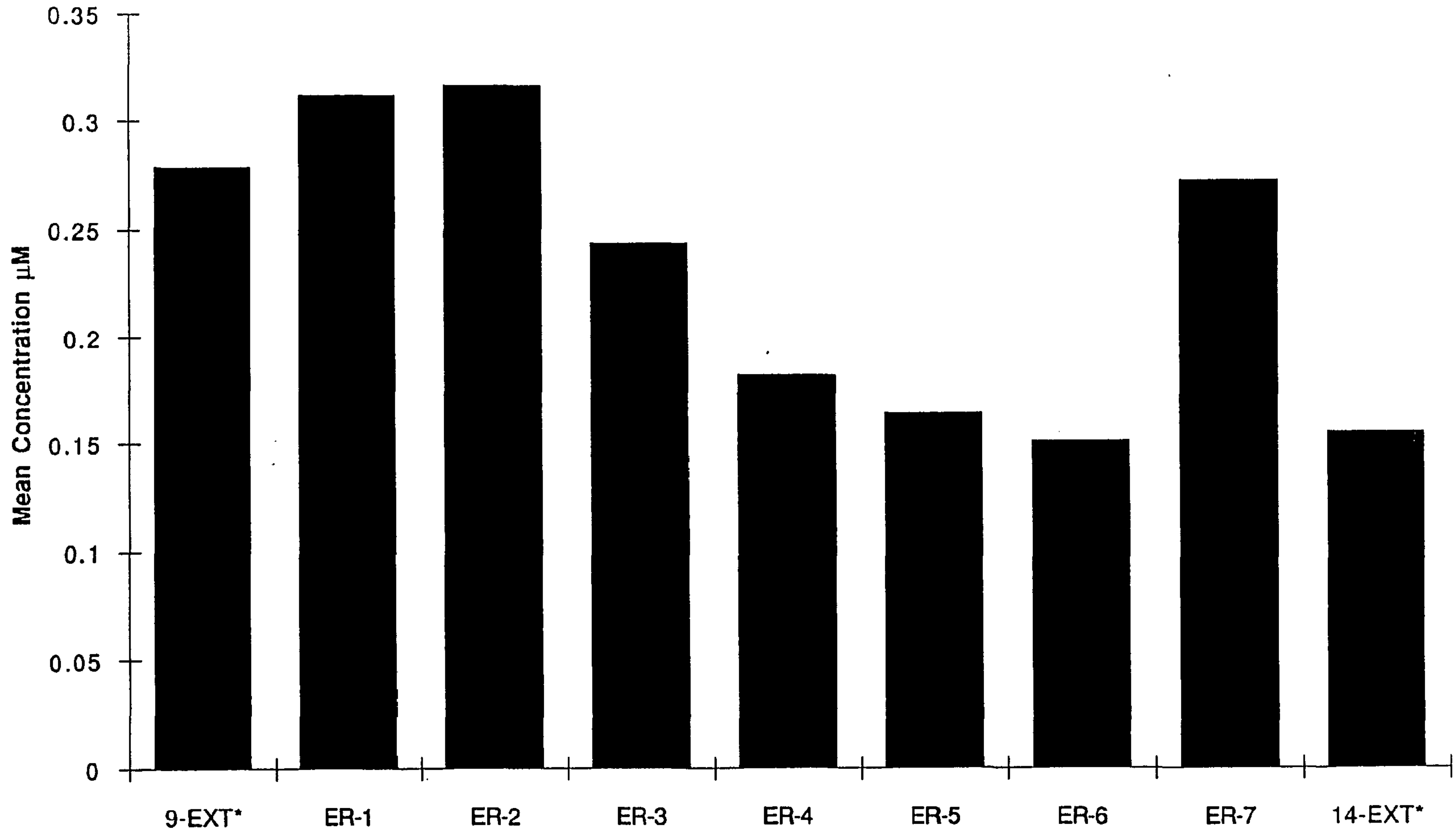


Figure 9. Geometric mean bacterial indicator levels in Squamscott River tributaries going clockwise from Newmarket to Exeter and back: 1994-95.

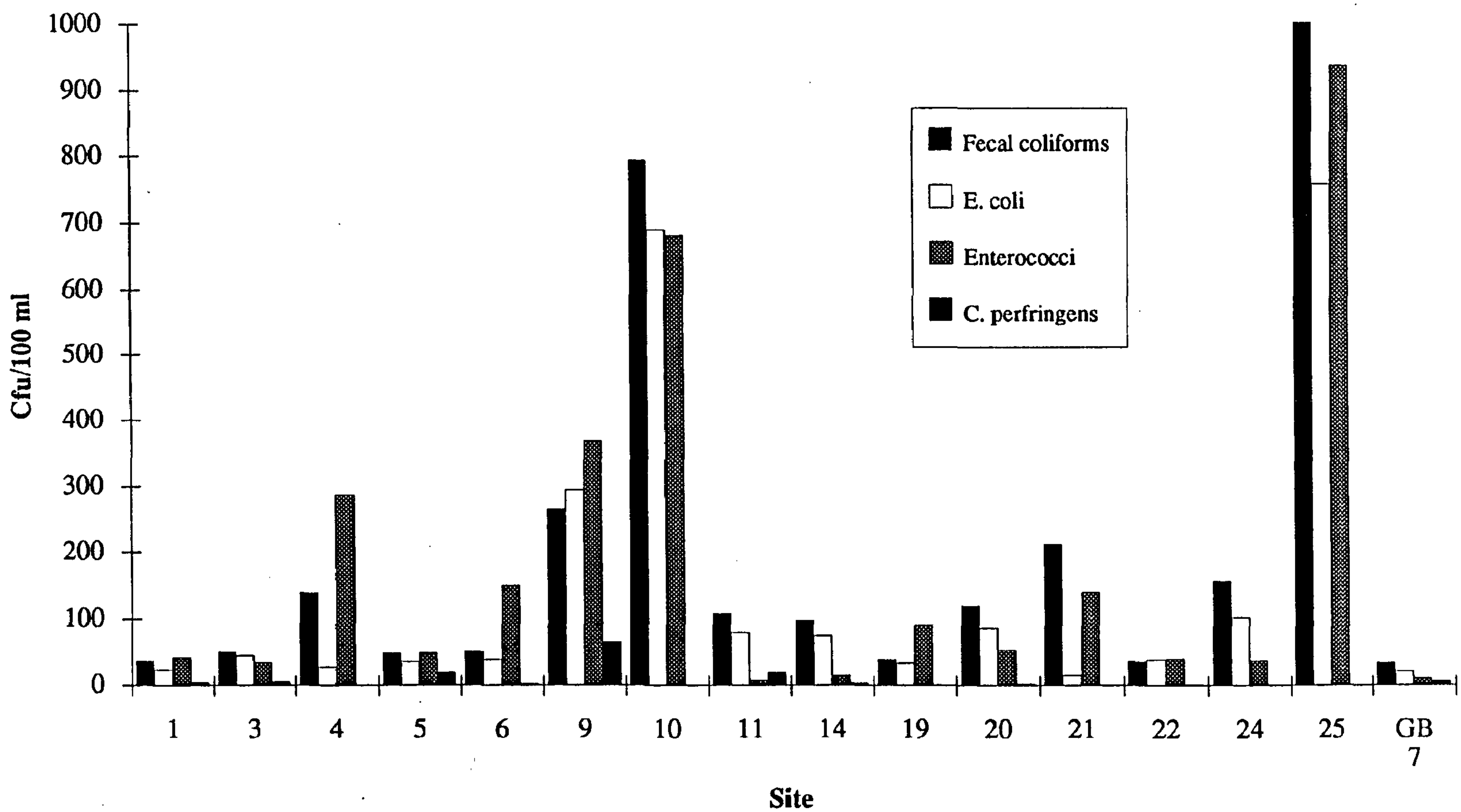


Figure 10. Mean concentration of NH4 in Squamscott River tributaries going clockwise from Newmarket to Exeter and back: 1994-95

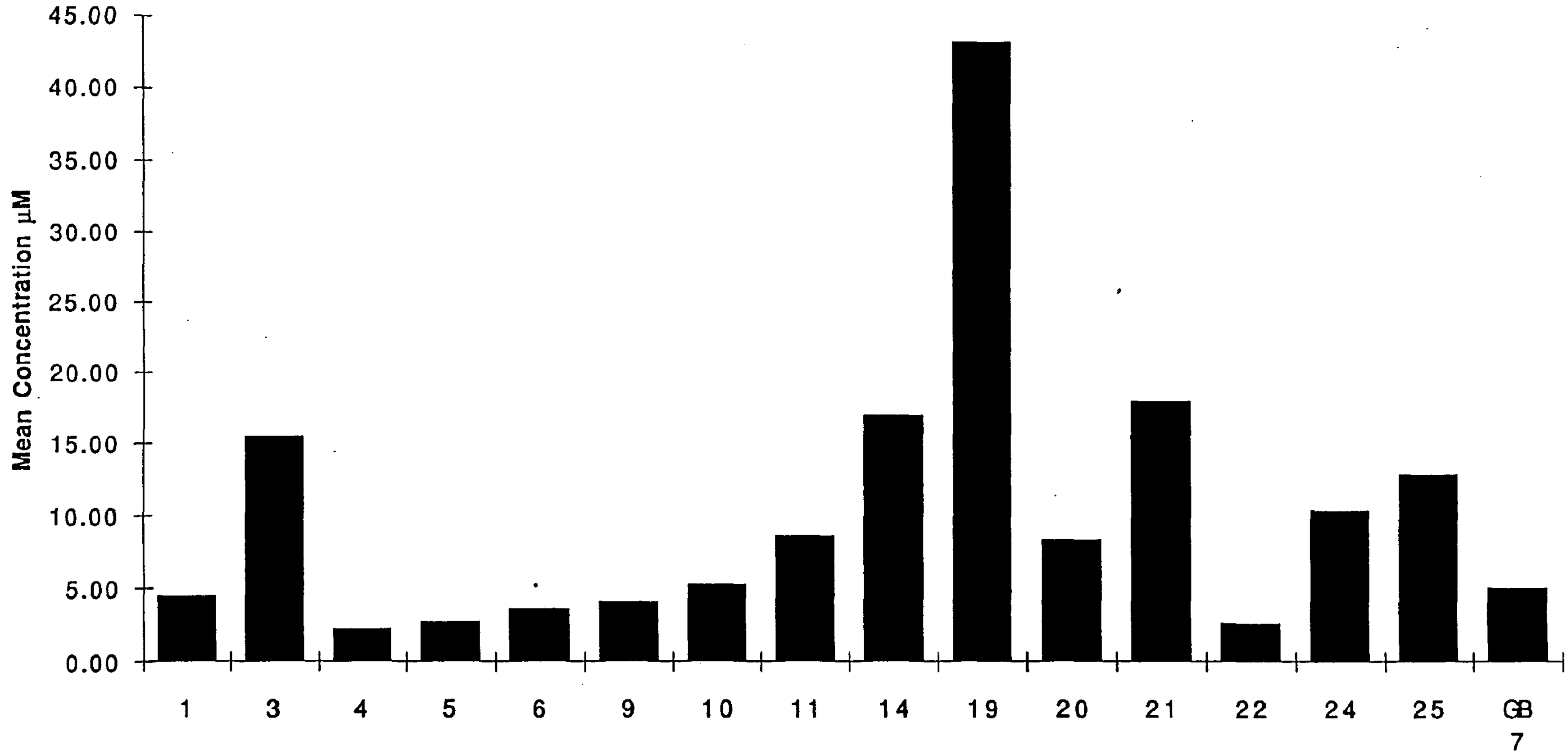


Figure 11. Mean concentration of NO3 in Squamscott River tributaries going clockwise from Newmarket to Exeter and back: 1994-95

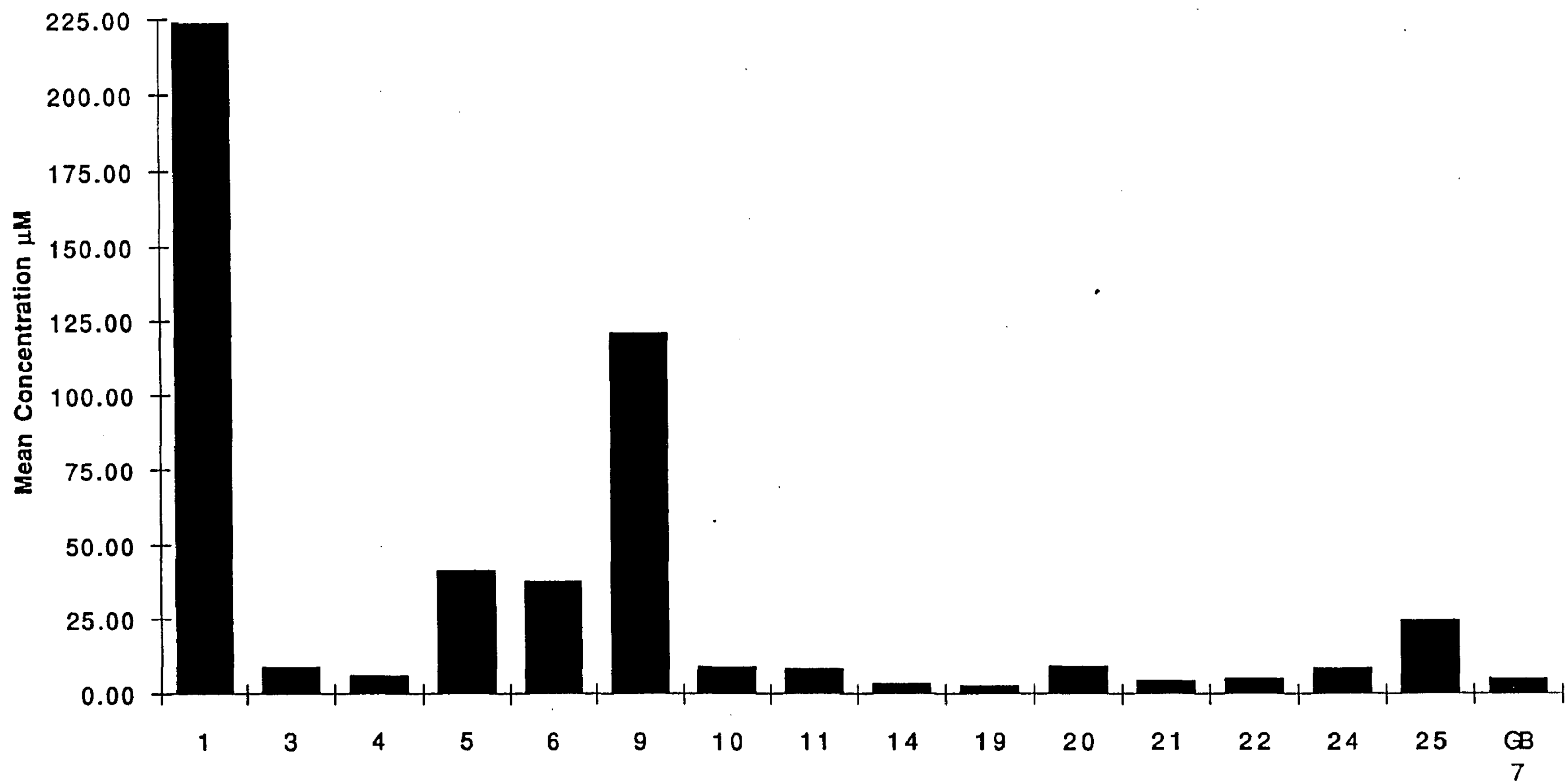


Figure12. Mean concentration of PO4 in Squamscott River tributaries going clockwise from Newmarket to Exeter and back: 1994-95

