FENGER BROOK
WATERSHED MANAGEMENT STUDY

CITY OF NEW LONDON AND
TOWN OF WATERFORD, CONNECTICUT

MAY 1996

Prepared For:

Coastal Resources Management
Sea Grant Marine Advisory Program
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EXECUTIVE SUMMARY

The Fenger Brook Watershed, located in southeastern Connecticut, is a small estuarine watershed consisting of a freshwater stream, two large salt water basins, and a tidal river. The basins and tidal river make up Alewife Cove (the Cove). The watershed falls within the boundaries of the Town of Waterford and City of New London. The main source of freshwater to the Cove is the small freshwater stream, Fenger Brook.

Several studies have shown that Alewife Cove exhibits signs of ecological stress. The specific problems include elevated fecal coliform bacteria concentrations, algae blooms, high sedimentation rates, and freshwater flushing associated with intense stormwater runoff. These problems have resulted in the degradation of the Cove's water quality and have impaired the use of the Cove for fishing and recreation.

The Fenger Brook Watershed Management Study was undertaken in order to identify non-point source pollution impacts to Alewife Cove and to develop a strategy to mitigate such impacts. The evaluation involved the following components:

- Development of a Geographic Information System (GIS) database including the pertinent natural features and land use characteristics of the watershed.
- A detailed land use analysis using the GIS database to evaluate watershed features and evaluate pollutant loadings.
- A review of stormwater management practices to identify measures that could be implemented or modified to improve water quality of the Cove.
- A review of local regulations, including zoning, sub-division, and wetlands regulations to evaluate the effectiveness in minimizing and controlling non-point source pollution.
- An investigation of the water quality in Alewife Cove and the watershed which included a review of previous reports as well as supplemental studies of the Cove and watershed wetlands.
- Development of pollutant loading factors based upon land use characteristics.
- An assessment of non-point source pollutant loading for the Watershed to identify and quantify significant non-point source pollution contributions.
- An assessment of potential best management practices (BMPs), including a cost/benefit analysis, for implementation in the watershed.
- A review of the Fenger Brook Watershed study approach for non-point source pollution management applications in other coastal watersheds.

The following is a summary of the findings of the study, recommendations for the Fenger Brook/Alewife Cove Watershed, and recommendations for the evaluation of other coastal watersheds.

E.1 Summary of Findings

E.1.1 Watershed Management/Land Use

1. The most significant land uses in the watershed are urban and residential.

2. Some existing stormwater management measures in the watershed can be improved. Such improvements include better catch basin maintenance in New London and improved erosion control implementation and street sweeping measures in Waterford.

3. A number of areas adjacent to the Cove remain un-sewered. Additionally, a sanitary sewer pump station along the perimeter of the Cove has historically failed, resulting in the release of untreated sewage to the Cove. Both of these potential sources will be eliminated with tie-ins to a new sewer main and the replacement of the pump station. (Approximately 90 percent of the tie-ins have been completed as of the end of 1995.)

4. Approximately 13 percent of the watershed is potentially available for new development. This includes only those areas not delineated as wetland. The majority of developable area is within Waterford.

5. The regulations for both Waterford and New London can be modified to reduce non-point source pollution impacts. Enhancement to/of the regulations can also be implemented by both municipalities to improve stormwater management and reduce non-point source pollution.

6. A portion of the Fenger Brook Watershed has possibly been diverted to a nearby coastal watershed due to the construction of a railway in the 1850s; however, it is not certain that the area in question was a part of the original watershed. The topography of the area makes it difficult to determine whether the area north of the railroad line drained to Fenger Brook or to another watershed prior to the construction of the railroad.

E.1.2. Water Quality Characterization

Alewife Cove is currently classified by the Connecticut Department of Environmental Protection (DEP) as a Class SB/SA coastal water, indicating that the Cove is not meeting water quality goals. Existing data indicates that several conditions contribute to the non-attainment of a Class SA status. These include the following:

1. An ecological assessment of Alewife Cove conducted during the summer of 1993, indicated that the Upper Cove is eutrophic. This is consistent with previous studies of the Cove. High nitrogen concentrations are the likely cause of the eutrophic conditions as the Cove is an estuarine system.

2. Fecal bacteria concentrations in the Cove are above shellfishing standards resulting in the banning of shellfishing.

3. The Cove is subject to high localized sediment loads from discrete stormwater system outfalls.

4. Previous studies indicate that freshwater flushing associated with stormwater causes a high salinity variation in the Cove resulting in stress on organisms within the Cove.

As with the Cove, Fenger Brook is currently not meeting the water quality goals for a Class A surface water. Fenger Brook is currently classified by the DEP as a Class B/A surface water. The results of the sampling effort undertaken as part of this report support the fact that the Brook is not meeting the water quality standards for a Class A surface water. Sampling results indicate that Fenger Brook is subject to fecal coliform contamination.

A wetland assessment performed for the watershed indicated that the wetlands, overall, are of good integrity. However, impacts to the wetlands as a result of stormwater discharges, specifically channeling, erosion, and sedimentation, were identified. These impacts can be reduced via improved stormwater management or mitigative measures.

E.1.3 Pollutant Loading

1. An evaluation of potential pollutant loading to the Upper and Middle Coves, consisting of total suspended solids and nitrogen, was performed.

2. The pollutant loading analysis indicated that the significant sources of non-point source pollution are attributed to the urban and residential areas within the watershed.

3. The most significant loads to the Cove were determined to be contributed by areas immediately adjacent to the Cove including areas with stormwater collection systems that discharge directly to the Cove.

E.1.4 BMP Evaluation

A BMP Evaluation was performed to identify potential BMPs that could be implemented in the watershed to reduce pollutant loadings. The evaluation targeted those pollutants of concern. BMPs were separated into two categories: those measures for which cost and effectiveness could be quantified and those for which quantification was not possible. The cost and anticipated effectiveness of several structural and non-structural measures were determined. Other measures, such as regulatory controls, were described with the anticipated requirements and effectiveness qualified. The following conclusions were developed based on the BMP evaluation.

1. The BMP evaluation indicates that the most cost-effective measures that could be implemented in the watershed for pollution reduction to the Cove include improved street sweeping practices, annual catch basin maintenance, conveyance of stormwater runoff to level spreaders discharging to forested areas, sand filters, and a fertilizer management program.

2. BMPs can be implemented in a phased approach in conjunction with water quality monitoring of the Cove to determine the effectiveness of such measures. Measurable improvement in water quality may be attained before implementation of all measures.

3. Recommended modifications to the regulations for both municipalities include specific revisions to the zoning and subdivision regulations to reduce impervious areas, minimize concentrated run-off flow, and increase infiltration; revisions to the wetland

regulations to increase regulated areas and activities; and improvements to stormwater system maintenance and garbage collection for private property owners. It is also recommended that municipal staff members receive formal stormwater/non-point source training.

4. The existing wetland systems can be restored to improve runoff quality and wildlife habitat. Potential retrofits include level spreaders, check dams, stream bank stabilization, enhancement of channel geometry, and creation of channel pools.

5. It is not certain whether restoration of the "historical" Fenger Brook Watershed by diversion of the area north of the railroad that currently drains to Jordan Cove will improve the quality of Alewife Cove. A detailed environmental impact assessment should be performed to fully evaluate rediverting this drainage area.

E.1.5 GIS Database

1. The GIS database was developed as part of the Watershed Management Study. The GIS database was used to delineate and map land uses and other pertinent watershed features such as topography, soil types, wetlands, watercourses, storm drainage systems and sub-drainage area boundaries within the watershed.

2. The GIS database was used to develop weighted curve numbers for use within the TR-20 hydrologic model developed for the watershed.

3. GIS was successfully used to assess potential pollutant loads to Alewife Cove from the varied land uses in the Watershed. Pollutant loading factors were assigned to each land use within the Watershed for the pollutants of concern. For each subwatershed, total annual loading of pollutants were calculated using the GIS database.

E.2 Recommended Measures for the Fenger Brook/Alewife Cove Watershed

1. A phased approach for implementing BMPs in the watershed should be used. The phased approach would involve implementing BMPs from the most cost effective to the least. A phased approach in conjunction with water quality monitoring would improve the quality of the Cove and minimize costs associated with implementing BMPs. The following BMPs should be considered in the watershed:

   - Improved and increased street sweeping
   - Level spreaders installed at locations that discharge to forested areas
   - Sand filters
   - Catch basin maintenance in New London

   Finally, retrofits to the existing wetlands can be implemented to improve the natural ability to up-take nutrients and reduce solids.

   (Section 6.5 of the report provides the order and locations in which BMPs could be implemented.)

2. Potential non-point source pollutants could be addressed in part by strengthening the local zoning, wetland or subdivision regulations or by requiring that certain

procedures be implemented as a condition of local permit issuance. Recommendations regarding local stormwater management practices which could be addressed within the local review/approval process might include:

- Requiring permanent stormwater treatment systems, that are proven to help reduce non-point source pollution of receiving waters, for future developments. Such facilities should account for post-construction pollution.

- Reducing impervious areas and increasing infiltration in areas to be developed.

- Reducing direct discharges to wetlands and watercourses.

- Consideration for requiring maintenance of stormwater systems for private sectors (i.e. parking lots) to complement municipal efforts in maintaining stormwater systems.

- Enforce garbage collection and disposal regulations for commercial and private zones.

- Enforcing sediment and erosion control policies.

3. Pursue federal funding for implementing a best management practices strategy. Some sources of potential funding include the EPA 319 Non-Point Source Pollution Grant Program, EPA Clean Water Act Section 104b program, and the Coastal Zone Management Act. Such programs would likely require matching funds by the municipalities.

E.3 Recommendations for Other Coastal Watershed Studies

The following are the critical tasks performed in the Fenger Brook Watershed Study and recommended applications for use in other coastal watershed studies.

1. Identification of the critical water quality degradation issues in the Watershed.

2. Interviews with municipal personnel provide useful information regarding existing management practices, such as street sweeping, refuse collection, etc., watershed-wide land uses, existing non-point pollution sources and future plans that might impact non-point pollution.

3. A review of existing regulations of the local governments. Generic guidelines should be developed against which regulatory controls can be measured for adequacy.

4. A site survey, or reconnaissance, of the watershed to collect pertinent site information such as observed water quality, land uses in the watershed, and potential areas of concern.