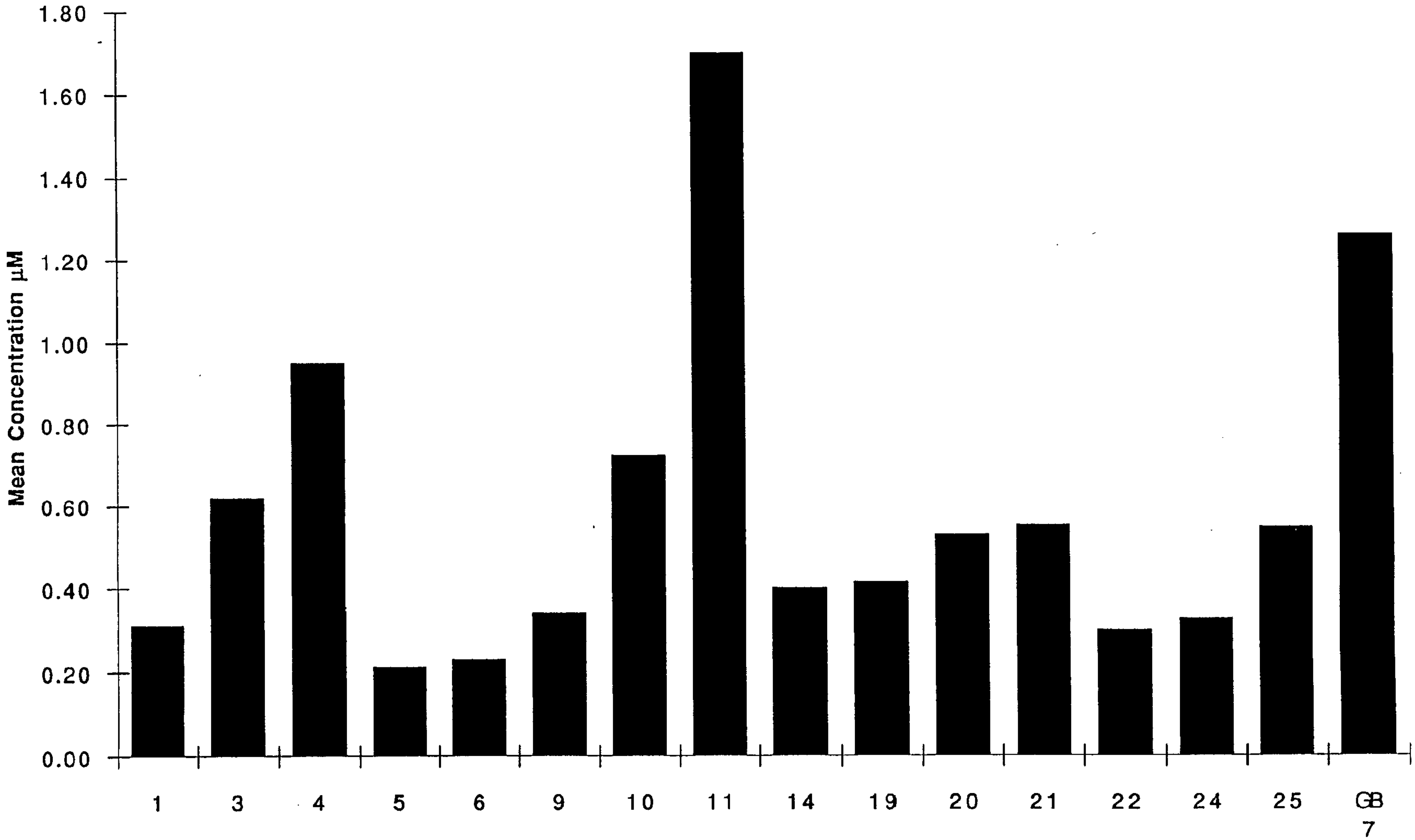


Figure 13. Bacterial indicator levels in Squamscott River tributaries going clockwise from Newmarket to Exeter and back on 6/7/95.

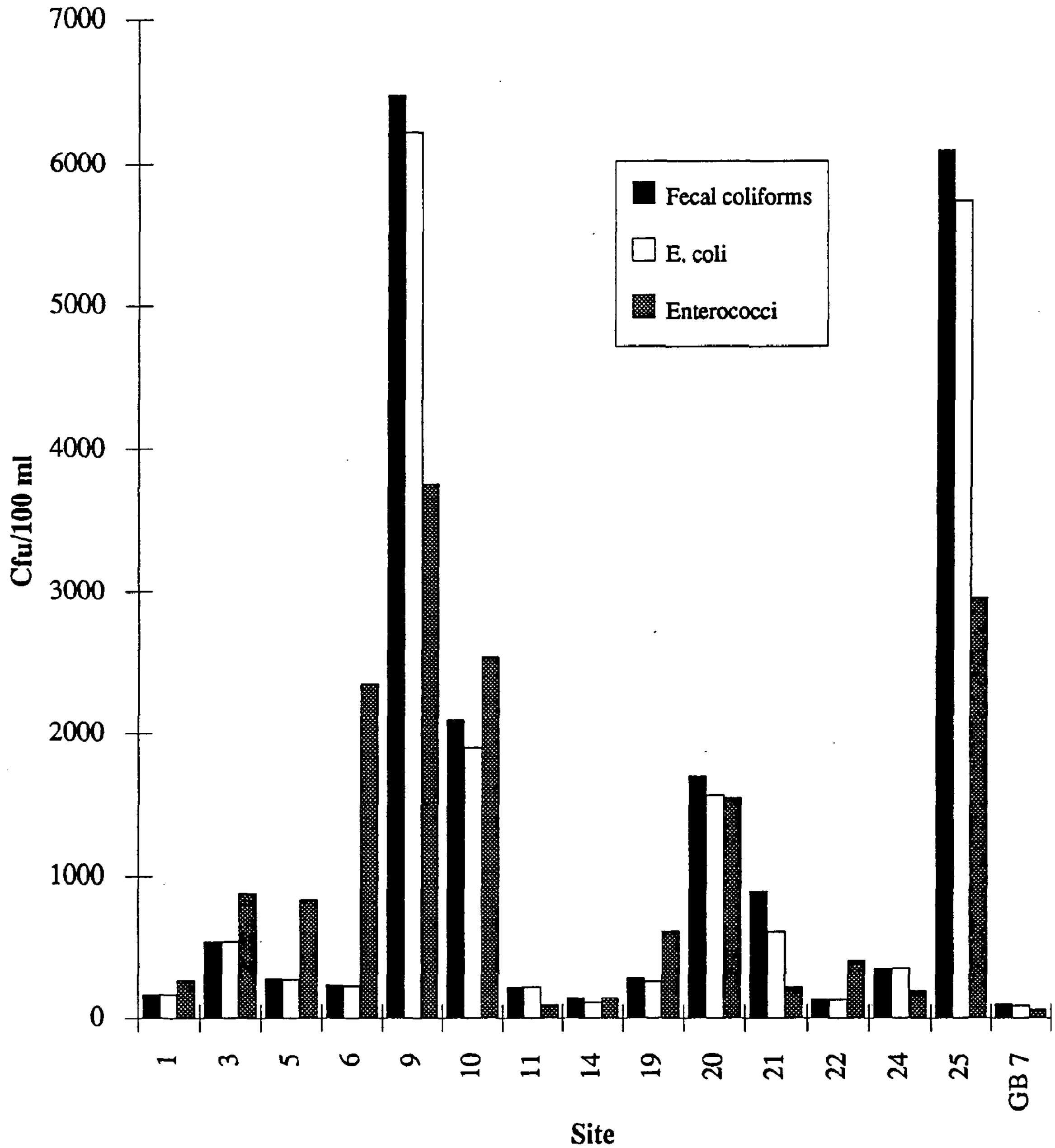


Figure 14. Geometric mean bacterial indicator levels in the Squamscott River at tributary mouths going upstream from Newmarket to Exeter: 1994-95.

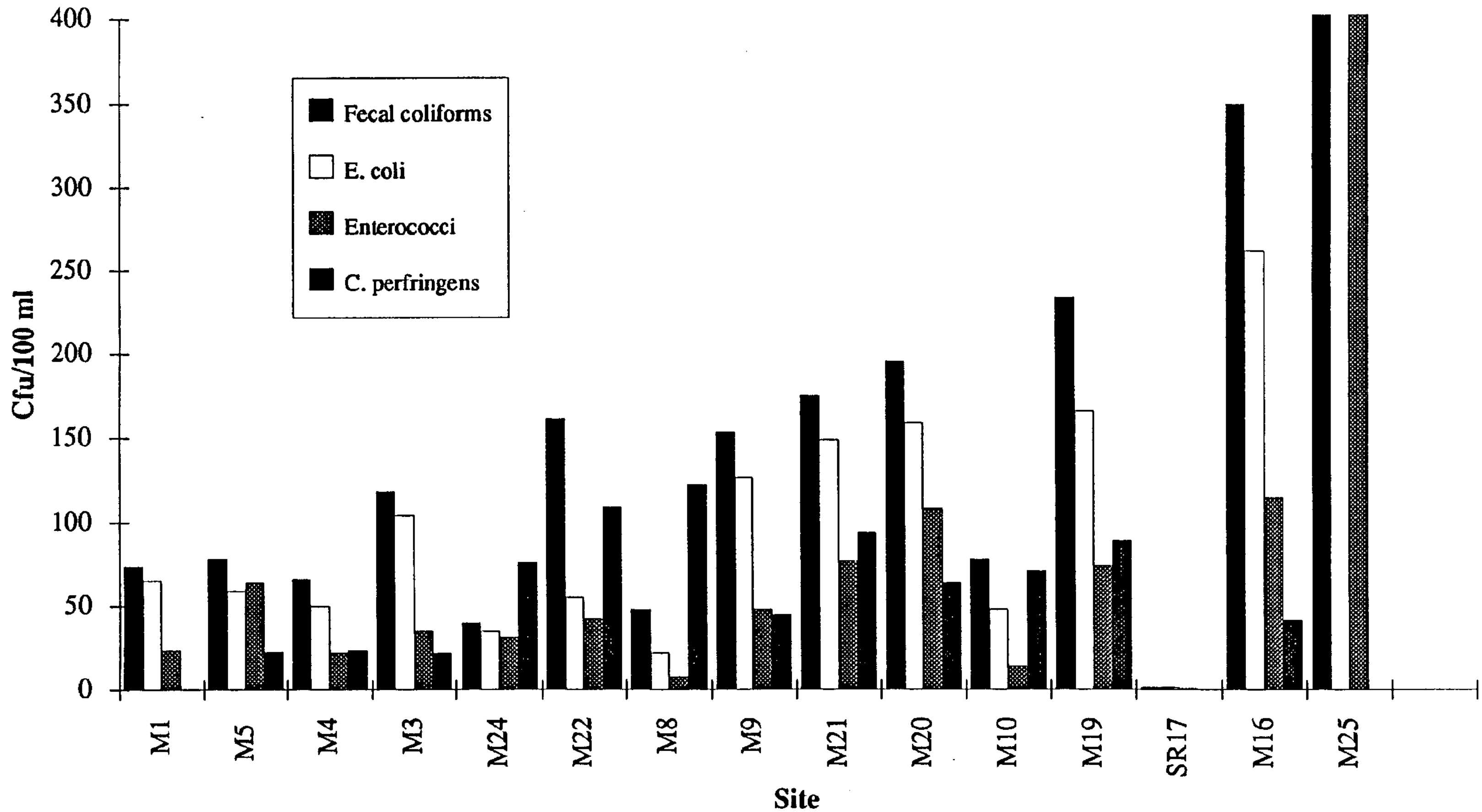


Figure 15. Nutrient concentrations in the Squamscott River at tributary mouths going upstream from Newmarket to Exeter

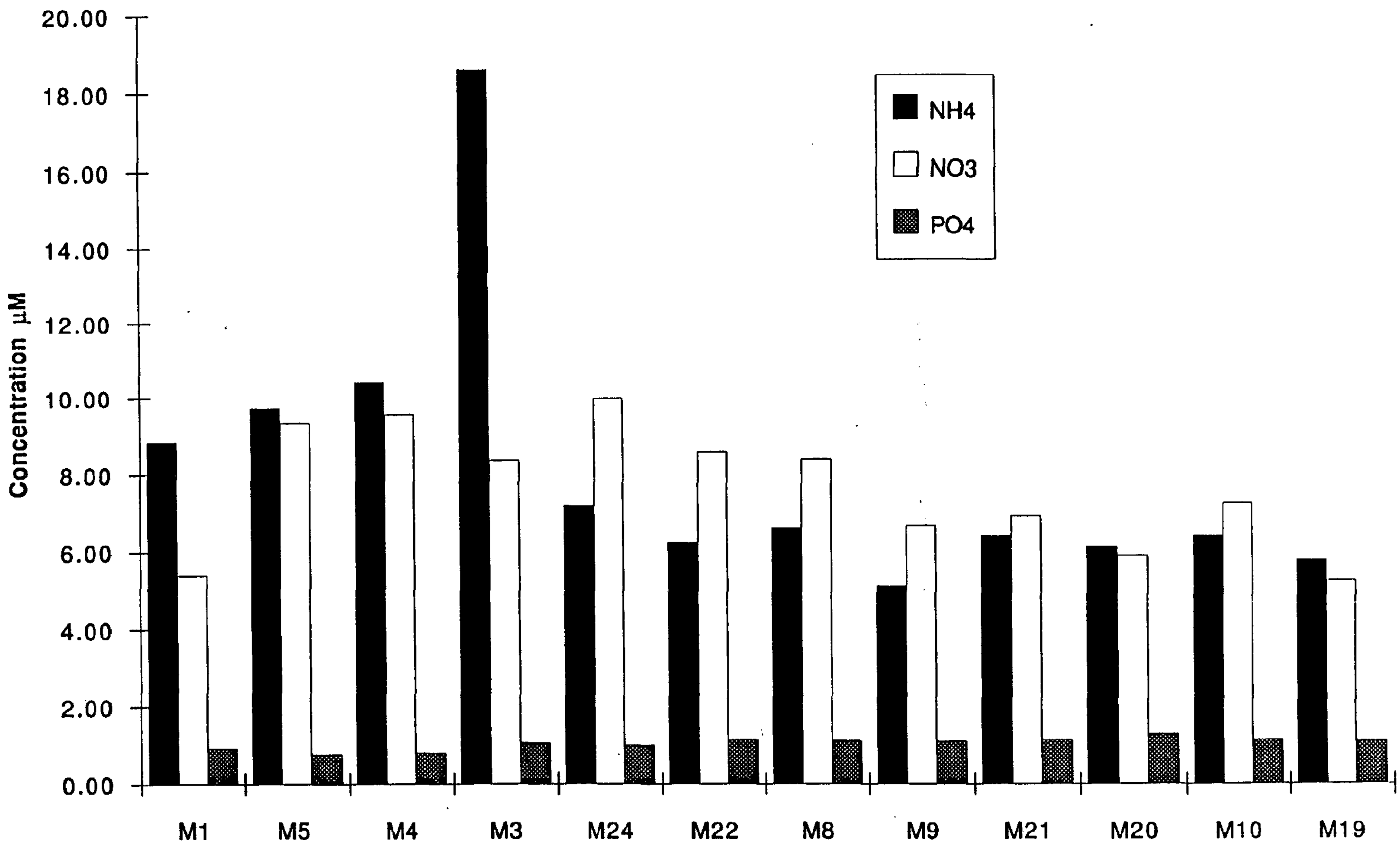
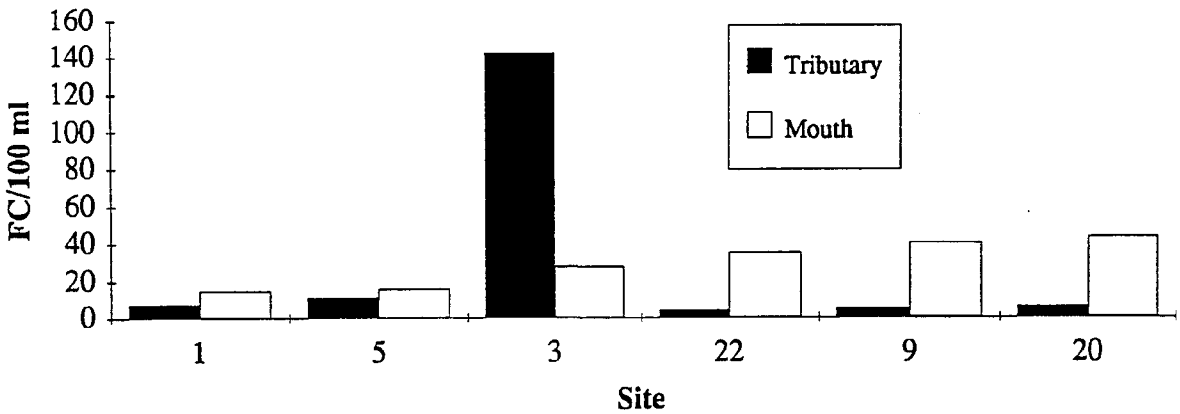