5. Use of a GIS database for pollutant loading assessment as an effective way to identify significant potential sources of non-point source pollution. Existing stormwater management measures/features in the watershed should be accounted for in developing the loading evaluation.

6. An assessment of the development capacity in the watershed should be conducted. This can provide information on impacts to the watershed that may occur under future development and allow for planning to address future development.

7. Evaluation of potential BMPs for the watershed. A cost/benefit evaluation should be utilized to select and prioritize the appropriate BMP measures.

8. Mapping of zoning data could be used in watershed management programs to assess the impact of changing of zoning or new developments. (Note that for the Fenger Brook Watershed Study, zoning was mapped but development scenarios were not evaluated.)

9. Evaluation of the watershed on an individual property parcel or lot basis is not recommended in other studies. It is recommended that a watershed be separated into sub-drainage areas and evaluated by the major land uses within these drainage areas. Evaluating land uses with the GIS database on a micro-scale, i.e. lot basis, resulted in time-consuming information retrievals and map production that did not provide useful data.

10. Use of hydrologic modeling in a watershed study is recommended if the flows, with sample results, are going to be used to simulate pollutant loadings. Hydrologic modelling is particularly valuable when stormwater management and/or flood control storage is contemplated as a means to reduce peak flood flows and peak flow velocities in receiving watercourses. Its use requires detailed information on channel geometry and hydraulic structures throughout the watershed.

11. The development of a detailed storm drainage system map is not necessary for a watershed evaluation. It is more valuable to identify the individual drainage areas that are served by stormwater conveyance systems and their individual points of discharge or to simply identify the drainage destination.

12. Stormwater quality sampling should not be a one-time event. Sampling should be undertaken in such a fashion as to provide a useful data set for evaluation. The costs of such efforts are an important consideration in developing a sampling program.

1.0 INTRODUCTION

The Fenger Brook Watershed, located in southeastern Connecticut, is a small coastal watershed consisting of a freshwater stream and an estuarine system - Alewife Cove (the Cove). The drainage area of the watershed is approximately 1,130 acres consisting primarily of residential/urban and forested areas. The watershed falls within the boundaries of two municipalities: the Town of Waterford and the City of New London. Alewife Cove, which is approximately 42 acres (17 Ha) in size, consists of two large basins, the Upper and Middle Coves, as well as a tidal river referred to as the Lower Reach. The main source of freshwater flow to the estuary is Fenger Brook, a small freshwater stream that runs the length of the watershed. A site map, that shows the major features of the watershed, is provided in Figure 1.1.

Alewife Cove is an estuary of the Long Island Sound, and, as such, is tied to the water quality of the Sound. Comprehensive studies reveal severe degradation to the water quality of the Sound (LISS, 1994). The water quality of the Sound has been impaired by past and existing uses. Residential, commercial, and recreational development have increased pollution, altered land surfaces, reduced open spaces, and restricted access to the Sound. Development along the Sound has increased waste disposal and runoff and has reduced the natural processing mechanisms used to reduce pollutant loadings. These problems are similar to those associated with Alewife Cove.

Previous studies have shown that Alewife Cove exhibits signs of ecological stress. The specific problems include elevated fecal coliform bacteria concentrations, algae blooms that occur during the summer months, and high sedimentation rates. Additionally, freshwater flushing of the Cove associated with intense runoff, has been identified as causing stress to organisms within the Cove. These problems have resulted in the degradation of the Cove's water quality and have impaired the use of the Cove for fishing and recreation.

The purpose of the management study was to identify significant non-point pollution sources that lead to the degradation of the Cove and evaluate potential measures to minimize the impacts. To achieve this goal, several tasks were performed as follows.

Data Collection - Spatial data coverages (i.e., parcels, water bodies, land uses) used in the watershed evaluation were compiled from either analog or digital sources, rectified and merged, using ESRI's ArcCAD software package, in a Geographic Information System (GIS) database. The sources of this data included the City of New London, Town of Waterford, and Connecticut Department of Environmental Protection.

Land Use - A detailed land use analysis was developed to provide a basis for non-point source pollution load evaluation.

Watershed Management - A review of existing management practices and regulations relative to stormwater runoff was performed to determine the extent of existing measures in the watershed. Recommended improvements to these measures were included.

Watershed Mapping - The GIS database was used to map the watershed and as a tool to evaluate the watershed. The software package used for mapping was ArcView. The GIS data base was used to develop land use coverages, sub-watersheds and drainage areas, and other pertinent watershed features including roads, waterways, and soil coverage. The GIS database was used to produce mapping included in this report.

Water Quality Characterization - An evaluation of the existing water quality of the Cove was performed to identify the major pollutants leading to the degradation of the Cove. The evaluation consisted of a review of previous studies performed on the Cove as well as additional assessments of the watershed wetlands, watercourses, and Cove.

Watershed Hydrology - A hydrologic evaluation of the watershed was performed to determine the runoff response. The Soil Conservation Service TR-20 Hydrologic model was used to develop a hydrologic analysis of the watershed and subwatersheds. The GIS database was used to develop some of the model parameters.

Pollutant Loading Assessment - A pollutant loading assessment was performed to identify the significant areas contributing pollutants to the Cove. Land use coverage and loading factors reported in the literature were used in the assessment. GIS was used to relate the spatial database to the pollutant loading factors and queries were performed on the drainage basins. This system allowed multiple iterations with various pollutant loading scenarios to be performed efficiently and accurately.

Evaluation of Best Management Practices - Stormwater best management practices, including structural and non-structural measures, were evaluated to determine the most effective means of reducing non-point source pollution to the Cove. This included a cost/benefit analysis of several BMPs.

Identification of Funding - Several potential mechanisms for funding the implementation of BMPs in the watershed were identified.

An additional objective of the study was to evaluate the approach developed herein for application to other coastal watersheds. The study provides a review of the approach used in the evaluation of the Fenger Brook/Alewife Cove Watershed to assess its application in other coastal watersheds.

2.0 WATERSHED MANAGEMENT/LAND USE ACTIVITIES

Aquatic ecosystems in urban watersheds are particularly susceptible to the impacts of urbanization. No single factor is responsible for their progressive degradation. Rather, it is typically the cumulative impacts of many individual factors such as sedimentation, scouring, increased flooding, lower summer flows, higher water temperatures, and pollution. The net affect of urbanization is to increase loading and rate of transport to receiving waters. The impact of the higher loading is exhibited in adjacent streams and downstream receiving water bodies.

The evaluation of current watershed stormwater management and land use activities and existing regulatory requirements must be performed in order to identify the activities associated with development that will likely result in the most severe receiving water impacts.

2.1 Methodology

The evaluation of current watershed stormwater management, land use activities and existing regulatory requirements involved several tasks. These included interviews with Municipal managers, field surveys performed throughout the watershed, and a review of the municipal regulations relative to environmental protection and stormwater management.

Meetings with municipal staff were performed to determine existing stormwater management practices performed in the Fenger Brook watershed. Meetings were held with staff from the City of New London and Town of Waterford including Town Planners, Peter Gillespie (New London) and Tom Wagner (Waterford), Department of Public Works (DPW) Michael Gambro (New London) and Edward Steward (Waterford), Director of Public Utilities, Arthur Petrini (New London), and Environmental Planner, Patricia Snarski (Waterford) as well as James McDermott, Director of New London Public Works.

The field surveys of the Fenger Brook Watershed and the surrounding area were performed to observe first-hand existing stormwater practices and potential sources of non-point pollution. (Surveys were conducted on July 7, October 26 and 27, 1993 and May 18, 1994.) The watershed field surveys provided information regarding land use practices, drainage area boundaries, existing stormwater control systems and watershed management practices, and whether existing local regulations were enforced.

To identify existing regulatory measures relative to environmental protection and stormwater management, a review of local land use regulations including zoning, wetlands, and subdivision regulation for New London and Waterford was performed. The purpose of such a review was two fold. The first was to identify existing regulatory measures that serve to protect the quality of Alewife Cove and the second was to determine what regulations could be improved to enhance the quality of the Cove. (A summary of the regulatory review is contained in Appendix A.)

The following sections describe the evaluation of current land use activities, watershed stormwater management practices, and regulatory requirements affecting non-point source pollution.

2.2 Watershed Land Uses

Non-point source pollution, particularly from urban runoff, may contribute significant sediment and nutrient loadings to watercourses. Excessive nutrient and sediment loads may lead to degradation of the water quality in the Fenger Brook Watershed. The following are land uses identified in the watershed and the potential non-point source pollutants typically associated with these land uses. A land use map developed from information provided by Waterford and New London is depicted in Figure 2.1. The following sections summarize the significant land uses within the watershed.

A number of specific locations are called out in the following sections. Figure 1.1 provides a site map with the location of the significant items and can be used to identify their locations within the watershed.

2.2.1 Low/Medium and High Density Residential Land Uses

As indicated in Figure 2.1 and Table 2.1, low/medium and high residential areas are a significant land use within the watershed. (High density residential areas are considered to be two family residential units or larger and single family residential of less than one-half acre). The watershed surveys included an assessment of the residential areas. The assessment was cursory and did not include a detailed overview of residential land use practices such as fertilization, composting or other activities with the potential to affect stormwater runoff. However, the survey did reveal some significant findings as follows.

1. In New London, piles of yard wastes, consisting of grass clippings, leaves and tree branches, were observed at the ends of streets overlooking Alewife Cove. The wastes are a potential source of sediments and nutrients to Alewife Cove.

2. An eroded embankment was observed at the end of Greenway Road and may be a source of sediments to the Cove. The erosion was likely the result of the discharge from a concrete swale outlet, with no flow dissipation, at the top of the bank.

3. The stormwater collection/conveyance system in residential areas within New London were observed to be antiquated. Observations of the stormwater system indicated that many catch basins either had no sumps or the sumps were filled with sediment. A number of catch basins were observed with significant sediment build-up. The system was likely installed many decades ago when regard for stormwater detention or pollution reduction was not typical.

4. A new subdivision, which was approximately one-third complete at the time of the survey, located at Stuart Hill on Pepperbox Road in Waterford, was being developed. The houses within the new development were designed with septic systems.