Figure 16. Fecal coliforms and enterococci in tributaries and at their mouths going upstream along a transect of the Squamscott River on 4/26 (tribs) and 4/28 (mouths), 1995.



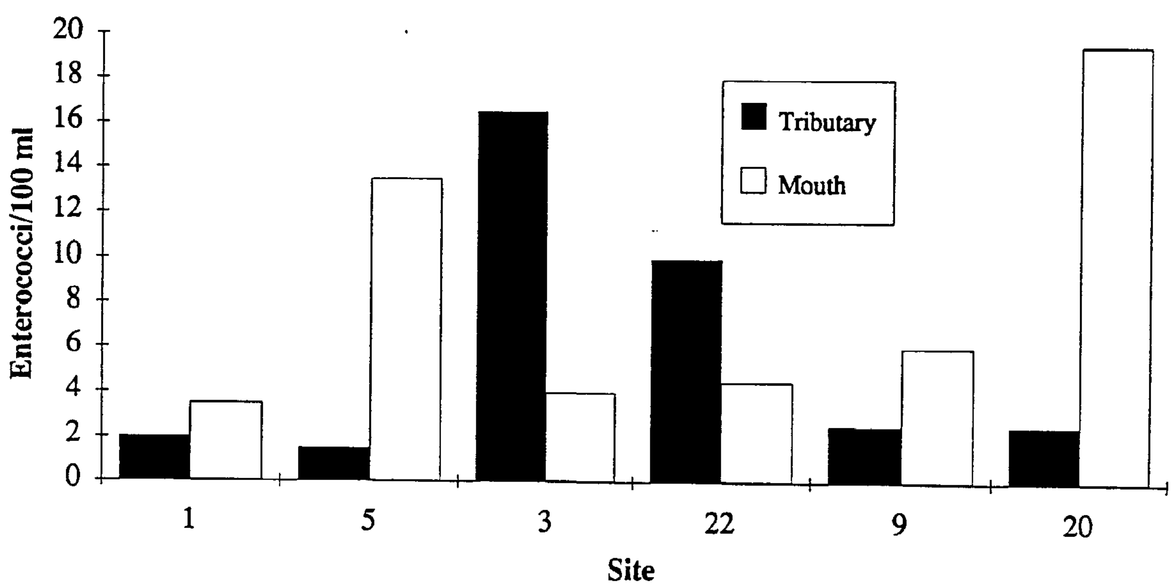


Figure 17. NO_3 concentrations in tributaries and their mouths in the Squamscott River on 4/26 (tribs) and 4/28 (mouths): 1995

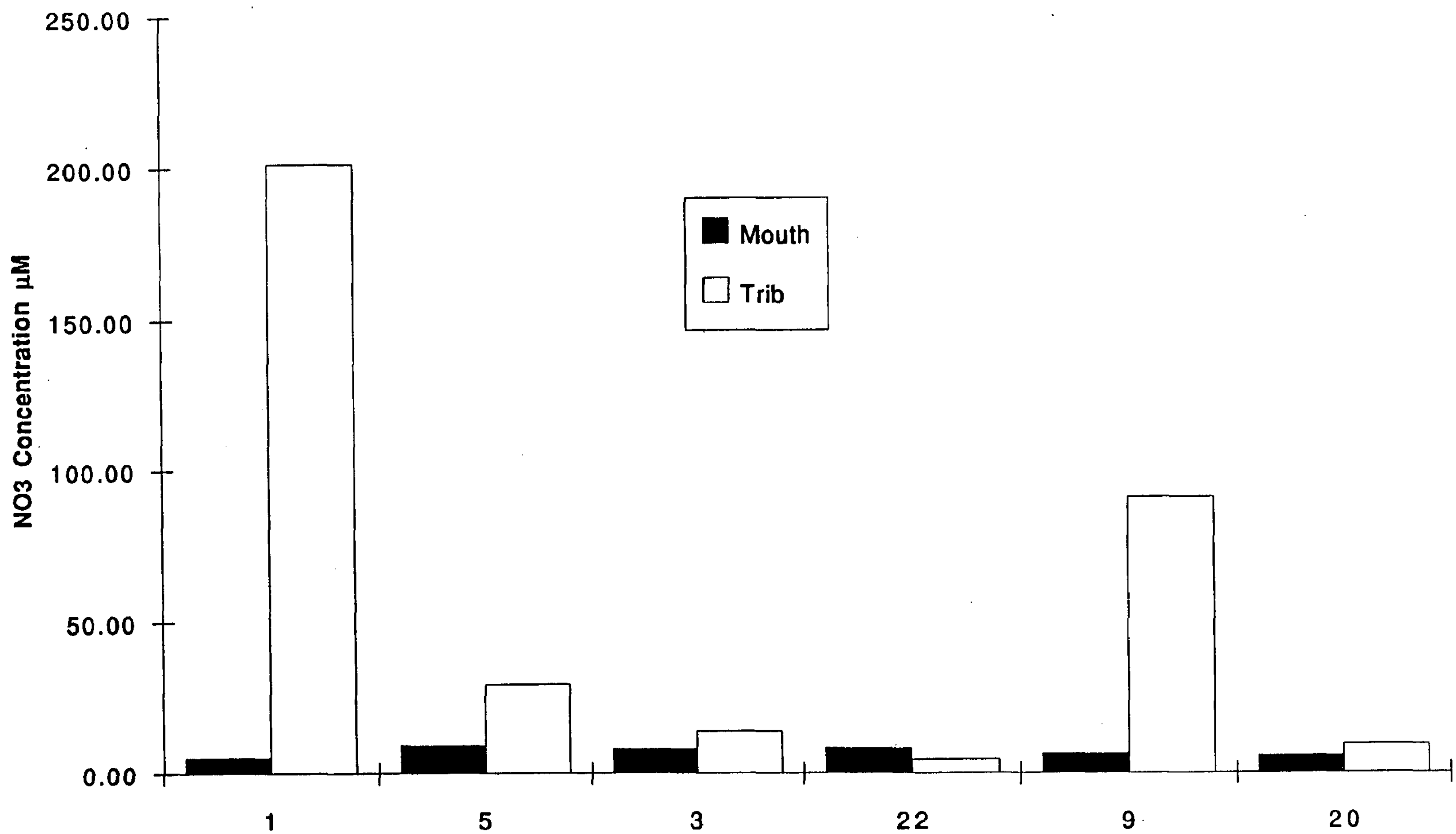


Figure 18. NH4 concentrations in tributaries and their mouths in the Squamscott River on 4/26 (tribs) and 4/28 (mouths), 1995

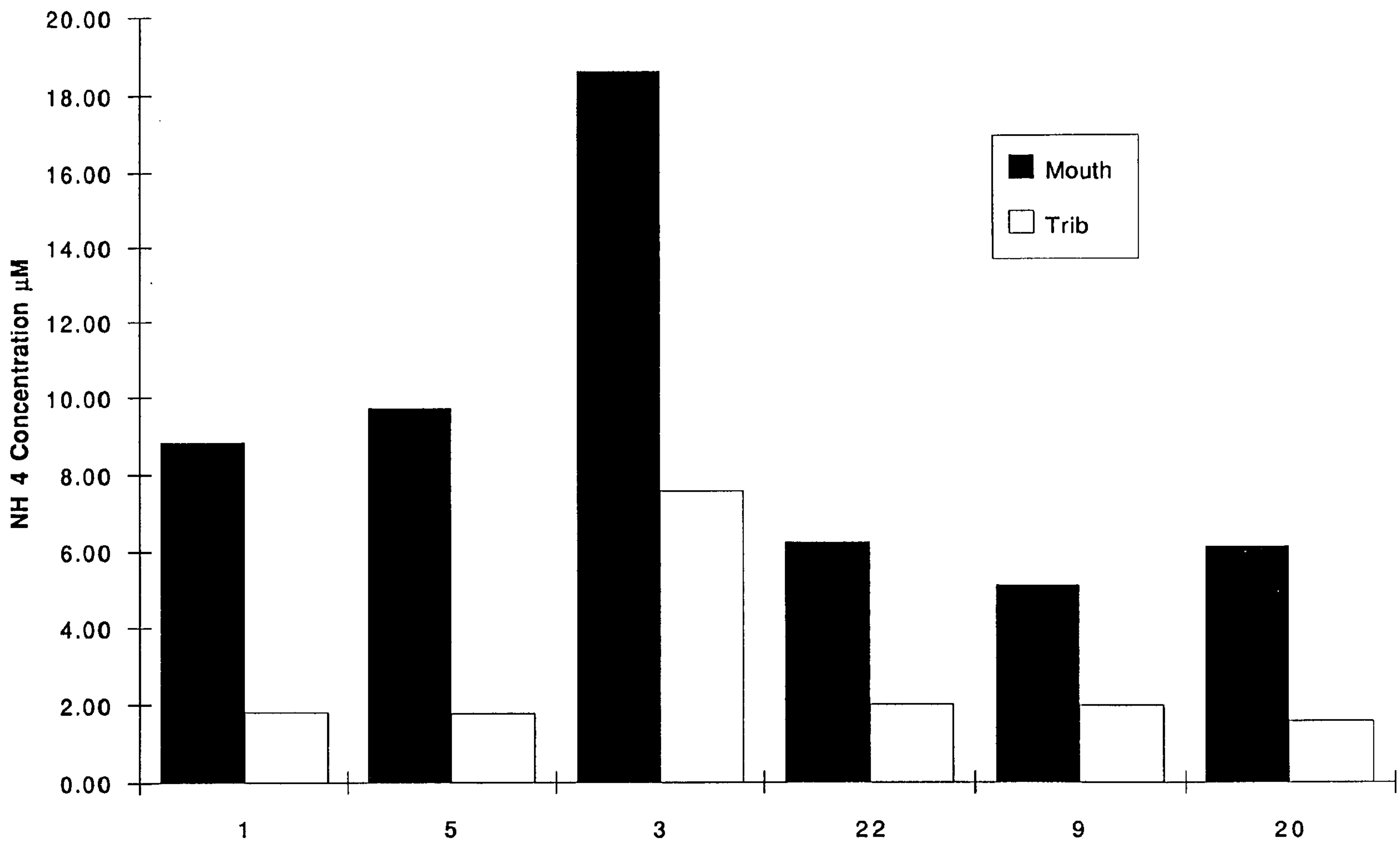
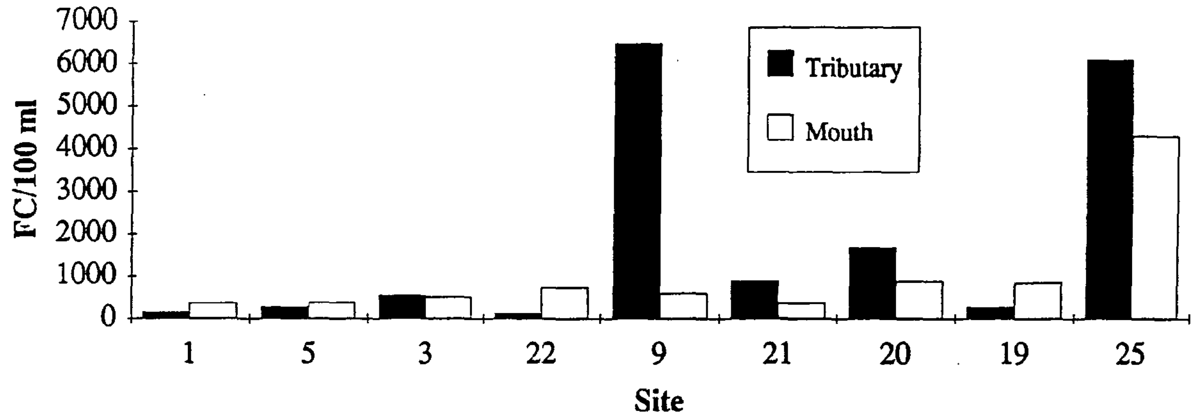


Figure 19. Fecal coliforms and enterococci in tributaries and at their mouths going upstream along a transect of the Squamscott River on 6/7/95.