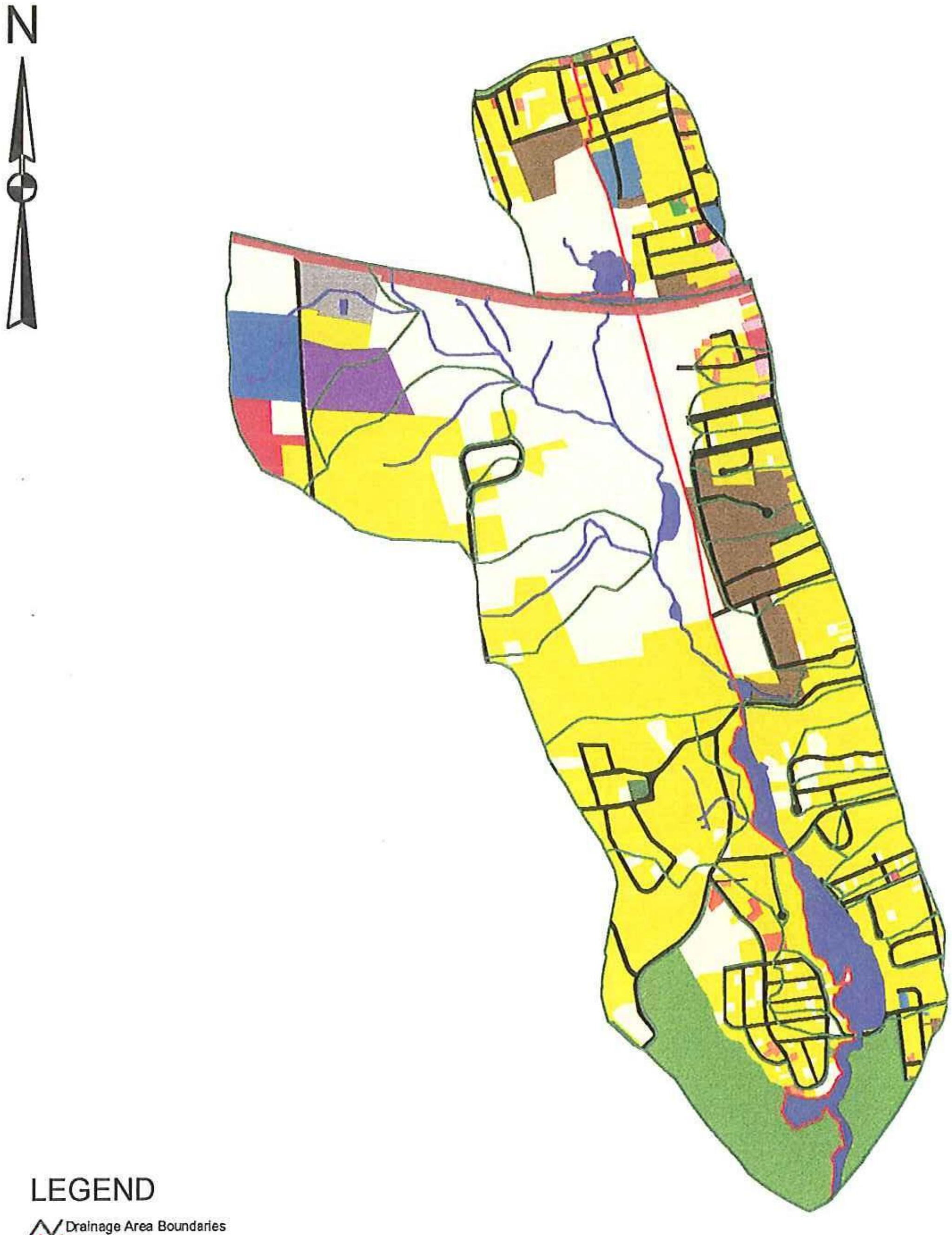
5. Most of the residential areas in New London are served by a sewer system. In Waterford, on the other hand, a number of parcels located immediately adjacent to the Cove have septic systems. A new sewerage system in Waterford was being installed which would serve the homes adjacent to the Cove.

2.2.2 Commercial, Industrial, and Utility Land Uses

The Fenger Brook Watershed has few commercial, industrial and utility land uses within it's boundaries, as can be seen in Figure 2.1. As such, these land uses are anticipated to have minimal impacts to the Cove. The following is a summary of the commercial, industrial and utility land uses.

1. The commercial land uses within the New London portion of the watershed include a car dealership at the corner of Ocean and Evergreen and several minor commercial establishments along Ocean Avenue on the eastern portion of the watershed. It was noted that the car dealership had an active groundwater remediation system in place to treat contaminated groundwater in the area.

2. The upper watershed within New London has two institutional uses including a private hospital. The majority of the drainage area from the hospital is directed to the Thames River.



LEGEND

Drainage Area Boundaries
Town Line
River/Stream
Water Bodies

Landuse

- Residential - Single Family
- Residential - Two Family
- Residential - Three Family
- Residential - Four to Six Family
- Residential - More Than Six Family
- Commerical - General Retail and Service
- Commercial - Automotive Sales and Service
- Commercial - Office
- Institutional - Private
- Utilities
- Park, Recreation & Open Space - Public
- Park, Recreation & Open Space - Private
- Open Space - Nursery
- Vacant Land
- Vacant Building
- Waterways
- Railroad
- Roadway
- Landfill
- Industry
- Residential & Farm Animal
- Trash Hauler & Piggerie

SOURCE CREDIT: LAND USE DATA PROVIDED BY CITY OF NEW LONDON AND TOWN OF WATERFORD.

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FENGER BROOK WATERSHED MANAGEMENT STUDY

Land Uses Within The Watershed

SCALE: 1" = 2000' | DATE: MAR. 1995 | FIGURE 2.1

PROJECT NO.: 92603A1 FILE NAME: J:FENGER.APR

TABLE 2.1

LAND USE PERCENTAGES IN FENGER BROOK WATERSHED

FENGER BROOK WATERSHED MANAGEMENT STUDY
DECEMBER 1995

LAND USE	AREA (acres)	% OF TOTAL
Low/Medium Density Residential	254	22.5
High Density Residential	235	20.9
Commercial/Industrial	34	3.0
Parks	66	5.9
Parking Lots/Roads	130	11.5
Agricultural	36	3.2
Forest	338	30.0
Water	34	3.0
TOTAL	1,127	100.0

3. Along the lower reach of the Cove is the Ocean Beach amusement park. The amusement park has a large parking lot located just adjacent to the Cove. Although there is a small vegetated buffer strip between the Cove and the edge of the parking lot, most of the stormwater is collected in a few catch basins or paved swales and discharged directly to the Cove.

4. A few small utilities are located in Waterford including a sanitary sewer pump station and electric utility substation associated with the railroad. Nothing of significance was noted at these locations.

5. A trash hauling facility is located on the western portion of the watershed (adjacent to the Waterford Landfill). The facility also operates a piggery. At this location, several garbage dumpsters were located outdoors and exposed to stormwater.

6. The most significant industry identified in the site survey was Connecticut Carting Corporation (CCC), located on the eastern side of Miner Lane. Operations at CCC include a solid waste management facility that engages in the following activities:

   - A collection center where newsprint is received from local collection vehicles and transferred to Willimantic Waste Paper Company.

   - Corrugated cardboard processing where used cardboard is received for recycling. The product is bales of cardboard that are shipped to a variety of markets.

   - Bulky waste processing that involves receiving and sorting wastes. Ferrous metals are segregated and shipped to market. Inert materials (rocks, bricks) are recovered for markets. Wood is processed in a grinder and the product is shipped to a market/user.

   Residue from these activities is placed in covered containers for transport and disposal off-site. Both exposed product and debris were observed during the site survey. Stormwater that comes in contact with the materials and debris generated may be contaminated with pollutants associated with paper, wood, cardboard, scrap metals and printing inks.

2.2.3 Landfill

The Waterford Landfill, a bulky waste landfill which no longer accepts typical municipal waste, located on the western side of Miner Lane was the only active landfill within the watershed during field investigations. Fenger Brook watershed bisects the landfill and approximately half the drainage area is directed toward Fenger Brook.

Observations made of the landfill indicate that adequate operation and maintenance of the landfill is performed. Drainage areas surrounding the landfill appeared to be clean and no leachate seeps were observed. A review of previous annual landfill monitoring reports demonstrated that there are minimal impacts to adjacent surface waters within the watershed (Fuss & O'Neill, 1994). The 1994 annual report includes an evaluation of nearby surface waters including those within the Fenger Brook watershed. The report also evaluates groundwater impacts. Based on a review of the report, the following is evident:

1. Groundwater in the area of the landfill flows to the north which is in a direction away from the watershed. As such, impacts from potentially contaminated groundwater flow are not anticipated.

2. There are no identified point source stormwater discharges from the landfill nor are there any leachate seeps from the landfill into Fenger Brook. Additionally, surface water quality data for the area surrounding the landfill indicate that water impacts are relatively minimal. Minor impacts have been observed in surface water in the northwestern portion of the landfill which is outside of the Fenger Brook Watershed. As such, there are little anticipated stormwater impacts from the landfill to the watershed and subsequently the Cove.

2.2.4 Agriculture

Stormwater runoff from agricultural lands is of concern because the runoff may contain high quantities of organic material, nutrients, fecal coliform bacteria, and, potentially, pesticides and herbicides. However, few agricultural activities are undertaken within the watershed. Two agricultural activities were identified in the watershed; a piggery located along the eastern side of Miner Lane and a small residential farm also located on Miner Lane. (It should be noted that the piggery was identified as an area of concern by Waterford officials.) The main portion of the piggery area is located in a natural depression or basin; runoff from a portion of the area is directed to a culvert under Miner Lane. As with the Waterford Landfill, groundwater in this area likely flows northerly away from the Cove. No specific manure management activities were observed.

2.2.5 Construction Activities

Construction activities have the potential to disturb and expose soils to runoff. Without adequate sediment and erosion controls, soils exposed to runoff have the potential to erode and introduce sediments to surface waters. The only construction activity observed during the site survey was on Niles Hill Road in the Ridgewood Park area of Waterford. Road reconstruction and stormwater system installation was conducted as well as an upgrade of the existing sanitary sewer system. Observations made of the construction activities on October 26, 1993 revealed decaying haybales used for erosion and sediment control within the brook south of Niles Hill Road. In addition, silt fence was not observed around soil stockpiles in the Ridgewood area. These stockpiles were located within close proximity to catch basins. The construction activity was found to be lacking in certain control measures and was, therefore, not consistent with State or local erosion and sedimentation control guidelines. It is significant to note that these observations were made during a single visit. According to Waterford personnel, this was a single isolated event. The Town has a strong erosion and sedimentation program in place and uses trained inspectors to oversee/inspect construction activities within the Town.

2.2.6 Railroads

Two railroad tracks, operated by AMTRAK, bound the northern section of the watershed. AMTRAK provides commuter service for the rail-line. The railroad is bounded by wetlands at the head of Fenger Brook. Waterford officials have voiced concern regarding herbicide application to the railroad bed which is performed 3 to 4 times a year. During the site survey, several additional problems were identified. These problems included the disposal of scrap metal and chemically preserved railroad ties adjacent to the railroad and, in several instances, directly into wetlands. These practices have the potential to introduce toxic chemicals, specifically herbicides, chemicals associated with the preserved railroad ties, and metals, into Fenger Brook and the upper wetlands.

2.2.7 Potential for New Development

An important factor in assessing the watershed is to determine the potential for new development. The GIS database was queried to identify the potential for new development in the watershed. This involved identifying the total open and forested areas within the watershed that are not delineated as wetlands. (Note that this method does not consider other factors such as terrain, accessibility, and other development considerations such as land ownership i.e., municipally versus private ownership.) For Waterford, the total area for potential development is approximately 117 acres and the area of potential development in New London is approximately 31 acres, for a total of 148 acres in the watershed. This accounts for more than 13 percent of the total watershed.

2.2.8 Summary

A summary of the land uses and potential impacts of such land uses discussed above is as follows:

1. The major land uses in the watershed are low and high density residential.

2. Residential areas in both Waterford and New London were observed with areas of yard wastes piled adjacent to the Cove. Sections of erosion were also observed along the banks of Alewife Cove.

3. Industry is limited in the watershed. The only industry in the watershed may contribute non-point source pollutants to the surface water; however, its proximity to the Cove (approximately 7,000 feet upstream) would minimize impacts to the Cove.

4. A single landfill is located on the boundaries of the watershed. The impact to surface waters is minimal and likely negligible within the watershed. The location within the watershed with respect to the Cove makes it unlikely to be a significant contributor of pollutants to the Cove. In addition, groundwater in the area of the landfill does not flow toward the Cove.

5. Minimal agricultural practices exist within the watershed. A piggery located on the western border of the watershed may result in some impact to surface waters. Due to the topography of the watershed in the area of the piggery, however, it is likely that the agricultural activities do not contribute pollutants to the Cove. Additionally, groundwater from the piggery does not flow toward the Cove.

6. Construction activities observed in Waterford showed a lack of effective sediment and erosion control measures; however, this was of a single event and likely not indicative of on-going practices.

7. Debris associated with the railroad is strewn along the railroad banks. Housekeeping practices by the railroad could be improved.

8. The area for potential development in the watershed is approximately 148 acres. This accounts for approximately 13 percent of the total watershed.

2.3 Stormwater Management Practices

New London and Waterford have established policies for managing stormwater. Management practices include control measures for flow volumes and pollutants. The following summarizes the various management practices, including local maintenance activities, instituted at the time of the site surveys.

2.3.1 Stormwater System

The percentage of area within the watershed served by storm sewer systems is estimated to be 33 percent. This is a significant portion of the watershed. As such, maintenance of the storm system is an important consideration for non-point source stormwater management.

Field observations of New London revealed a dated and deteriorating storm sewer system. The stormwater system was likely installed before 1950. The system located within the watershed lacked, to a large degree, adequate piping and catch basins compared to current standards. A large portion of the stormwater is likely conveyed over the streets directly to the Cove. Several catch basins were found with either the sumps completely filled with sediment or with no sumps at all. In some areas, stormwater from overland flow was conveyed by swales, at the end of steep sloped streets, directly to Alewife Cove.

According to Ed Steward of the Waterford Public Utilities, Waterford has a new "complete" stormwater system. Most of the existing stormwater system has been installed or improved since 1978. Approximately 80% of the existing stormwater system was installed after 1978. The stormwater system was designed for a 10 year storm event with the outlets designed for a 25 year storm event. The system consists of concrete pipes with catch basins located at maximum interval of every 300 feet. In addition, most of the streets are curbed to contain stormwater flow. Waterford was in the process of replacing dry catch basins with new catch basins containing sumps. Catch basin sumps are cleaned annually and Town personnel inspect all culverts in the spring, and clear sediment or debris, such as fallen branches and leaves.

Waterford also was in the process of upgrading roadways and storm sewers within the Ridgewood Park area, the most densely developed section of the watershed within the Town. In addition to design and construction improvements, the points of stormwater discharge from this area was reduced from four (4) to three (3) direct outfalls to Alewife Cove. Additionally, the town installed grit separators for each of the outlets to improve stormwater quality. (Installation of these outfalls and separators was performed after completion of this study.)

2.3.2 Street Sweeping Practices

Street sweeping practices are an integral part of urban stormwater management. Large sources of potential pollutants including sand, other sediments and nutrients may be eliminated before affecting stormwater quality. Both New London and Waterford have established street sweeping policies.

According to James McDermott of New London Public Works, street sweeping is performed in New London on the roads adjacent to Alewife Cove approximately 5 times a year. The first pass is early spring following completion of winter sanding operations. Approximately three (3) passes are made during the summer and one is performed in the fall after leaf collection. Street sweeping is not conducted with a parking ban during sweeping operations. This has the potential to reduce the effectiveness of street sweeping by preventing access to gutters where most of the pollutants accumulate.

Waterford performs street sweeping once a year between March and May and as needed during construction activities. Sweepings from both towns are collected directly from the sweeping equipment to waiting trucks and delivered to the Waterford Landfill.

Street sweeping operations in both towns are facilitated by curbs along most of the streets. The curbs detain sand and other debris within the roadway and provide the sweeping equipment better access to this debris. There is a benefit, however, in some areas to maintain roads without curbing. Where topography and street grades permit, it is beneficial to allow roadway runoff to flow as sheet flow to vegetated strips. The grassed strips provide removal of pollutants associated with stormwater.

2.3.3 Leaf and Bulky Waste Collection

A properly managed leaf and bulky waste collection program, when supported by the community, can reduce nutrient, sediment, and other pollutant loadings. To an extent, both municipalities have instituted effective programs.

New London provides leaf and bulky waste collection. Leaves are collected weekly in the fall but must be placed in paper bags sold by the city. Bulky waste is collected from curb sides during annual collection programs. Both leaves and bulky waste are transported to the Waterford Landfill. New London officials believe there is significant resident participation in the leaf collection program.

Residents of Waterford also collect and place leaves in paper bags sold by the Town. The leaves are transported to the Waterford Landfill. Leaves are also delivered to the Waterford Landfill directly by residents or private landscapers. Residences within the Ridgewood Park area, the most densely developed section of Waterford within the Fenger Brook Watershed, likely do not have great participation in the leaf collection program because many of the dwellings are vacation homes and not year round residences. Additionally, residents of Waterford may collect and dispose of leaves in compost piles on their lots. These factors make an accurate estimation of participation in the Waterford leaf collection program difficult.

Waterford's bulky waste collection program is an "on-call" collection system in which the Town will collect bulky waste from April to November by appointment. The bulky waste is transported to the Waterford Landfill. Additionally, the landfill accepts bulky waste from mid-March till the 1st of November.

2.3.4 Refuse Collection

Refuse collection is similar for both municipalities. For residential areas and small commercial businesses, curb-side collection is performed by the municipalities. This includes recycling pick-up. Private haulers are used for garbage and recyclables collection for larger businesses, industries, apartment complexes and condominiums.

During the site visits, garbage collection procedures were not observed for typical single family residences and small businesses. One of the apartment complexes in New London, however, was noted to have an overflowing garbage dumpster with refuse scattered on the ground in the vicinity of the dumpster. The dumpster was immediately adjacent to a stormwater outfall which outlets to wetlands in the watershed.

2.3.5 Sanitary Wastewater Management

Monitoring of Alewife Cove has indicated high fecal coliform bacterial counts. Fecal coliform bacteria is commonly associated with sewage contamination and urban stormwater runoff. Since a source of fecal coliform may be sanitary wastewater, an assessment of the wastewater management practices in the watershed was performed to identify potential sources of sanitary wastewater to the Cove.

Residences in the Ridgewood Park area of Waterford and almost all of New London are serviced by a sanitary sewer system. Areas in Waterford adjacent to the Cove were still unsewered at the time of the field evaluation. A sewer system was in place at these locations. As of the end of 1995, approximately 90 percent of the residences have been tied into the sanitary sewer.

A sanitary sewer pump station located near the Waterford/New London border adjacent to Fenger Brook at the bottom of Niles Hill Road has had a history of overflows. Many overflows occurred due to mechanical problems that were corrected in 1988. Since then, however, several major overflows have occurred. These include:

1. Construction accident involving excavation equipment that ruptured a sewer pipe in March 1993 which released approximately 70,000 gallons of raw sewage,

2. Generator failure on 11/20/90 released approximately 50,000 gallons of sewage to Alewife Cove, and

3. Generator failure on 5/12/92 released approximately 8,000 gallons of sewage to Alewife Cove.

New London was in the process of replacing the pump station with a new gravity interceptor which was to be completed in the summer of 1994. The interceptor will be tied into a pump station in Waterford. New London officials believe the new gravity interceptor will eliminate problems created by construction accidents and generator failures. The project was anticipated to be completed in the Fall of 1995.

Another potential sewage source to Alewife Cove is a section of New London sanitary sewer line overhanging Alewife Cove. The sewer pipe is strapped to a retaining wall. According to New London officials, city personnel perform regularly scheduled visual inspections of the exposed gravity sewer pipe and no known releases have occurred. In addition, the public utilities department was developing a contingency plan in case of an accidental spill or leak.

2.3.6 Industrial Wastewater Management

Other sources of wastewater, such as industrial discharges, have the potential to degrade surface waters. However, both a review of DEP records and the site survey failed to identify any direct industrial or non-industrial wastewater discharges to the Cove or Fenger Brook.