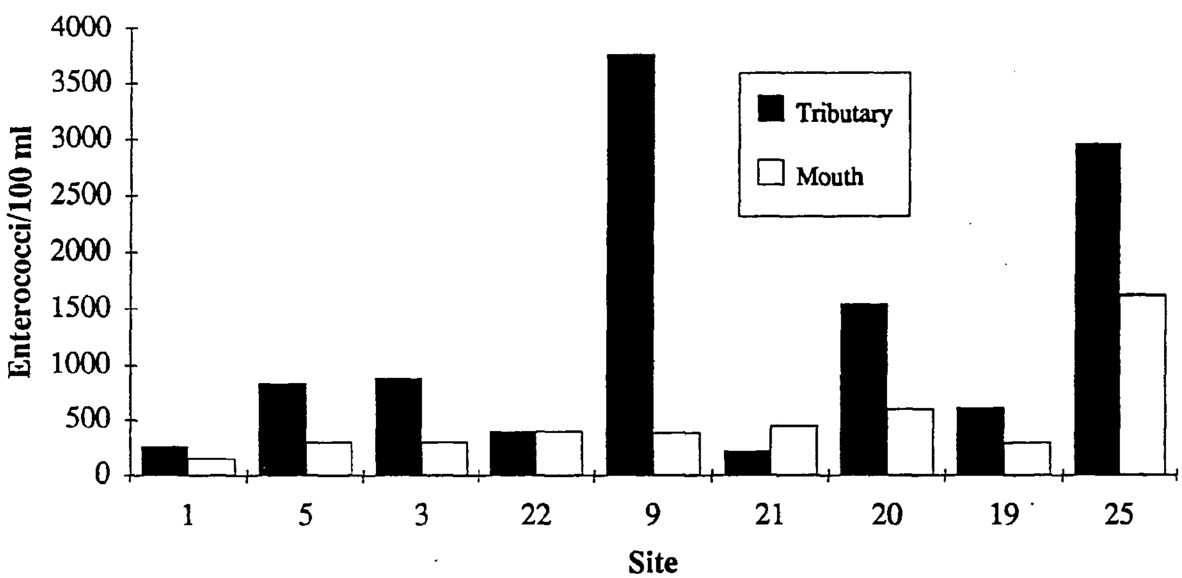


Figure 20. Flow rates in freshwater tributaries to the Squamscott River on 6/16/95.

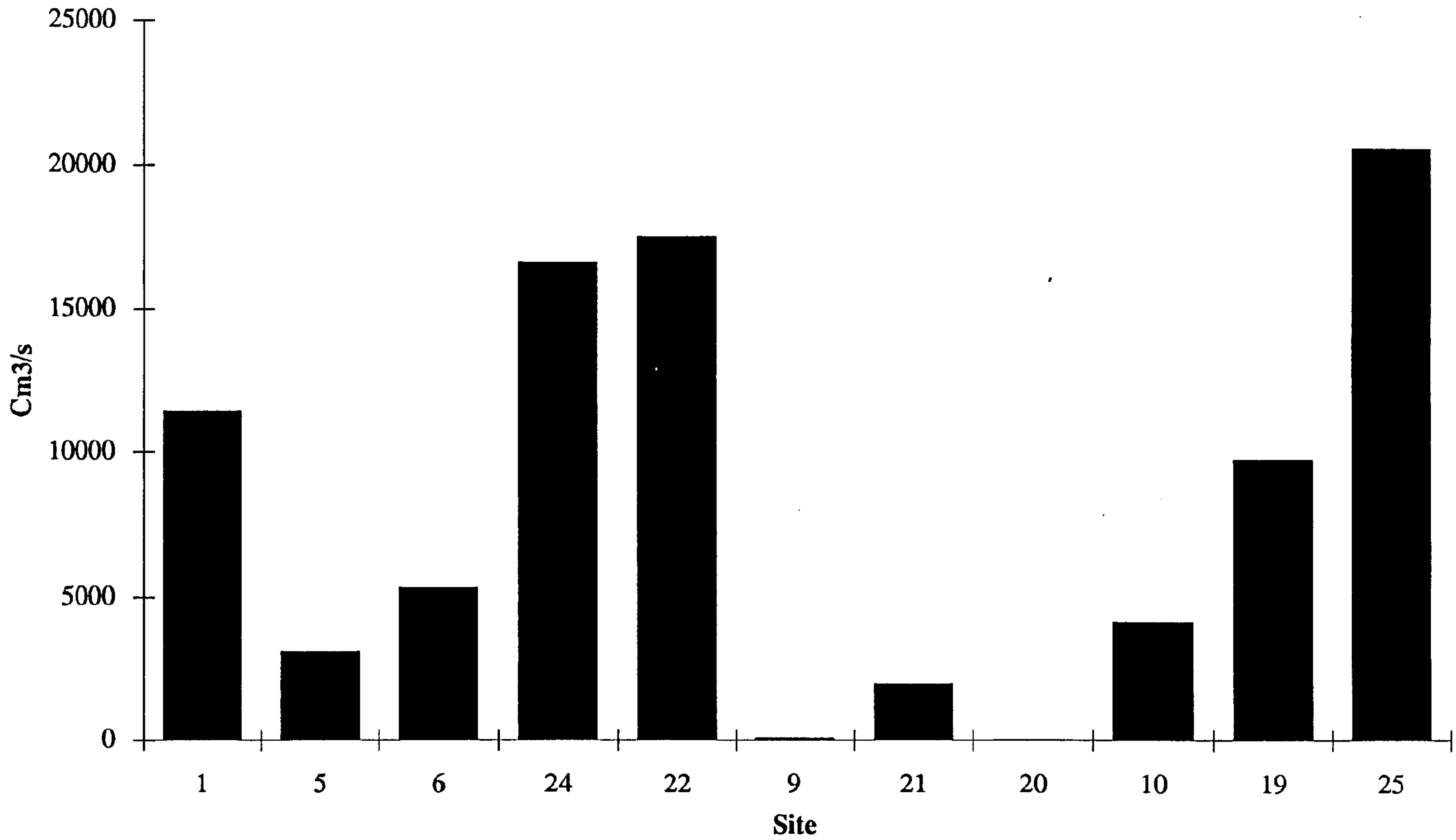


Figure 21. Estimated loading rates, based on 6/16/95 flow rates and 6/7/95 data, for bacterial indicators in Squamscott River tributaries.

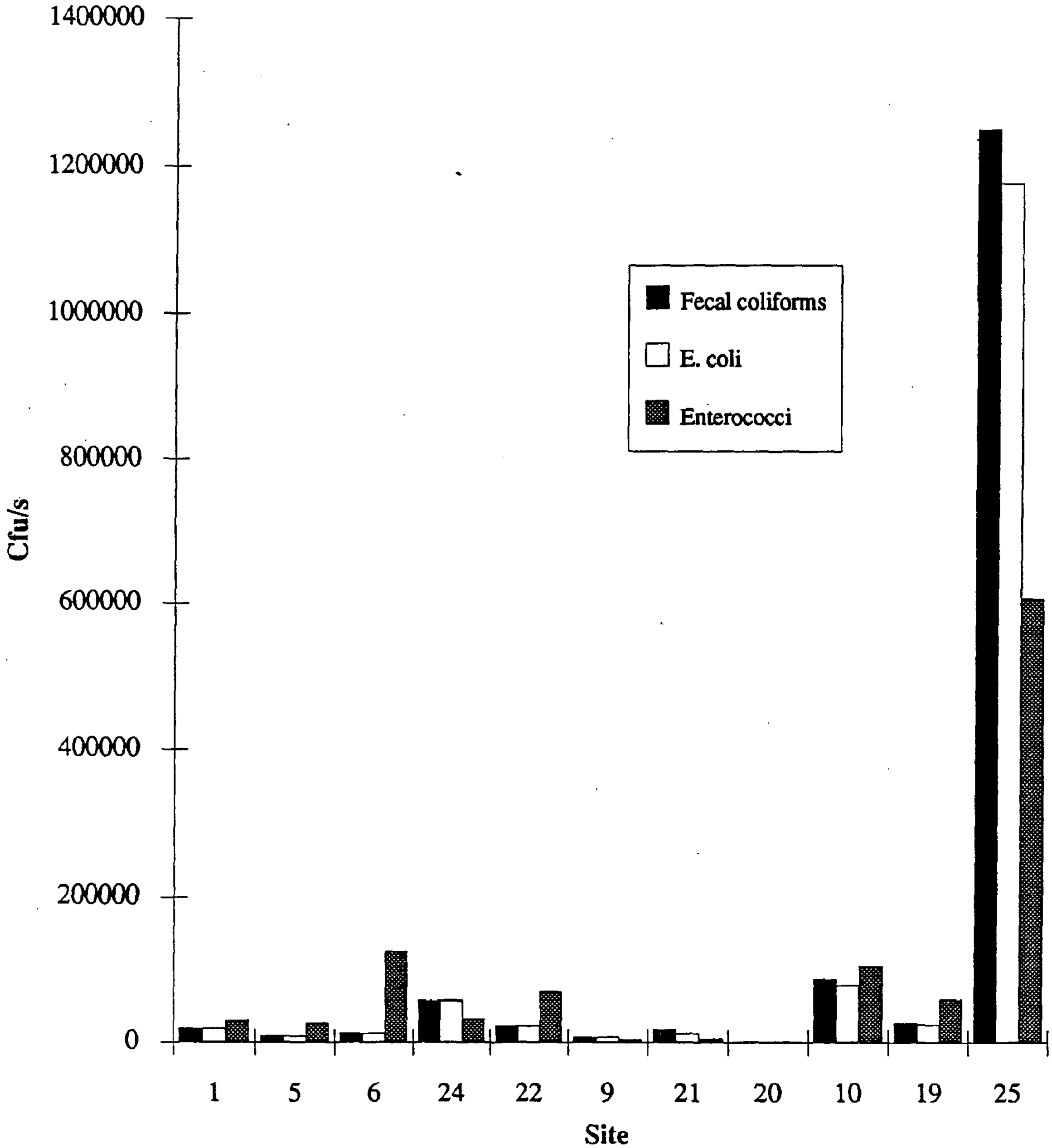
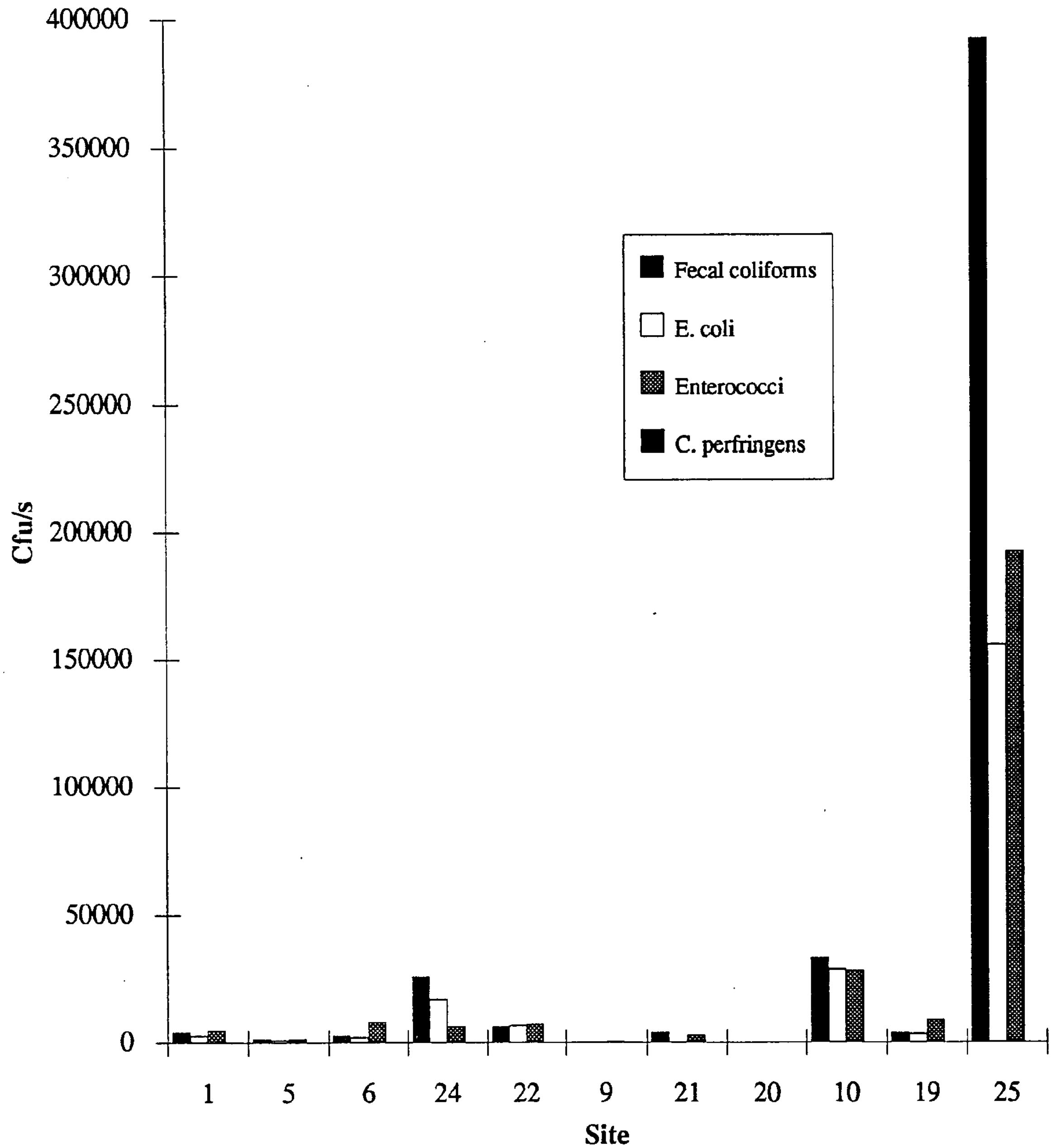


Figure 22. Estimated loading rates, based on 6/16/95 flow rates and overall geometric mean data, for bacterial indicators in Squamscott River tributaries.