2.3.7 Road and Bridge Maintenance

Road and bridge maintenance programs have the potential to impact local surface waters. Certain paving activities can contribute oil to surface waters and salt/sand operations can contribute sediment and chlorides to nearby water ways.

New London maintains all three (3) Alewife Cove bridge crossings. The public works department performs maintenance on bridges and roads on an as needed basis. No regularly scheduled maintenance program exists. New London is involved in a Bituminous Pavement Program designed to replace existing non-bituminous roadways and encourage the use of bituminous pavement for all new construction.

Crack-sealing of roads in Waterford is performed within 10 years of road construction and chip sealing is performed within 15 years. All new road reconstruction projects must use bituminous concrete.

New London and Waterford maintain salt/sand stockpiles at their respective maintenance garages which are located outside the boundaries of the Fenger Brook watershed. Waterford maintains several 55 gallon storage drums of salt/sand within the watershed but these drums are enclosed to prevent contact with stormwater.

The potential for sediment loading to the watershed is increased by sand application, and the presence of salt increases the salinity of freshwater wetlands and receiving streams, which could adversely affect the aquatic organisms present. The application of salt in the vicinity of the Cove is of less concern as it is an estuarine system. The deicing mixture used by both municipalities consists of 4 parts sand to 1 part salt as recommended by the State of Connecticut Department of Transportation (DOT). Additionally, Waterford gives consideration to potentially environmentally sensitive areas in the application of salt/sand.

2.3.8 Summary

The following is a summary of the significant findings regarding stormwater management in the watershed.

1. The stormwater system in New London adjacent to the Cove appeared to be antiquated and deteriorating. The system was found to be lacking sufficient culverts, catch basins, and catch basin sumps. (Note, sumps may have either been non-existent or completely filled.) Additionally, maintenance of the stormwater system in New London was inadequate.

2. Street sweeping is performed in both New London and Waterford. In New London, street sweeping is performed several times during the summer months and in the

Spring and Fall. In Waterford, street sweeping is performed once a year in the Spring.

3. Leaf and bulky waste collection for both municipalities appear to be well sponsored and effective. As described above, leaf management includes collection in paper bags and disposal at the Waterford Landfill.

4. Areas in New London adjacent to the Cove are connected to a sanitary sewer system. Portions of Waterford adjacent to the Cove are connected to the same system; a small number of residences still maintain septic systems. Most have been tied into the sanitary sewer system.

5. A sanitary sewer pump station adjacent to the Cove has periodically failed or leaked resulting in sanitary wastewater discharges to the Cove. The pump station was slated to be replaced by a gravity interceptor in 1995.

6. Both municipalities have adequate bridge and road maintenance programs that are not anticipated to result in degradation to the surface waters. Sand application on roads adjacent to the Cove may result in excess sedimentation.

2.4 Regulatory Review

Land use controls can be an effective means of controlling non-point source pollution associated with urban runoff (EPA, 1994). Controls can be used for redevelopment and can require structural or non-structural measures as a condition of approval. Zoning regulations can be used to control the type of development within an area or identify specific management measures associated with a land use to protect water resources. As portions of both municipalities are within the coastal zone and are thereby subject to the Connecticut Coastal Management Statutes, the zoning regulations incorporate provisions for coastal management. Wetland regulations can effectively limit development and degradation in environmentally sensitive areas and subdivision regulations can establish standards for development to protect surrounding surface waters. The following is a summary of these regulations relative to stormwater management for New London and Waterford. Tables 2.2 and 2.3 summarize strengths and shortcomings of these regulations regarding stormwater management and non-point source pollution control for New London and Waterford, respectively. A complete review of these regulations is provided in Appendix A. Section 6.5 of this report identifies specific recommendations to strengthen the regulations for non-point source pollution management with specific regard to the Fenger Brook watershed.

2.4.1 Zoning Regulations

New London

As indicated in the Purpose and Authority section of the New London Zoning Regulations (1993), the zoning regulations have been developed in part to "...encourage the most appropriate use of land and to protect important environmental features..." The regulations identify up front that one of the key elements is environmental protection. This element provides a good basis for non-point source pollution management.

TABLE 2.3

SUMMARY OF WATERFORD REGULATIONS

FENGER BROOK WATERSHED MANAGEMENT STUDY DECEMBER 1995

Regulation	Strengths	Shortcomings
Zoning	· General lot design standards that have specific requirements for lots in regards to septic systems, size, location, and access · Special approvals for certain activities including consideration of environmental impact · Detailed requirements for construction controls in areas adjacent to wetlands and waterbodies · Specific references to Connecticut Guidelines for Soil Erosion and Sediment Control · Contains specific requirements for open space · Stipulations for maximum building coverage	· No restrictions on location of potentially "troublesome" land uses in zones surrounding the Cove or Fenger Brook · Allows for waiver of set-backs for residents adjacent to waterbodies · No restrictions on storage of equipment with respect to location relative to wetlands or waterways · Does not include provisions regarding development in coastal zone areas
Wetlands	· Detailed sediment and erosion control requirements for regulated activities	· Requirements for a wetlands permit application approval could be enhanced
Sub-Division	· Requirement for all "as-built" plans show all soil erosion and sediment control measures and stormwater management facilities used for construction · Requirements for verification of installation and maintenance of soil erosion control measures · Measures for inspection and enforcement of erosion and sediment control plans · Requirements to minimize surface water runoff	· Stormwater control measures do not address potential non-point source pollution for post construction; design details do not include measures targeted to improve stormwater runoff quality following construction

As indicated in Table 2.2, New London's regulations have a number of strengths as well as several shortcomings. Overall, the zoning regulations provide adequate provisions to protect surface waters in New London. Such provisions include references to coastal management under the Coastal Area Management (CAM) Act. However, the regulations can be enhanced to include additional provisions to regulate zones adjacent to Alewife Cove or other waterways.

Waterford

As indicated in Table 2.3, the Town of Waterford Zoning Regulations (1993) have a number of strong zoning requirements that protect the Town's water resources. Significantly, the regulations include strong provisions for sediment and erosion controls for any activities that disturb the topography. Additionally, the regulations provide detailed provisions for general lot design standards. The environmental protection provisions, however, should be expanded to require stormwater pollution and runoff controls. The regulations also stipulate requirements for activities within coastal zone areas as defined in the Connecticut General Statues. In accordance with these regulations, Waterford has developed a detailed checklist for activities conducted in coastal areas in order to assess environmental impact. The checklist is used to determine whether or not to approve a project within a coastal area.

2.4.2 Wetland Regulations

New London

The purpose of New London's Wetland Regulations (1990) is to protect, preserve and maintain the City's inland wetlands and watercourses as well as maintain and improve the quality of the wetlands and watercourses. As such, the regulations have the potential to address non-point source pollution to Alewife Cove and other surface waters. A significant strength of the wetland regulations is the provisions for assessing stormwater runoff quantity and quality for proposed activities in regulated areas. In addition, the requirements for regulated activities are strict with a detailed permitting process. However, the definition of regulated activity is limited and does not include set-backs around wetlands for areas with a slope of less than 10 percent. As such, it is recommended that either the definition of regulated activities be broadened or specific criteria be established to evaluate proposed activities on a case by case basis.

Waterford

The Town of Waterford Wetland Regulations (1993) are similar to those for New London. As with New London, such regulations can be used to minimize stormwater runoff impacts to wetlands and watercourses. According to Waterford personnel, the Town regulates wetlands on a site-by-site basis by evaluating the potential impact of proposed activities and the value of wetland resources rather than by specifying a generic buffer width. The Town has implemented policies for identifying and regulating activities that may impact wetlands and watercourses. This applies to both activities within and adjacent to wetlands. For example, wetland issues are identified in the permitting process (such as building permits). The Town has committed adequate staff to address wetland permitting and the associated wetlands impact evaluation.

2.4.3 Subdivision Regulations

The Subdivision Regulations for the City of New London (1992) and the Town of Waterford (1990) have been established to regulate subdivision developments and ensure public safety with regard to new subdivisions. The subdivision regulations address, among other items, flood control, soil erosion and sediment control, and open space requirements.

New London's regulations include specific requirements for erosion and sediment control plans, coastal site plan requirements, and alterations to watercourses. Some of the strengths of the Waterford regulations include details for stormwater structures and drainage systems.

2.4.4 Summary

Overall, Waterford and New London regulations provide non-point source pollution controls within the Watershed. Specifically, runoff quantity and erosion and sediment controls are adequately addressed. Sections of the regulations, however, can be strengthened to further reduce the potential for non-point source pollutants to Alewife Cove and Fenger Brook. Specifically, areas of zoning, wetland and subdivision regulations could be strengthened as follows:

1. Provide non-point source pollution management requirements for certain land uses.

2. Include requirements to address non-point source treatment.

3. In New London, establish buffers for wetlands and watercourses or develop specific criteria or policies to regulate activities adjacent to wetlands.

4. Develop standard details for stormwater management in the Subdivision Regulations to address non-point source pollution in both municipalities.

5. In addition, the municipalities may consider requiring maintenance of stormwater systems for private sectors (i.e. parking lots) to compliment municipal efforts in maintaining stormwater systems.

Specific recommendations for regulatory revisions are provided in <u>Section 6.5</u> of this report.

3.0 WATER QUALITY CHARACTERIZATION

To confirm the suspected problems of the Cove, the water quality of the Cove and Fenger Brook was evaluated. Since extensive studies of the Cove have been performed in the past, information from previous studies was used to characterize conditions of the Cove. A summary of these studies is provided in the following section. Additional investigations of the Cove have been performed to supplement these studies including an ecological study of the Cove, an evaluation of the wetlands within the Watershed, and monitoring of Fenger Brook and another tributary to the Cove.

3.1 <u>Historical Problems of the Watershed</u>

Existing literature concerning the Alewife Cove/Fenger Brook Watershed was reviewed. Much of this information was obtained from studies performed during the 1970s by the

University of Connecticut Marine Sciences Institute that detailed the problems of the watershed. The following is a summary of the major findings of the past studies.

Welsh et al., 1974, reported on the state of four watershed systems in Waterford, Connecticut, relative to the future development in the Town. One of the watersheds included in the study was the Alewife Cove/Fenger Brook watershed. Several problems with the watershed were identified in this paper. Foremost, Fenger Brook was described as a watershed system with approximately "50 percent" of its wetland and watercourse diverted to another watershed system. The study indicated that the Penn Central Railroad (now AMTRAK) bisected the main branch of Fenger Brook. Construction of the rail-way did not include a culvert to allow the passage of stream flow. (A review of available mapping, provided by the National Railroad Passenger Corporation, Government & Public Affairs, Washington, DC, by Fuss & O'Neill indicated that a culvert was not installed to allow passage of the main stem Fenger Brook). In the upper reaches of Fenger Brook, the study documented waste in the stream bed, with trash and other debris surrounding the area. Downstream, at the Boston Post Road crossing, the report cited poor water quality conditions with observations of an oil film on the surface and raw sewage along the western bank of the stream. South of the railroad, a marsh system was becoming desiccated. Other sections of this area had a backup of water that had destroyed some of the wetland hardwoods. Fill and debris were also noted at this location.

Fenger Brook had very poor water quality conditions, especially where sewage and debris were observed. Dissolved oxygen concentrations were low, in the range of 2.4-4.6 parts per million (ppm). Nitrate and phosphate concentrations were high. Lower portions of Fenger Brook were also poor in water quality. The cove system itself showed normal concentrations of oxygen and nutrients. Raw sewage was found to be discharged to the cove from the New London Pump Station. In lower portions of the cove, erosion was evident due to human traffic and subsequent natural actions such as wind and runoff.

A second study performed by Welsh (Welsh, 1978 and Welsh et al., 1978) assessed the effect of reduced wetlands on watersheds. The objectives of this study were to: 1) examine the relationship between the loss of storage areas, ponds, wetlands and the size, stability and benthic productivity of the mixing zones between fresh and salt water within three watershed systems; and 2) determine whether meaningful biota ratios could be developed from these types of data.

As with the previous study, it was reported that half of the freshwater water courses and wetlands have been lost or blocked by urbanization, particularly, by the construction of the railroad in the 1850s. In addition, several wetlands have been filled in the Fenger Brook watershed system.

The salinity structure of the Cove changed sharply in response to precipitation. This went from a homogeneous salt pond to that of a highly stratified estuary and back again over a period of ten to fourteen days. These responses occur with as little as 0.8 cm of rain. It was reported that this would impose more osmotic stress on organisms than would be imposed by a normally fluctuating estuary.

Macro detrital fragments greater than 0.5 mm were identified in this study. The source was freshwater terrestrial matter. This matter contributed to conditions that inhibit macro invertebrate proliferation processes large enough to handle them. This perpetuates the organic loading to the cove by allowing a continued build up of organic matter.

Sediment in Alewife Cove was extremely high in silt, clay and organic content. These sediments were of considerable depth in some areas, reaching depths of greater than 2 meters. A vertical salinity gradient was found to exist in the top 10 cm of the sediment. This indicated a high groundwater intrusion rate. The pH of the sediment pore water was low under summer conditions. This was likely due to leaching of organic acids from detritus material and decaying vegetation. The combination of the low pH and variable salinity result in multiple stresses on the benthic community. The mixing zone was inhabited primarily by small species capable of avoiding stressful conditions. Lack of community integrity in the upper and middle basins was apparent. Temporal differences in communities were not consistent by season. Mollusks were notably scarce and a low diversity of biomass with a heavy dominance of opportunity organisms was observed. Nearby coves exhibited a better diversity of organisms. Detrital biomass fragments of leaves, twigs, etc. outweighed living bio-mass by one to three levels of magnitude in Alewife Cove.

The tidal flow to freshwater flow ratio under low discharge conditions was reported to be 300:1. It was concluded that the oscillating salinity regime resulting in osmotic stress may be less a factor than the interstitial conditions of the sediment such as low pH, detrital loadings, and groundwater flow. It was found that flocculation and concurrent siltation take place at the freshwater saltwater interface. (This is typical for estuarine systems.) This may result in a bottom silt too fine to support benthic organisms, which in turn leads to a high organic content of the sediments since incoming detritus is not readily assimilated.

Herring, 1978, completed a Masters Thesis on Alewife Cove considering the affects of processing freshwater runoff and tidal waters. It was reported that during spring tide conditions, the ratio of tide to freshwater flow, during low flow, was 300:1 and during neap tide conditions, the ratio of tide to high freshwater flow was 4:1. It was found that the lower cove was tidally dominated whereas the upper cover was influenced by both the tide and stormwater runoff. As with many estuaries, it was stated that Alewife Cove is a nutrient sink. The contributing sources of nutrients were from both Long Island Sound and Fenger Brook. Long Island Sound sources were greater than those from Fenger Brook except for conditions of high stormwater flow; in which case the nutrients from both sources were about equal. Algae blooms were noted in the upper portions of the cove. This was reported to be due to nutrient loadings in both the sediment and from the sewage source on the New London side of the cove.

A study of the siltation, eutrophication and hydraulic character of the Alewife Cove was performed by Welsh and Whitlatch, 1978. The study assessed the mechanisms of sedimentation, and eutrophication of Alewife cove. Shoaling of the Cove was determined to be from tidal actions of the Long Island Sound which has created a sill at the inlet of the Cove. The sill has been shown to control tidal characteristics in such a way that sediment is perpetuated. Additionally, the sill creates an impounding effect on the Cove. A recommendation to reduce shoaling was to dredge the lower cove. (Dredging of the Lower Cove was performed in 1988; Zajac and Whitlatch, 1991.)

The Cove was determined to be underlain by extremely soft silt high in organic content. The high silt content is typical of estuaries at the freshwater/saltwater interface. The rate of sedimentation in the Cove was stated to range from 0.8 to 1.2 cm/yr. Rates of sedimentation were found to be higher during the breakup of ice, indicating scouring as an important contributor. Deposition in the upper basin was highly coupled with freshwater flow. Eutrophication problems in the Cove were found to be mainly associated with organic loadings, derived in large measure, from lateral addition of terrestrial derived debris and freshwater inflows. Large amounts of leaves, stems, and grasses were found to enter the Cove, with less than one percent of these materials accounted for by Fenger Brook with the major share of these inputs from sources lateral to the Cove. Decomposition of the sediment was determined to be slow due to the nature of the organic material, resulting in poor development of the benthic biota. The basin area harbored major blooms of macroalgae during the spring and early summer.

Sampling for fecal coliforms at two locations in the Cove has been undertaken by the Department of Agriculture, Aquaculture Division (Citak and Kelly, 1993). The locations include the lower reach and the middle cove. The results indicate that neither station met the bacteriological water quality criteria for shellfishing under wet or dry weather conditions. The Connecticut fecal coliform water quality criteria for shellfishing waters is 14 colonies/100 ml. Table 3.1 summarizes the results of fecal coliform sampling events performed between 1989 and 1992. Citak and Kelly note that abatement of sewage discharges from the sewer systems in the area, specifically tie-in of the Ridgewood Association of Homes, could result in upgrading the current status of the Cove.

3.2 Existing Problems in the Watershed

3.2.1 Alewife Cove

Alewife Cove has been designated by the DEP as a Class SB/SA surface water (DEP, 1986) which indicates that it is presently not meeting the Water Quality Criteria for a Class SA coastal water. The water quality goal is achievement of Class SA criteria and attainment of Class SA designated use (DEP, 1992). The Class SA designated use is for marine fish, shellfish and wildlife habitat, shellfish harvesting for direct human consumption, recreation and all other legitimate uses including navigation.

A study of the Alewife Cove was performed to evaluate the existing conditions of the Cove. The study was conducted as one aspect of this project. A copy of the report, entitled Ecological Characteristics, Upper Alewife Cove, Waterford and New London, CT (1993) by Priscilla Baillie, summarizes this study and is provided in Appendix B. The specific objective of this study was to address potential eutrophication of the Cove caused by nutrient input from the watershed. The study consisted of sampling of the Cove on three occasions throughout the growing season. Since the lower reach is primarily influenced by Long Island Sound water (Herring, 1978), sampling was confined to the Middle and Upper Cove (see Figure 1.1). Temperature, salinity, and oxygen profiles from surface to bottom were measured in the upper and middle basins. Samples were collected from both basins for chlorophyll-a analysis and phytoplankton identifications. (See Figure 1 of Appendix B for sample locations.) Macrophyte distributions and density were noted, with special attention to such problem organisms as Ulva, Enteromorpha, Vaucheria or mat-forming blue-green algae. The Cove was checked for the presence of the aquatic macrophytes Zostera (eel grass) and Ruppia (a brackish water plant), both of which were previously reported for the Cove (Herring, 1978). Surface samples were collected from the two basins for nutrient analyses (nitrate/nitrite, ammonia, organic nitrogen, and phosphate).

A summary of the major findings of the ecological study is as follows:

TABLE 3.1

ALEWIFE COVE FECAL COLIFORM SAMPLE RESULTS FOR THE PERIOD OF JANUARY 1, 1991 TO JULY 7, 1993*

FENGER BROOK WATERSHED MANAGEMENT STUDY DECEMBER, 1995

		Dry Weather		Wet Weather	
Parameter	Units	Lower Cove	Middle Cove	Lower Cove	Middle Cove
Count		14	13	5	5
Minimum Concentration	Col./100 ml	1.6	1.6	8.6	8.6
Maximum Concentration	Col./100 ml	79	110	920	240
Mean	Col./100 ml	15.9	32.5	219.9	67.3
Geometric Mean	Col./100 ml	10.6	21.2	67.6	33.0
Median	Col./100 ml	8.7	18.0	67.9	33.0

* Source: Citak, J.S. and Kelly S. (1993)

- There appeared to be significant differences between the conditions of the upper and middle basins. The upper basin is less prone to wind mixing then the middle basin. Additionally, most of the freshwater flow from the watershed flows to the upper basin.

- The presence of specific organisms observed in the middle basin indicated a well flushed system with good circulation, clear waters and low nutrients. These factors together with elevated oxygen concentrations, were present in the middle basin during the course of this study.

- The upper basin exhibited signs of stress including warmer temperatures and lower dissolved oxygen concentrations. The dissolved oxygen concentration near the sediment interface was less than the water quality standard of 5.0 mg/l at most locations during the August sampling event. Additionally, Station 3 had dissolved oxygen concentrations less than the water quality standard at all depths. The water clarity was poor and chlorophyll-a levels were greater in the upper basin indicating the presence of large numbers of phytoplankton.