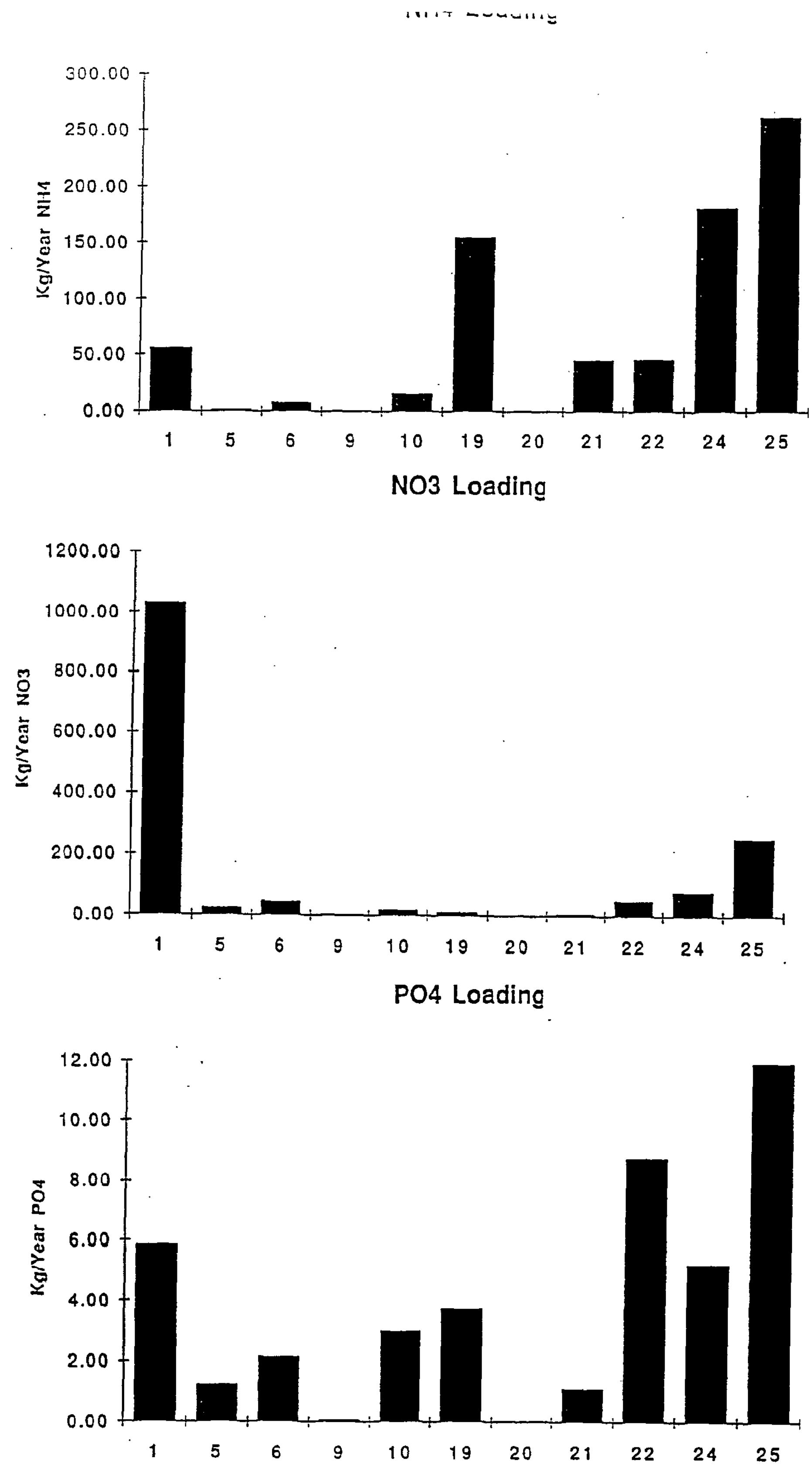
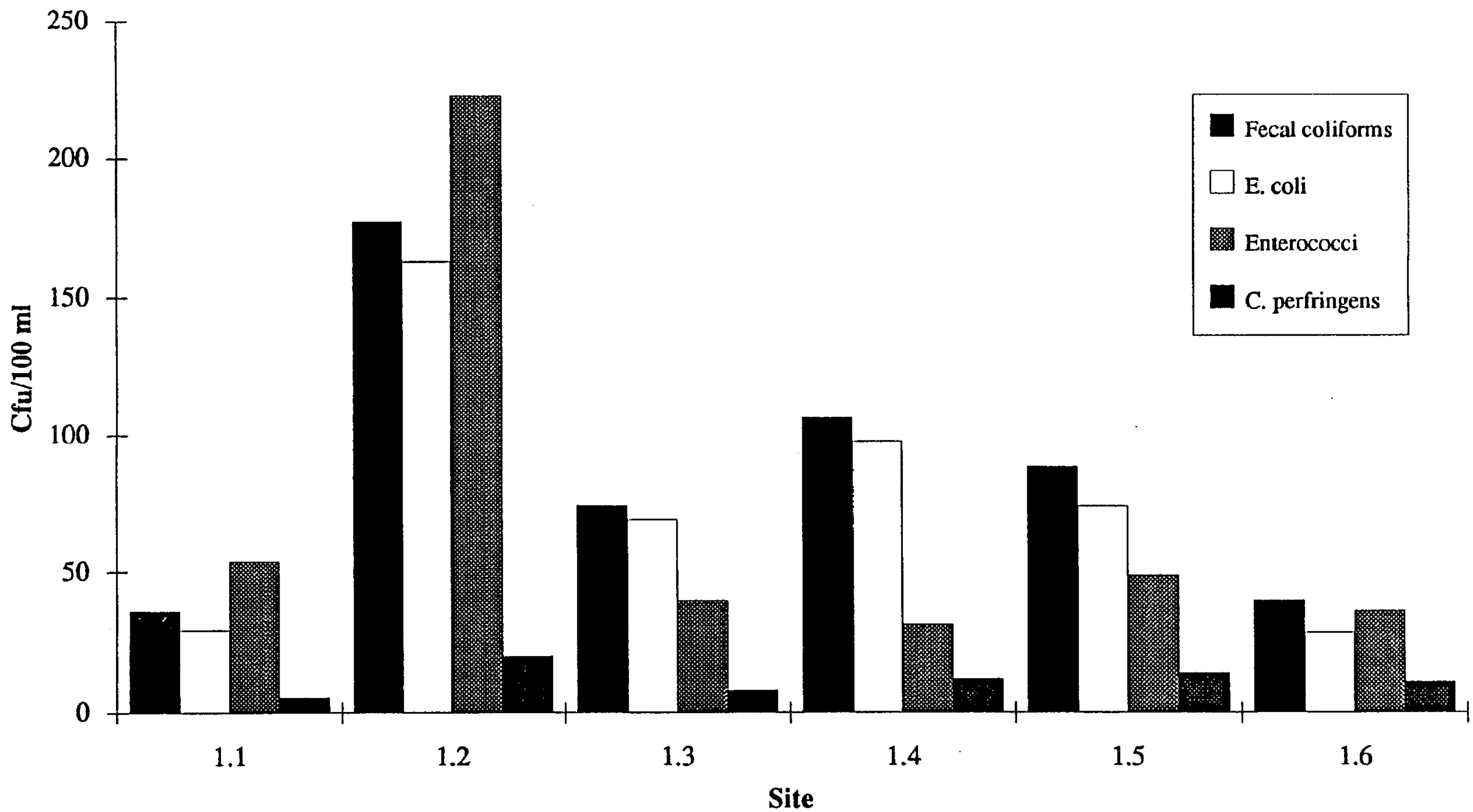
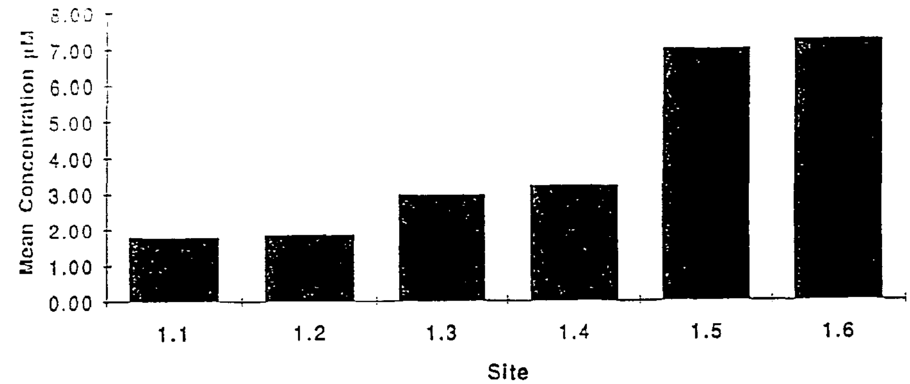


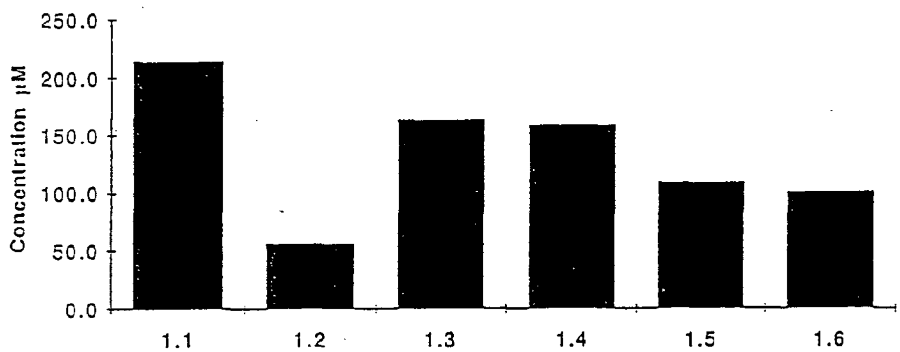
Figure 23. Estimated loading rates, based on 6/16/95 flow rates and 6/7/95 data, for nutrients in Squamscott River tributaries.

Figure 24. Geometric mean bacterial indicator levels in a small tributary going downstream to the Squamscott River in Newfields: 1994-95.





Mean NO3



Mean PO4

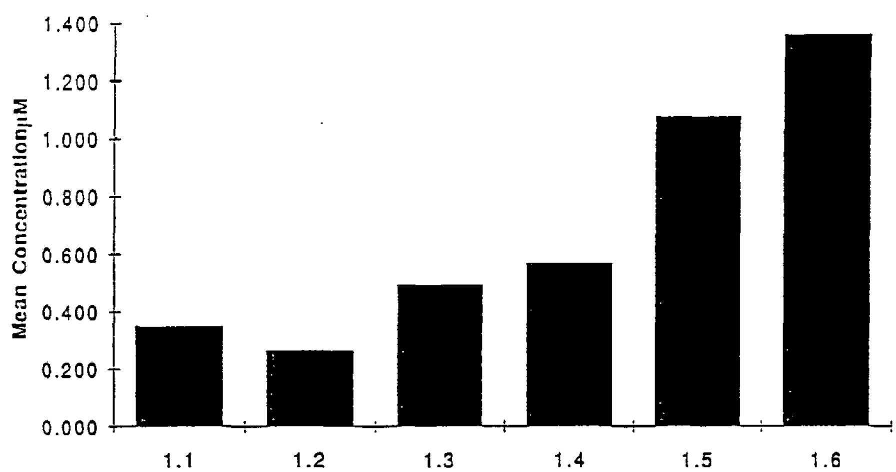


Figure 25. Mean nutrient concentrations in a small tributary going downstream to the Squamscott River in Newfields: 1994-95.

Figure 26. Mean Total suspended solids in Squamscott River tributaries and Chapmans Landing (GB7)

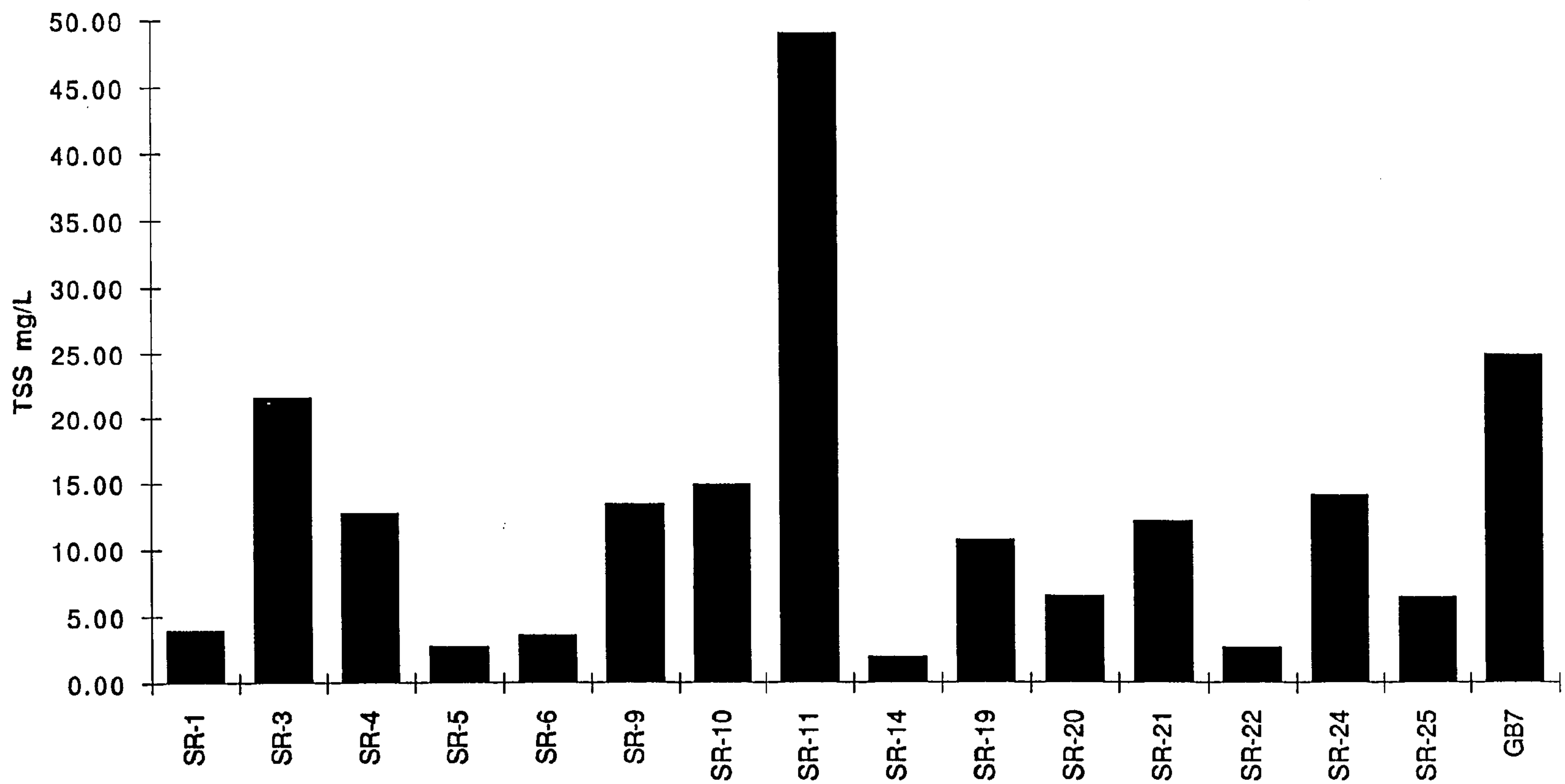


Figure 27. Mean total suspended solids at sites in the Exeter River and tributaries

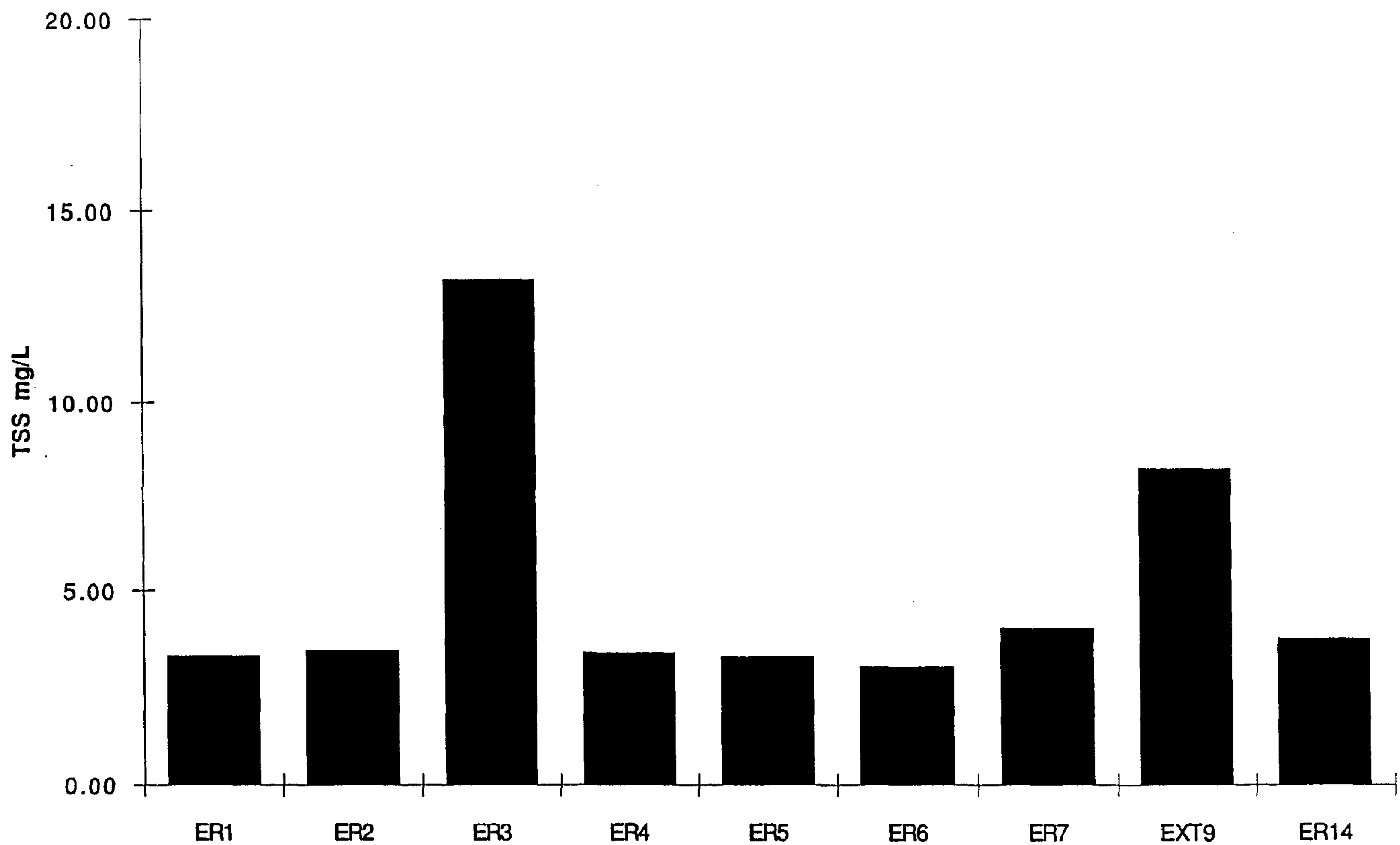


Figure 28. Mean total suspended solids at sites from Chapmans Landing (GB 7) to just above the Exeter POTW (GB 13)

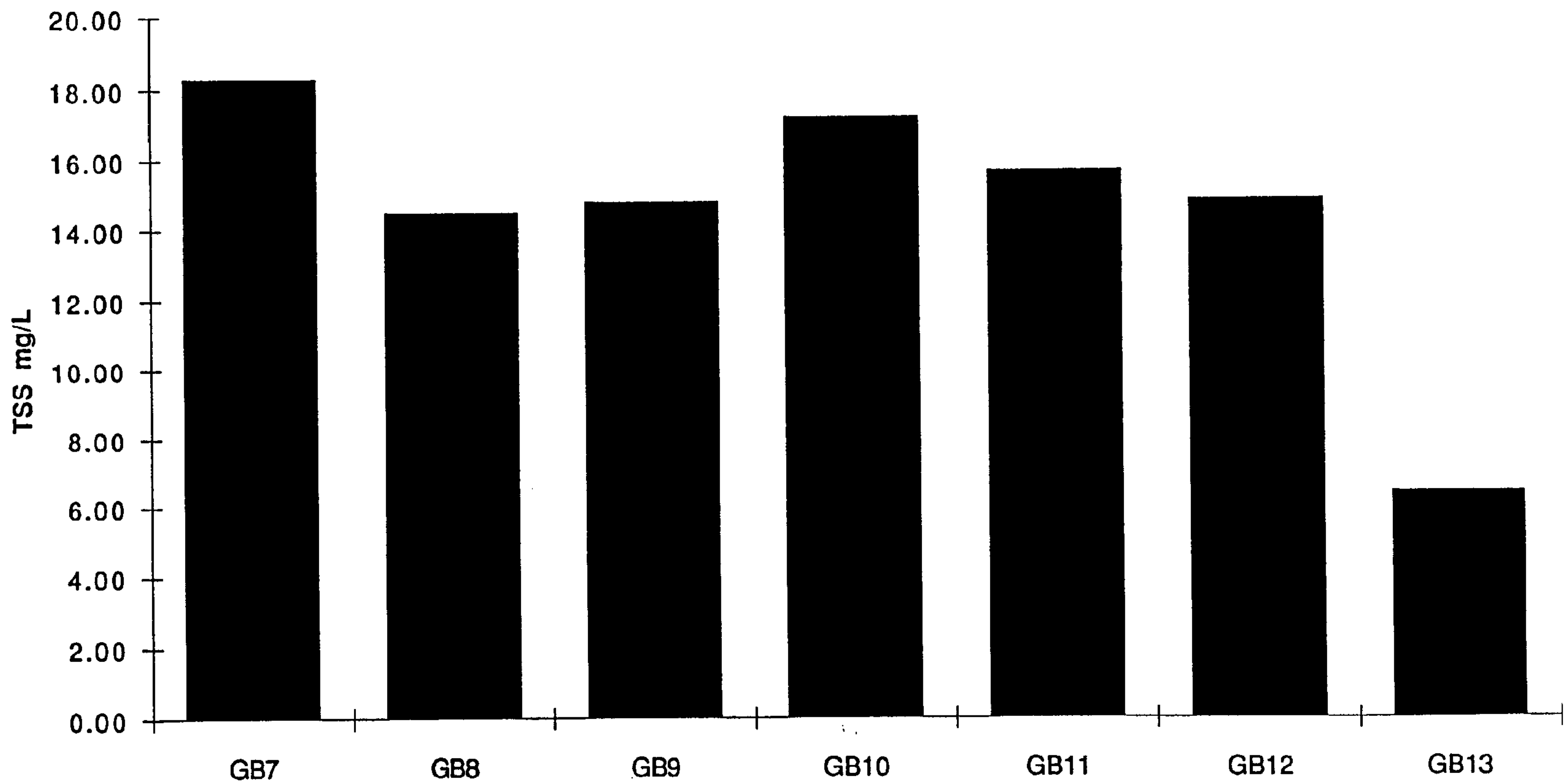


Figure 29. TSS (mg/L) at the mouths of tributaries to the Squamscott River

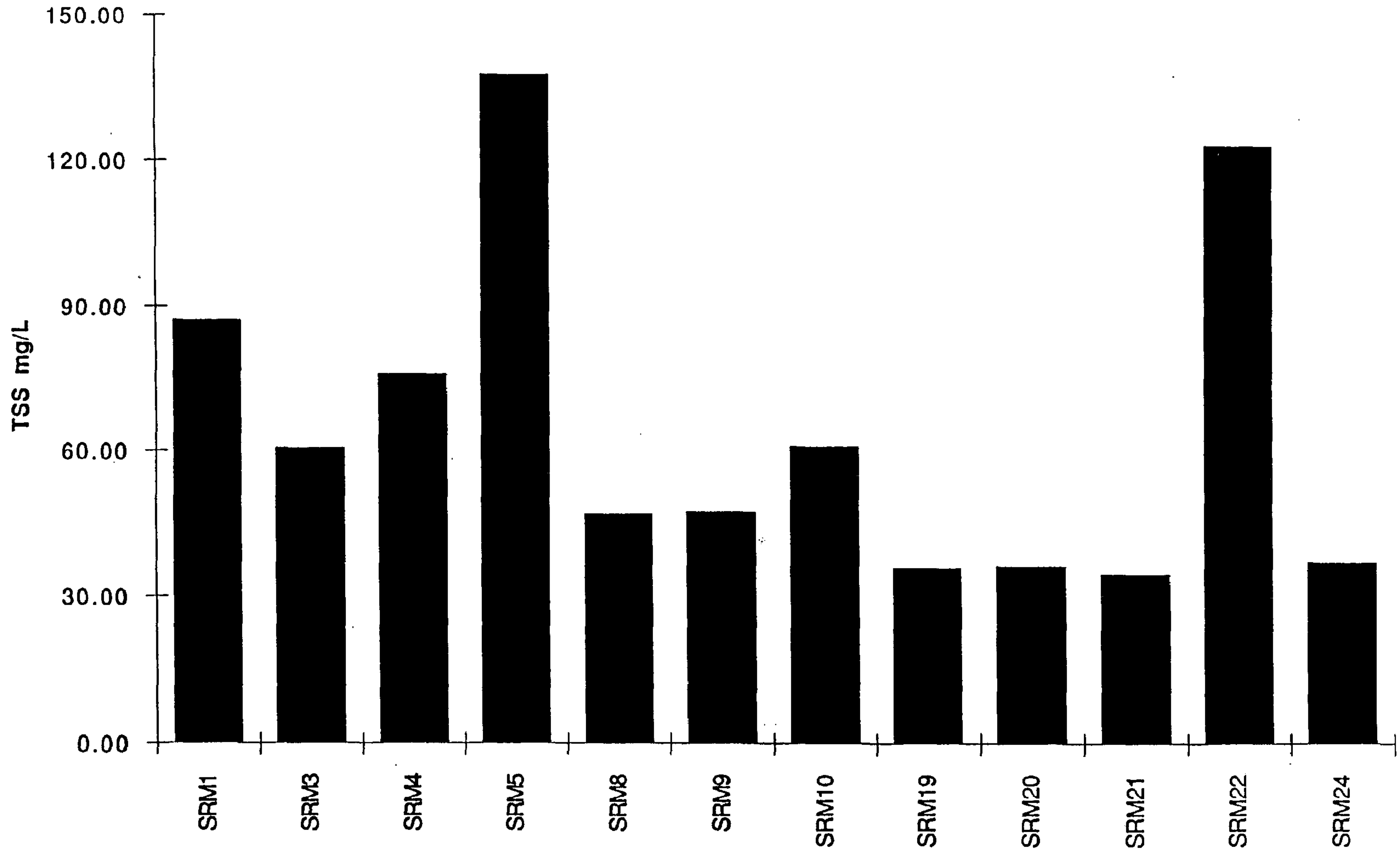
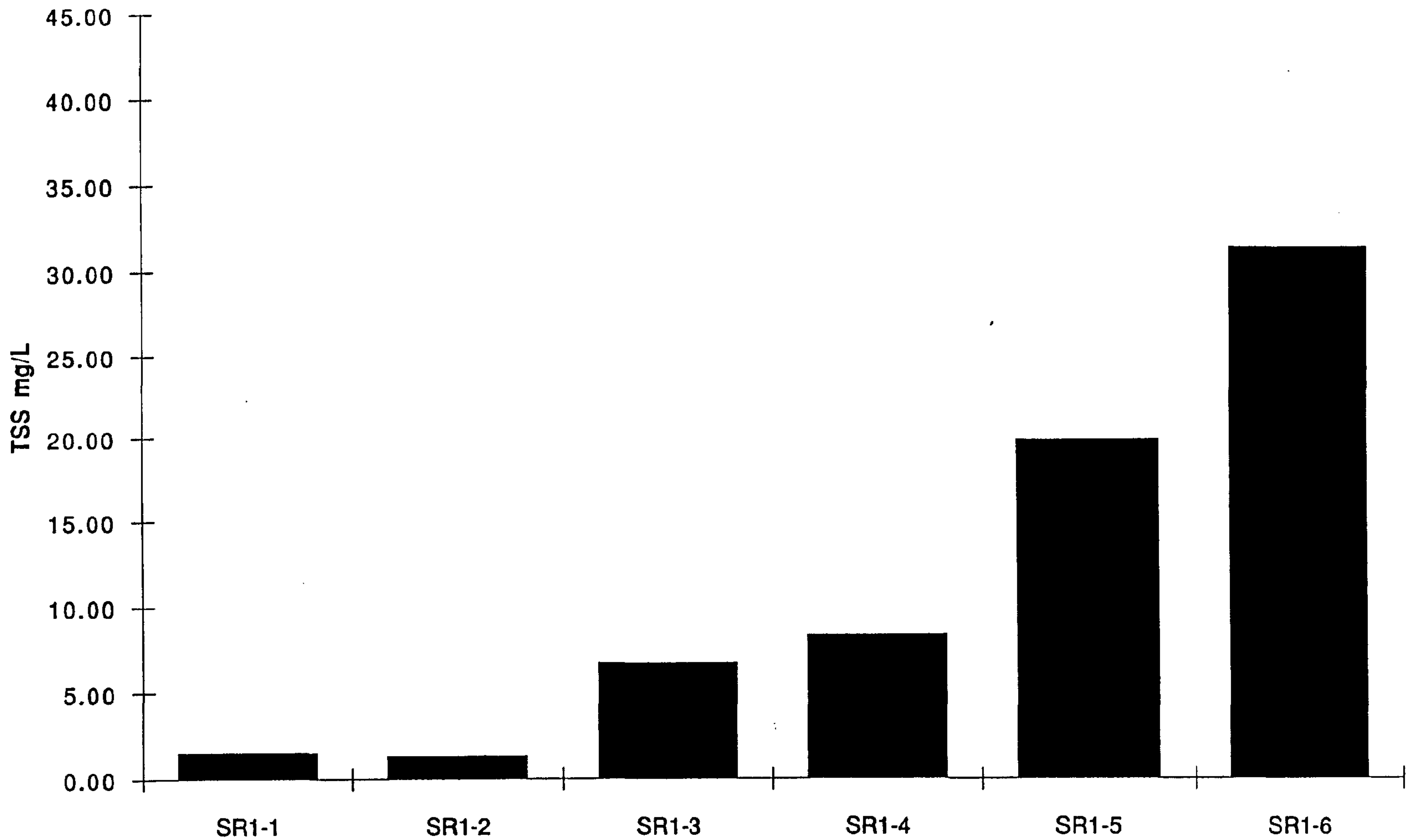


Figure 30. Mean total suspended solids in a small tributary going downstream to the Squamscott River