- A phytoplankton bloom in the upper basin was noted during the study; however, no macroalgae blooms were observed.

- Total nitrogen and total phosphorus were higher in the upper basin than the middle basin on two of the three sampling events.

The above conditions indicate that the upper basin is eutrophic.

3.2.2 Water Quality of the Fenger Brook Watershed

The major freshwater system in the watershed is Fenger Brook. Fenger Brook has been designated by the DEP as a Class B/A inland surface water (DEP, 1986) which indicates that the Brook is presently not meeting the Water Quality Criteria for a Class A criteria and attainment of Class A designated uses (DEP, 1992). The designated uses for a Class A surface water are: potential drinking water supply, fish and wildlife habitat, recreational uses, agriculture, industrial supply and other legitimate uses including navigation.

Two sampling events were scheduled for the watershed, one during dry weather and the second during wet weather. The purpose of the sampling events were two-fold. First, the results are used as a qualitative indicator of the water quality of stormwater and freshwater flows to the cove. Second, a long-term monitoring effort will be based on the sampling plan developed for these sampling events. Appendix C contains a copy of the Quality Assurance Project Plan (QAPP) for the sample events. Wet and dry weather sample locations are shown in Figure 2 of Appendix C.

It should be noted that only dry weather sampling was performed as part of this study. The logistics involved in collecting a wet weather sample combined with a mix of extended periods of dry weather and inopportune storm events made sample collection difficult. It is anticipated that the QAPP will be used in the future to collect stormwater runoff in the watershed.

TABLE 3.2

DRY WEATHER SAMPLE RESULTS
SAMPLE DATE: JUNE 21, 1994

FENGER BROOK WATERSHED MANAGEMENT STUDY
DECEMBER, 1995

Parameter (1)	Units	Sample Station 2D (2)	Sample Station 3D (3)
Nitrate-Nitrite	mg/l	0.507	2.514
Ammonia	mg/l	0.208	0.027
Particulate Nitrogen	mg/l	0.057	0.029
Total Diss. Nitrogen	mg/l	1.171	3.134
Total Nitrogen (4)	mg/l	1.228	3.163
Particulate Phosphorus	mg/l	0.65	0.55
Total Diss. Phosphorus	mg/l	0.181	0.02
Total Phosphorus (4)	mg/l	0.831	0.57
Total Suspended Solids	mg/l	4	3
BOD5	mg/l	2.1	0.7
Total Coliform	Col./100 ml	40000	500
Fecal Coliform	Col./100 ml	37000	400
Lead	ug/l	ND	ND
Total Petroleum Hydrocarbons	mg/L	1.5	ND
pH	SU	7	6.18
Temperature	C	18.9	13.5
Specific Conductivity	umhos/cm	299	372
Dissolved Oxygen	mg/l	5.7	1.9

Footnotes:

1. Parameters included copper and zinc; however, presence in the field blanks negated sample results.
2. Fenger Brook outfall to Alewife Cove.
3. Tributary outfall to Upper Alewife Cove.
4. Sum of dissolved and particulate

The dry weather sampling event was performed on June 21, 1994. Sampling consisted of collecting grab samples at two locations in the watershed. A third location was slated for sampling; however, the location was dry at the time samples were collected. The two sample stations consisted of the outfall of Fenger Brook to Alewife Cove and a small tributary to the west of Upper Cove. A copy of the laboratory report and field data sheets is provided in Appendix D. A summary of the sample results is given in Table 3.2

It is important to note that it is difficult to draw conclusions from a single sample event. However, several items of significance should be noted. The nitrogen concentrations from both sample locations were high. The nitrate/nitrite concentration of these samples is a large fraction of the total nitrogen. Additionally, the majority of nitrogen was in the dissolved form. The form of nitrogen, i.e. dissolved, is important in considering best management practices for nitrogen reduction.

The results also indicated a very high fecal and total coliform count for Fenger Brook near Alewife Cove. These counts were much higher than typically observed in freshwater systems. It is possible that the high coliform counts were the results of sewage contamination. The sample was collected at a location immediately adjacent to a sewage pump station that has had historical failures. Another potential source of the high coliform counts was the local on-site septic systems.

Also of significance was the low dissolved oxygen (DO) recorded for the unnamed tributary to the Upper Cove. A DO of 1.9 mg/l is significantly below the Connecticut water quality criteria of 5 mg/l. Because the biochemical oxygen demand of the water was less than one (1) mg/l, it is likely that the elevated nitrogen contributed to the reduced oxygen concentration in the tributary.

As indicated in the table, sampling included copper, lead, and zinc. However, the field blank used during the sampling event indicated the presence of copper and zinc. As the field blank should not contain metals, the sample results for metals are unreliable and, therefore, not discussed in this assessment.

3.2.3 Wetland Function Assessment

A functional assessment of the wetlands within the Fenger Brook/Alewife Cove Watershed was performed during the Summer and Fall of 1993. The purpose of this assessment was to evaluate the significance of the wetlands within the watershed, assess the current and future value of the wetlands for stormwater management, and review the current impacts of stormwater discharges on the wetlands. A copy of the report, entitled Functional Assessment of and Storm Water Impacts to the Fenger Brook Watershed Wetlands by Jodie Chase (October 1994) summarizes this assessment and is included in Appendix E. This section is provided as a summary of the report. Appendix E should be reviewed for a complete summary of the wetlands. Figure 1 of Appendix E shows the location of the wetlands within the watershed.

The functional assessment performed on the wetlands was based on the Department of Environmental Protection's (DEP) Method for the Evaluation of Wetlands (1991). The method includes an evaluation of fourteen wetland functional assessments. Table 3.3 provides a summary of the wetland functional assessment. In addition to the DEP method, a review of the wetlands was performed to determine the extent of stormwater impacts.

TABLE 3.3

WETLAND FUNCTIONAL ASSESSMENT[1]

FENGER BROOK WATERSHED MANAGEMENT STUDY
DECEMBER, 1995

FUNCTION	WETLAND FUNCTIONAL VALUE UNITS						
	1 *	2	3	4	5	6	7
Ecological Integrity	12.2	2.9	102	2.0	3.6	0.6	16.3
Wildlife Habitat	8.6	2.1	114	0.96	2.0	0.36	8.4
Finfish Habitat							
Rivers and Streams	0	0	0.08	0	0	0	0
Ponds and Lakes	0.13	0	1.0	0	0	0	0
Educational Potential	6.7	1.7	80.0	1.1	2.0	0.36	8.64
Visual/Aesthetic Quality	0.84	0.2	4.38	1.04	1.04	0.36	0.72
Water-Based Recreation	3.7	0	110	0	0	0	0
Flood Control	18.5	7.1	157	1.15	3.35	1.18	23.5
Groundwater Use Potential	0	0	0	0	0	0	0
Nutrient Retention and Sediment Trapping	8.4	2.9	106	0.96	1.7	0.4	12
Shoreline Anchoring	0.08	0.03	0.33	0.11	0.11	0	0.3
Forestry Potential	6.9	3.6	52.8	0	0.0	0.4	13.2
Archaeological Potential							
Native American Habitat	0.28	0.28	0.28	0.28	0.28	0.28	0.28
Industrial Site	0	0	0	0	0	0	0
Urban Wetland Quality	11.1	2.2	112	1.18	2.11	0.3	11.3
Noteworthiness	0	0	160	0	0	0	0
Acreage	21.0	7.2	160.0	2.4	4.3	1.2	24.0

* Key to Wetland Numbers

1. Longview 2. Miner Lane 3. Evergreen 4. Evergreen Pocket 1
5. Evergreen Pocket 2 6. Mansfield 7. Great Neck

[1] Functional assessment based on "Method for the Evaluation of Inland Wetlands", Connecticut Department of Environmental Protection, 1986. See Appendix E for more detail.

There are nine (9) wetlands within the Watershed. The wetland evaluation revealed that the majority of the wetlands are forested wetlands with stormwater as a large hydrologic source. Field inspections indicated that the overall integrity of the wetlands was remarkably good considering the urban setting. Two (2) tidal wetlands exist in the watershed. These two wetlands were not evaluated using the DEP method as this method only applies to freshwater systems. The functional assessment revealed that the most significant and valuable wetland within the watershed is the Evergreen wetland in the center of the watershed. This was mainly due to the size of the wetland, a major factor in the DEP method, which is approximately 160 acres. The ecological integrity and wildlife habitat values for all wetlands were relatively high considering their sizes.

For the most part the field investigations indicate that the wetlands have been impacted by stormwater runoff. These impacts include channeling through the major wetlands, erosion, and sedimentation at stormwater outfalls. This has reduced the potential for the wetlands to provide nutrient retention and sediment trapping functions. Degradation of the wetlands via stormwater runoff resulted in habitat loss and invasion of herbaceous species.

Although wetlands have been impacted by stormwater runoff, measures can be implemented to reduce these impacts. Measures such as reducing solids loads to the wetlands and diffusing the stormwater runoff to minimize erosion and channeling can be implemented to improve the quality of the wetlands. This, in turn, would likely improve the water quality of Fenger Brook and Alewife Cove by providing additional solids removal and greater nutrient retention. Specific measures for improving the existing wetlands are provided in Section 6.5.2.

3.3 Summary

A summary of the current and historical problems with the Fenger Brook watershed identified in this section is as follows.

1. A large section of the watershed has been diverted to an adjacent estuary due to the construction of a railroad system before 1850. This has potentially eliminated a large freshwater source to the Alewife Cove estuary.

2. Raw sewage was intermittently discharged to the Alewife Cove due to periodic problems with a pump station in New London. According to New London sources, this problem has since been eliminated.

3. Several wetlands have been filled in the watershed in the past due to urbanization and development.

4. The salinity structure of the cove changes sharply in response to precipitation. This imposes a higher osmotic stress on organisms than would typically be imposed by a normally fluctuating estuary. Under low flow freshwater conditions the tidal flow to freshwater flow ratio is 300:1. During neap tide conditions and stormwater flush conditions, the ratio has been reported to be as low as 4:1.