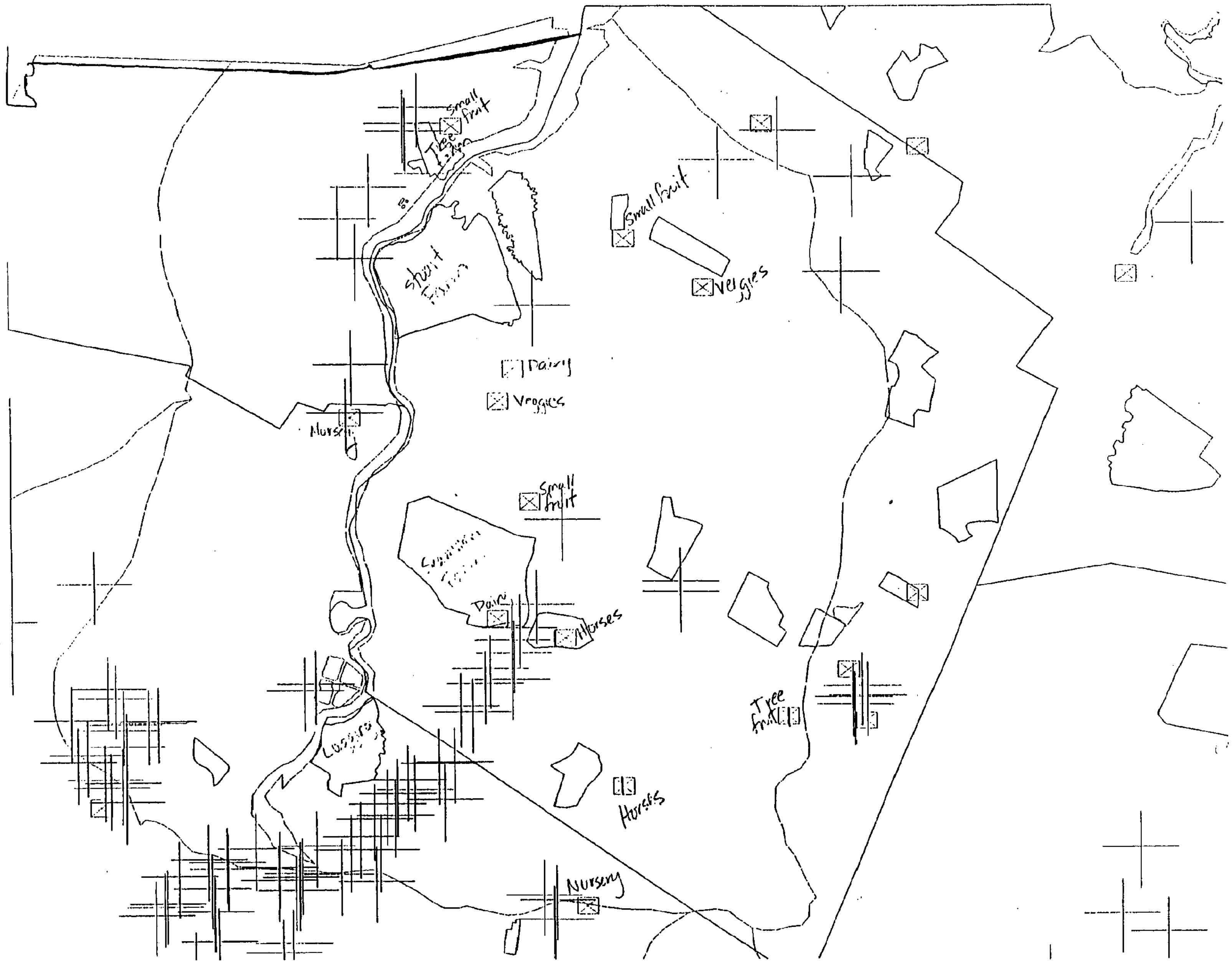


Figure 31. Location of farms and other potential sources of contamination in the Squamscott River watershed.

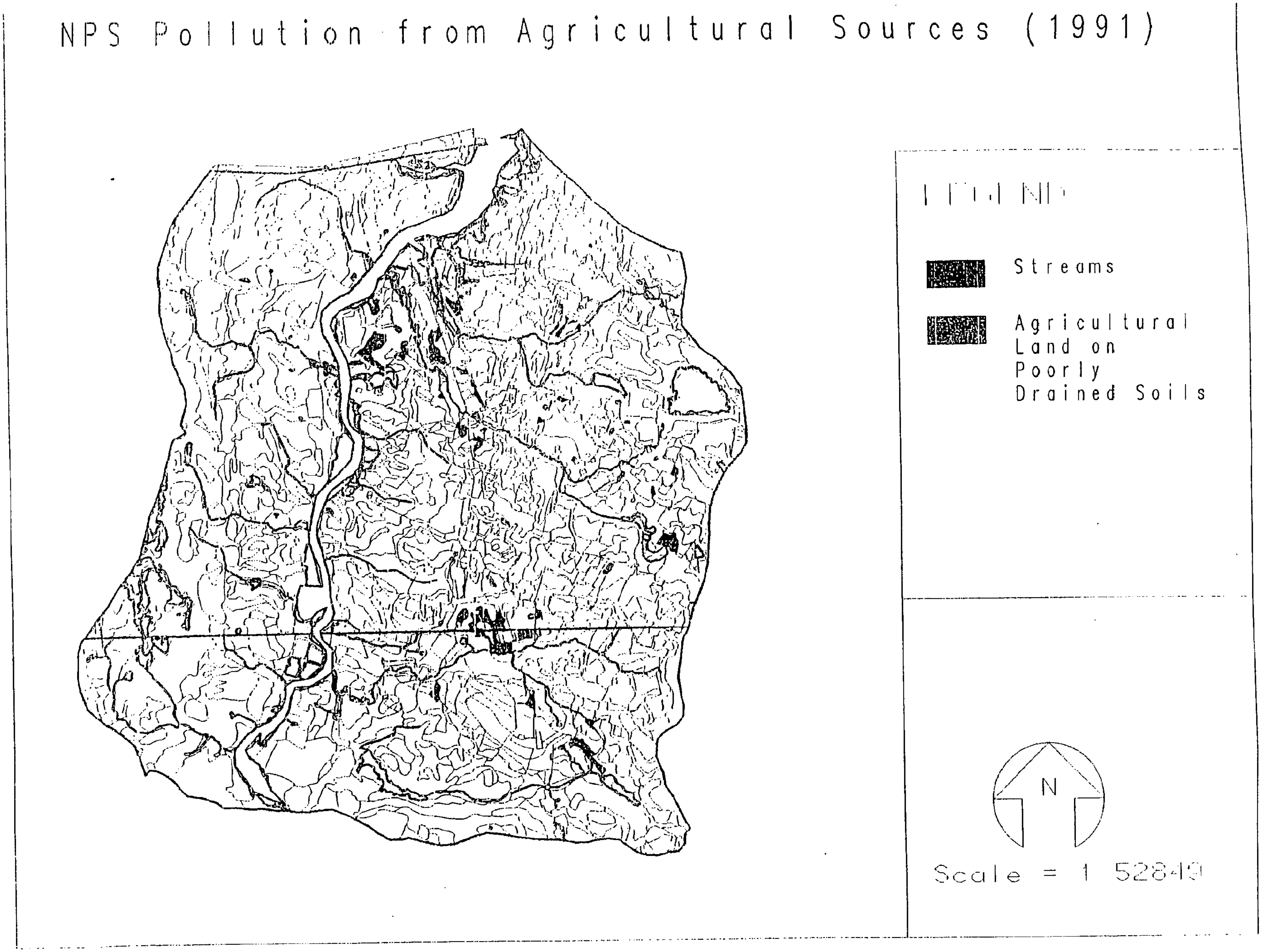
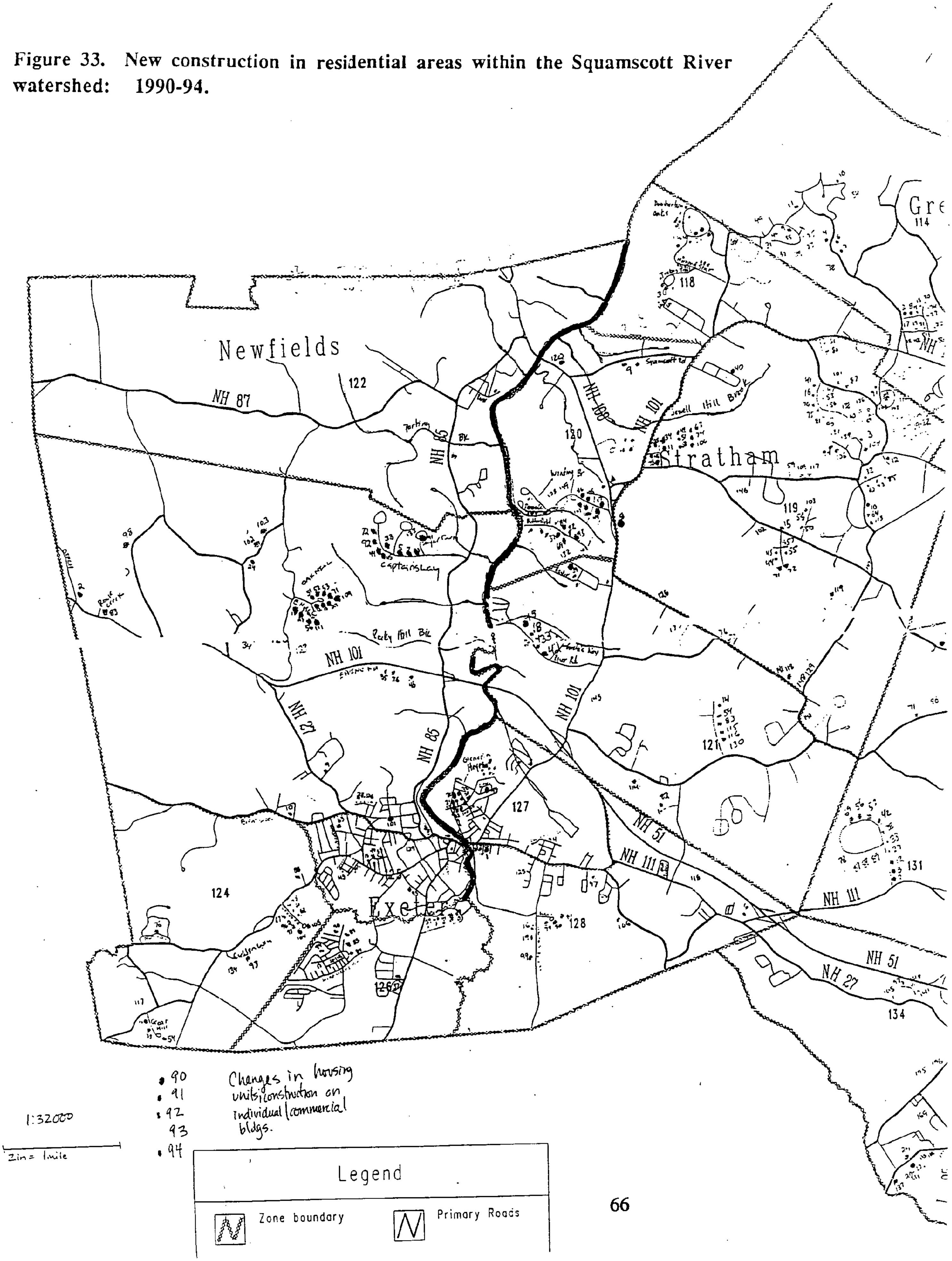


Figure 32. Location of agricultural lands on poorly drained soils in Stratham: 1991.

Figure 33. New construction in residential areas within the Squamscott River watershed: 1990-94.



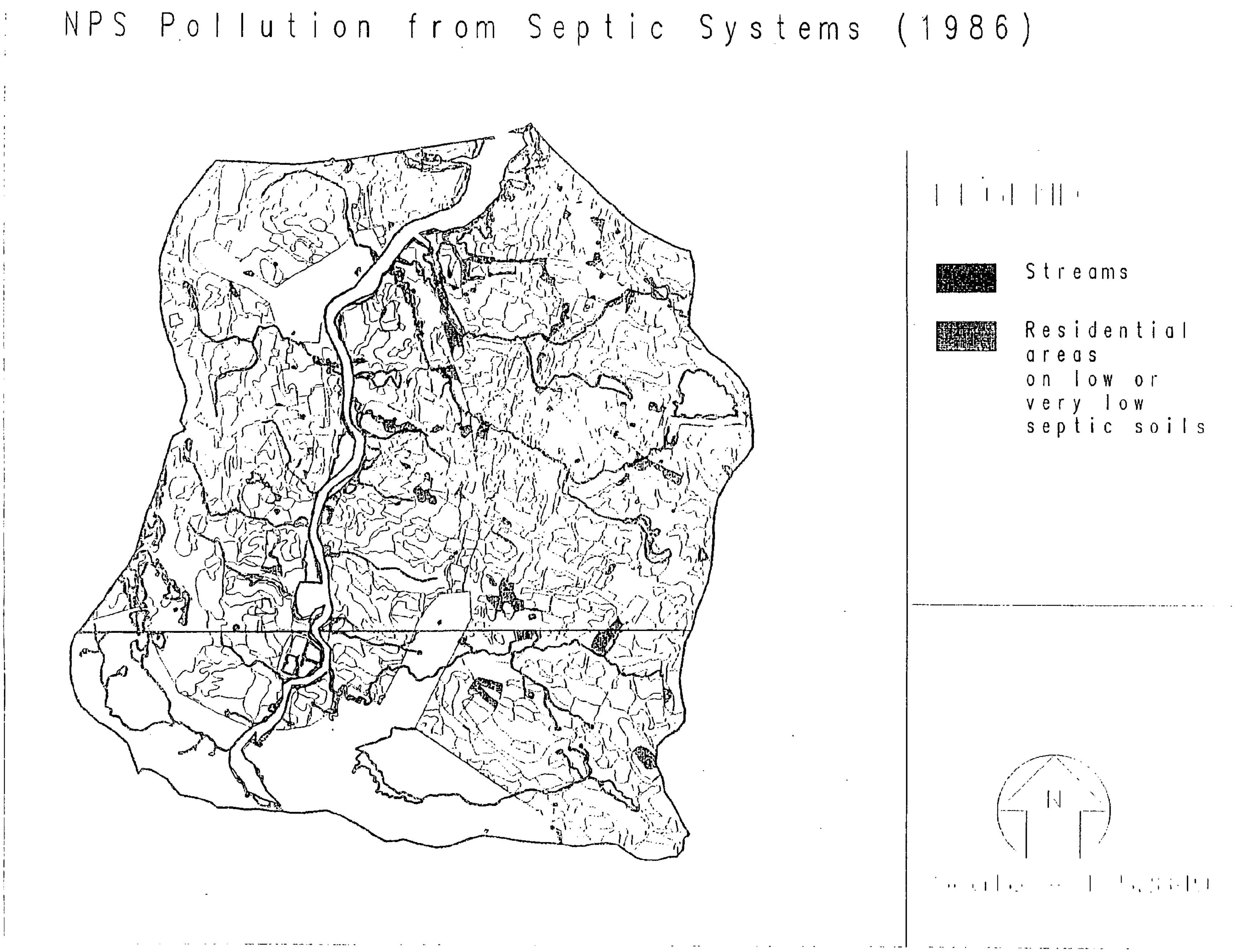


Figure 34. Residential areas on soils with low or very low potential for septic systems in the Squamscott River watershed: 1986.

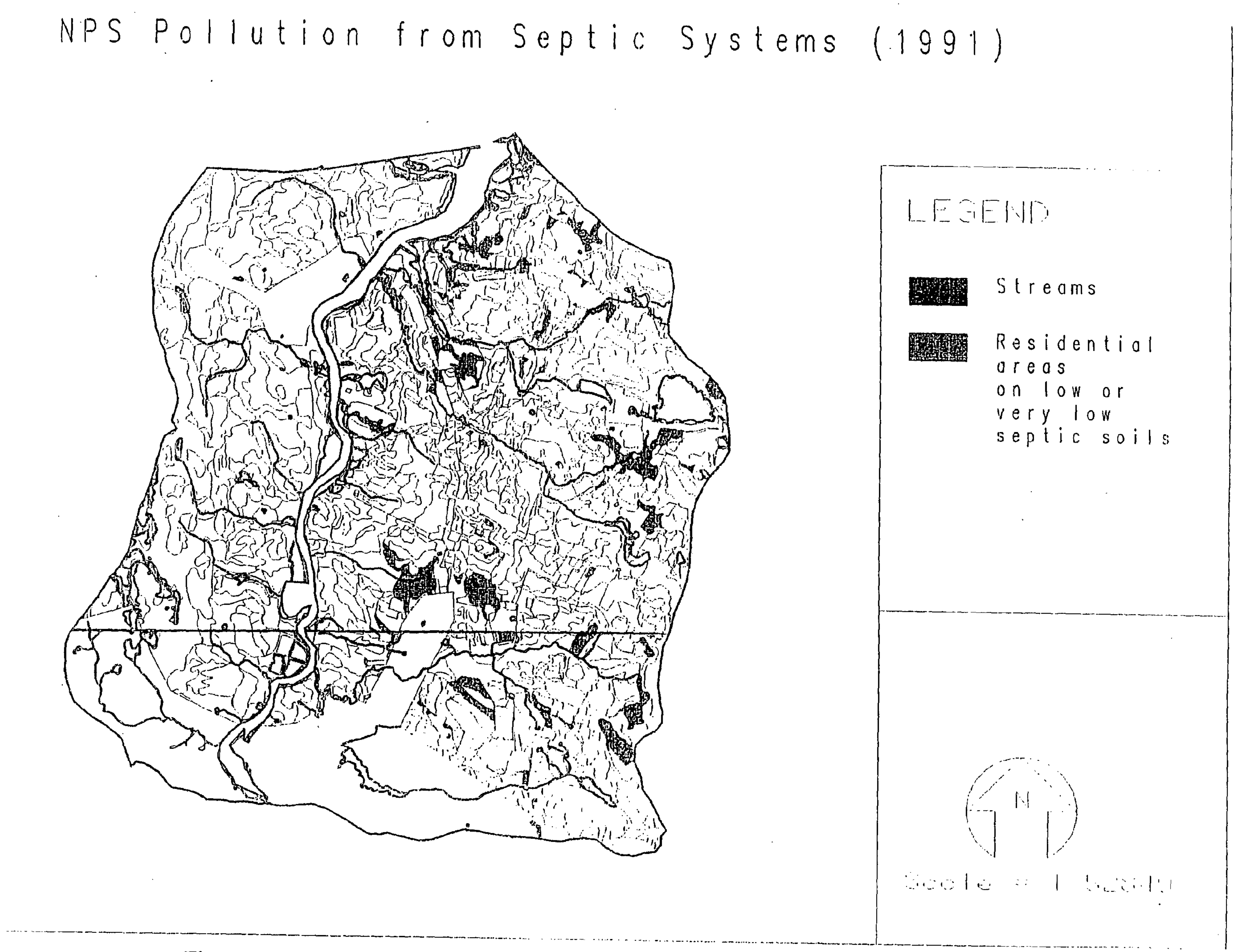


Figure 35. Residential areas on soils with low or very low potential for septic systems in the Squamscott River watershed: 1991.

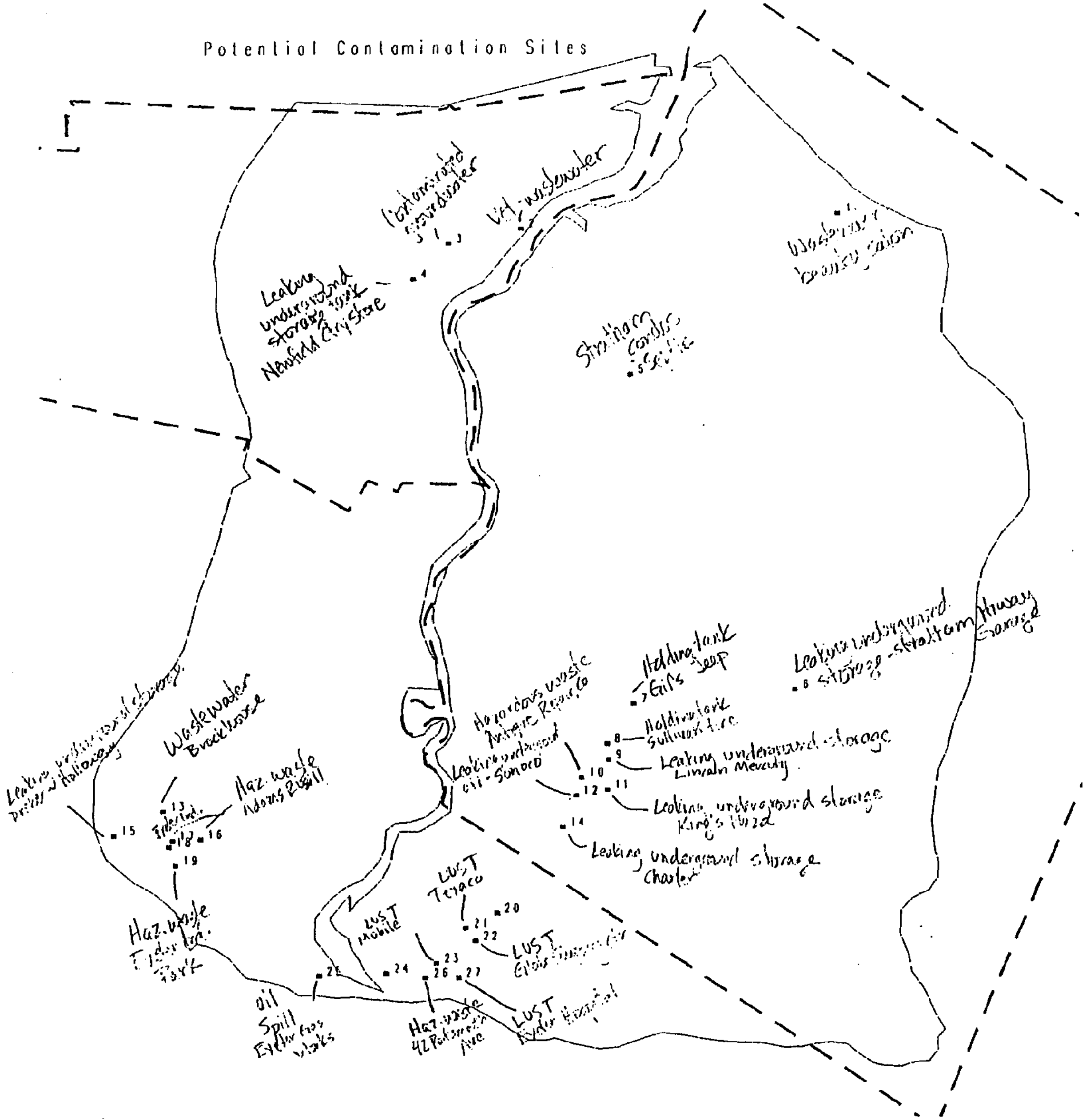
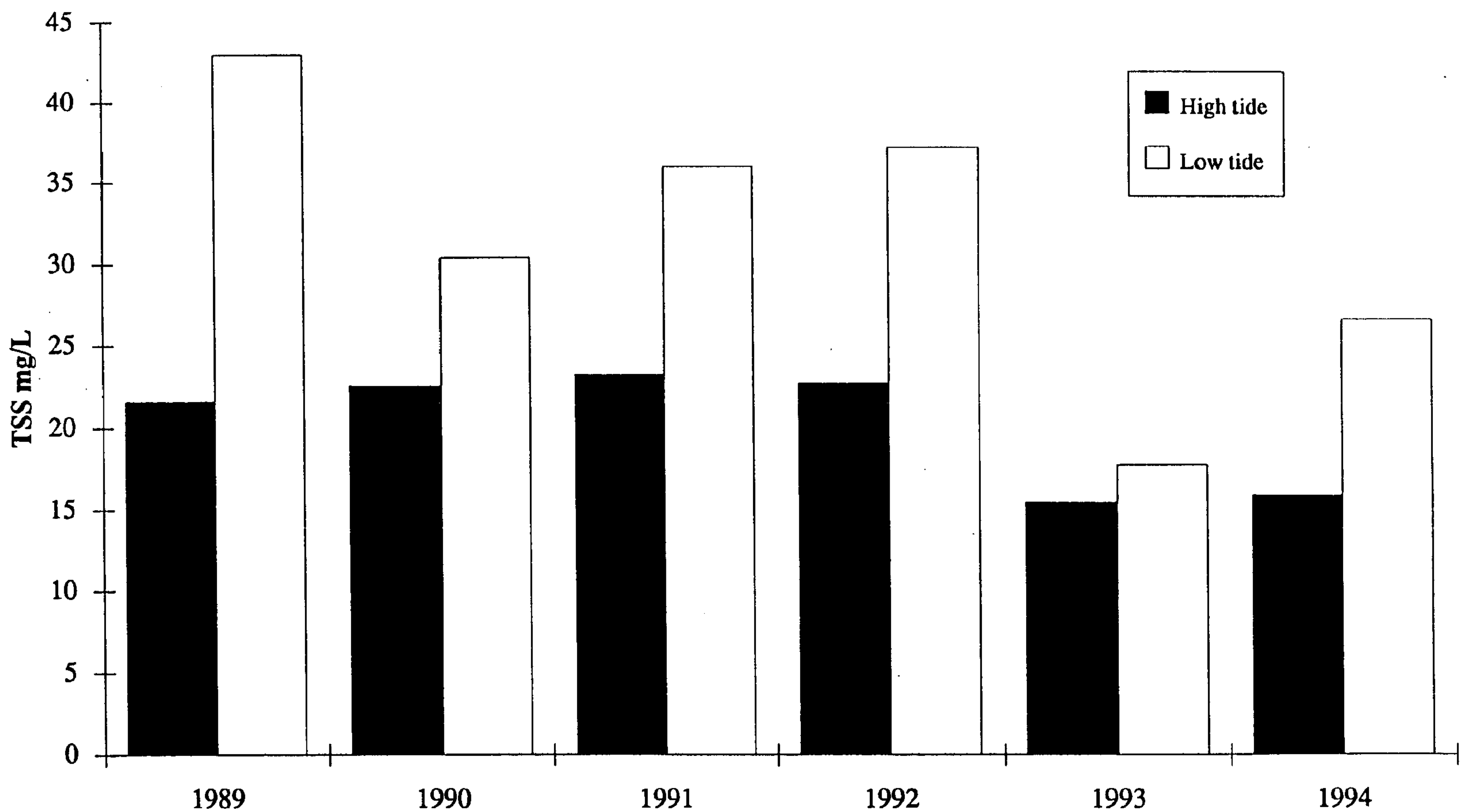


Figure 36. Locations of potential sources of other types of contaminants in the Squamscott River watershed.

Figure 37. Annual averages of monthly total suspended solids at Chapmans Landing in the Squamscott River: 1989-1994.



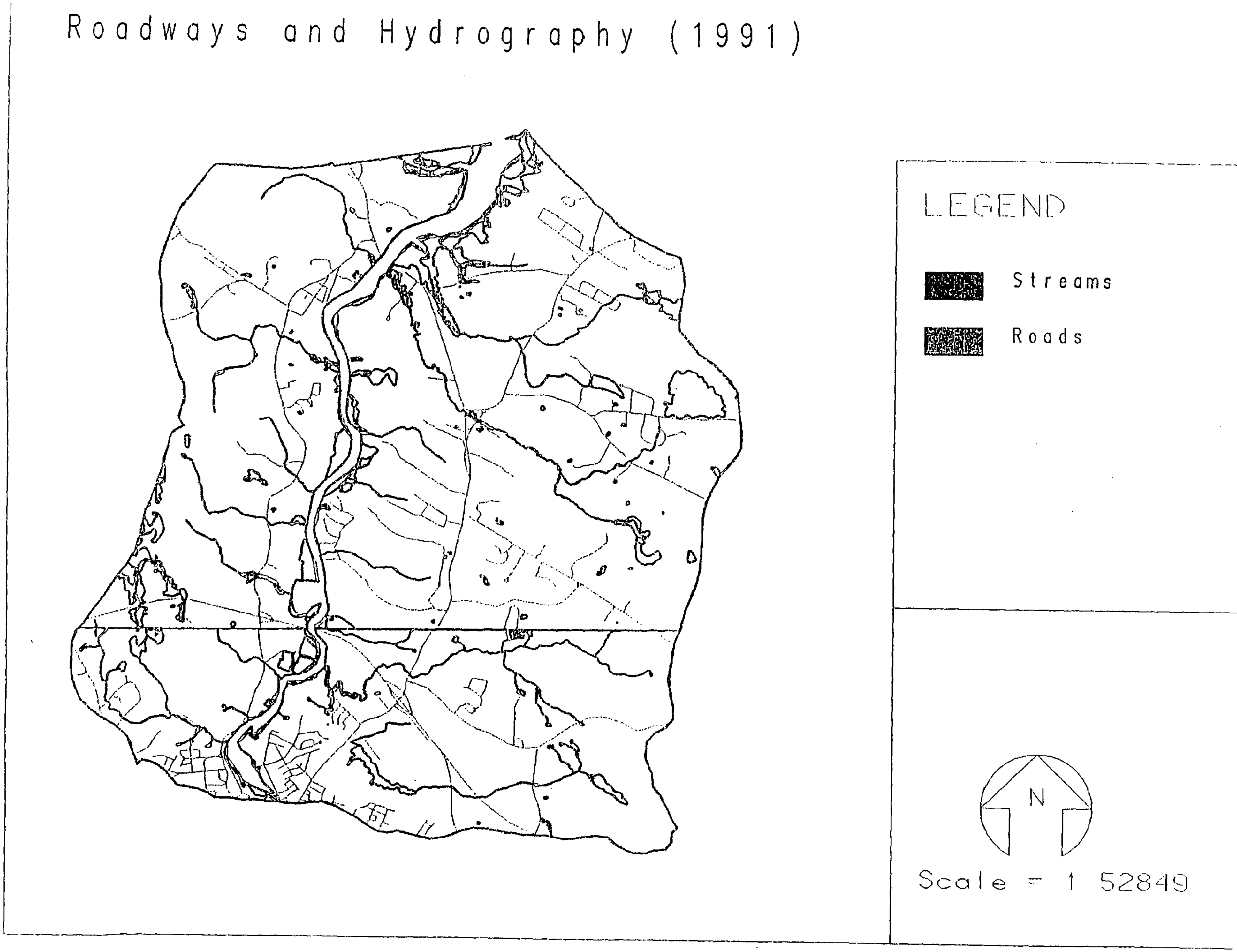


Figure 38. Roadways and hydrography in the Squamscott River watershed: 1991.

Figure 39. Building permits within the Squamscott River watershed: 1990-94.