5. Alewife Cove is subject to high sediment loads, with the sediment layer reaching depths of two meters. Flocculation and concurrent siltation was reported to occur at the fresh/salt water interface.

6. The low pH of the sediment pore water in the Cove observed in one study was likely due to leaching of organic acid from detritus material and decaying vegetation.

7. A lack of infuanal community integrity in the Cove, was observed with nearby coves exhibiting better diversity of organisms. Mollusks were notably scarce and a low diversity of biomass with a heavy dominance of opportunistic organisms was reported.

8. Alewife Cove was reported to be a nutrient sink. Algae blooms were observed in the upper cove due to nutrient loadings. The upper Cove was reported to be eutrophic due to excess nitrogen.

9. Fecal coliform bacteria sampling, performed by the Aquaculture Division of the Department of Agriculture, of the Cove for the period of 1990 to 1992 indicated levels above shellfishing standards. Coliform sampling of Alewife Cove was suspended due to the existence of remaining septic systems adjacent to the Cove and the continued sewage pump station failures.

10. Dry weather sampling of the Cove showed high concentrations of nitrogen, mainly in the dissolved form, from the terrestrial portions of the watershed. Additionally, elevated levels of fecal coliform bacteria were measured at freshwater outlets, specifically Fenger Brook, to the Cove.

11. The wetland assessment indicated good integrity of the wetlands within the watershed. The most valuable wetland in the watershed is the Evergreen wetland located in the center of the watershed through which Fenger Brook flows. The assessment showed that there are impacts to the wetlands due to stormwater discharges. Specifically, erosion, channelization, and sedimentation have been observed in the wetlands. Measures can be implemented to the stormwater collection/discharge system that can reduce these impacts. This, in turn, could enhance the natural capabilities of the wetlands to further reduce stormwater impacts, such as nutrient enrichment, to Fenger Brook and Alewife Cove.

12. The pollutants of concern which are affecting the water quality of the Alewife Cove are nitrogen impacting the Upper Cove, total suspended solids impacting the Upper and Middle coves, and fecal coliform impacting the entire Cove.

4.0 WATERSHED HYDROLOGY

4.1 Sub-Watersheds/Drainage Areas

The Fenger Brook/Alewife Cove watershed is approximately 1,130 acres in size to its confluence with the Long Island Sound and includes areas in both New London and Waterford. (Figure 1.1 delineates some of the major features of the watershed.) In general, the headwaters of this system begin just to the north of the existing AMTRAK commuter rail line where the runoff from a largely residential area drains to a small shallow pond located on the northern side of the AMTRAK railroad embankment. This pond likely provides some detention of runoff before outletting through a 30 inch corrugated metal pipe culvert to Fenger Brook. From here, Fenger Brook generally flows to the south through a relatively large wooded wetland before entering Alewife Cove. This cove is a small estuary to the Long Island Sound and is about 2.2 kilometers in length. The Cove is comprised of two major basins (Upper and Middle Cove) and a tidal river leading to the Long Island Sound (Lower Reach).

Figure 4.1 outlines the watershed to this system based on available topographic and street drainage mapping. This watershed is divided into four sub-watersheds, the area north of the AMTRAK embankment, the area draining to the Upper Cove, the area draining to the Middle Cove, and the area draining to the Lower Reach. Drainage to the Cove is by either point source stormwater discharges, i.e., structures designed to convey stormwater, or as sheet flow directly to the Cove or Fenger Brook. The drainage area for each individual point discharge as well as sheet flow areas to the Fenger Brook/Alewife Cove system has also been delineated. The point discharges include both storm sewer outfalls for municipal street drainage as well as existing watercourses. As shown, the runoff from most of the heavily developed portions of this watershed is collected in the local street drainage system. The outfalls for these drainage systems typically empty into channels which then drain directly into Fenger Brook or the Cove system with little dissipation. The undeveloped portions of the watershed largely drain overland either directly into Fenger Brook or one of its small tributary streams. Table 4.1 summarizes the acreage for each delineated drainage area in this watershed and identifies both point and sheet flow discharges of stormwater.

4.2 Watershed Land Use

Figure 2.1 outlines current land uses in the watershed. These land uses were obtained from information provided by New London and Waterford. (Section 2 provides a complete description of the land uses in the watershed.) The areas surrounding the Upper and Middle Coves consist largely of single family housing on relatively small lots (typically 5,000 square feet (sf) to 25,000 sf). The area draining into Fenger Brook above Alewife Cove includes both heavily developed residential areas as well as significant undeveloped areas. Much of the area draining to the Lower Reach includes Ocean Beach Park and its parking lot.

The heavily developed areas which drain into Fenger Brook are largely located in New London with the exception of a significantly developed area in Waterford to the north of the railroad embankment. This developed area includes both single family housing as well as multi-family housing and apartments. Some limited commercial and residential development also exists. In Waterford, current land uses include some single family housing on larger lots as well as solid waste (Waterford Landfill and local trash hauler) and agricultural (piggery) activities. The area immediately surrounding Fenger Brook is a large wooded wetland which is densely vegetated.

4.3 Watershed Soils

Based on current Soil Conservation Service (SCS) soils mapping, Figure 4.2 delineates the soil coverage in the watershed. In general, these soils have moderate to very slow infiltration rates. Figure 4.3 outlines the hydrologic soil classifications in the watershed per SCS classifications. The soils are assigned to hydrologic soil groups A through D based on the following definitions.

A. Soils having high infiltration rates
B. Soils with moderate infiltration rates

TABLE 4.1

SUB-WATERSHED AND DRAINAGE AREA SIZES

FENGER BROOK WATERSHED MANAGEMENT STUDY
DECEMBER 1995

Watershed/ Drainage Area	Area (Hectares)	Area (Area)	Point Source or Sheet Flow
Sub-Watershed 1	59.8	148	Both
D.A.2A	115.5	285.4	Sheet
D.A.2B	3.0	7.3	Point
D.A.2C	4.4	10.9	Point
D.A.2D	4.6	11.5	Point
D.A.2E	4.4	10.8	Point
D.A.2F	3.9	9.6	Point
D.A.2G	8.7	21.6	Point
D.A.2H	8.0	19.7	Point
D.A.2I	2.7	6.6	Point
D.A.2J	20.0	49.4	Sheet
D.A.2K	5.2	12.8	Point
D.A.2L	3.4	8.4	Point
D.A.2M	26.0	64.2	Point
D.A.2N	17.5	43.2	Sheet
D.A.2O	1.1	2.8	Point
D.A.2P	2.0	4.9	Point
D.A.2Q	26.0	64.3	Sheet
D.A.2R	32.7	80.9	Sheet
Sub-Watershed 2 - Total	289	714.2	
D.A.3A	2.8	6.9	Point
D.A.3B	3.8	9.4	Point
D.A.3C	0.2	0.5	Point
D.A.3D	1.1	2.7	Point
D.A.3E	3.6	9.0	Point
D.A.3F	2.4	6.0	Point
D.A.3G	1.4	3.5	Point
D.A.3H	3.1	7.6	Point
D.A.3I	18.7	46.2	Sheet
Sub-Watershed 3 - Total	37	92	
D.A.4A	24.5	60.5	Point
D.A.4B	43.5	107.5	Sheet
D.A.4C	2.5	6.2	Point
Sub-Watershed 4 - Total	71	174	
Total	456	1128	

LEGEND

Soils

- ADRIAN AND PALMS MUCKS
- CANTON AND CHARLTON
- CHARLTON-HOLLIS
- DUMPS
- HOLLIS-CHARLTON-ROCK OUTCROP COMPLEX
- NARRAGANSETT
- PAWCATUCK
- PAXTON AND MONTAUK
- RIDGEBURY, LEICESTER, AND WHITMAN
- SCARBORO
- SUDBURY
- SUTTON
- UDORTHENTS-URBAN LAND COMPLEX
- URBAN LAND
- WALPOLE
- WATER
- WOODBRIDGE

SOURCE CREDIT: ELECTRONIC DATA PROVIDED BY DEPARTMENT OF ENVIROMENTAL PROTECTION.

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FENGER BROOK WATERSHED MANAGEMENT STUDY

Soil Coverage of the Watershed

PROJECT NO.: 92603A1 FILE NAME: J:FENGER.APR

SCALE: 1" = 2000' DATE: MAR. 1995 FIGURE 4.2

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FENGER BROOK WATERSHED MANAGEMENT STUDY

SCS Soils Classification of the Watershed

PROJECT NO.: 92603A1 FILE NAME: J:FENGER.APR

SCALE: 1" = 2000'	DATE: MAR. 1995	FIGURE 4.3

C. Soils having low infiltration rates
D. Soils having very low infiltration rates

As shown, much of the watershed has soils with poor infiltration rates (Groups C and D) and some limited areas with moderate infiltration rates. Also, while most of these soils have at least five feet of cover over bedrock, much of the developed portions of the watershed has groundwater within three feet of surface.

4.4 Hydrologic Modeling

The TR-20 computer program was used to estimate runoff volumes and peak flows generated in the watershed. This program was developed by the Soil Conservation Service for stream flood routing using the Modified Att-Kin coefficient method. For the purposes of this evaluation, the watershed was divided into four study areas as outlined below:

1. The drainage area above the AMTRAK embankment.
2. The drainage area below Area 1 but above the Niles Hill Road Bridge.
3. The drainage area below Area 2 but above the Glenwood Avenue Bridge.
4. The drainage area below Area 3 but above the Middle Cove.

(Note the study areas differ from the above-defined subwatersheds.)

Table 4.2 summarizes the acreage, curve numbers and times of concentration for each of these four study areas. Curve numbers are based on typical SCS curve number values. These curve numbers were weighted for each area to account for land uses and surficial soils. As shown, curve numbers for this evaluation ranged from 81 to 85 which was largely due to the poor infiltration rates of the soils in the watershed as well as the amount of development. Times of concentrations were also estimated based on expected sheet flow, shallow concentrated flow and channelized flow paths in the watershed using SCS methods. For these study areas, times of concentrations ranged from 0.2 to 0.96 hours. Weighted curve numbers were developed utilizing the GIS database developed for the watershed management study. By assigning curve numbers to land use and soil sampling, the GIS database was used to calculate the weighted curve numbers for each study area. Time of Concentration and curve number worksheets are included in Appendix F.

Table 4.3 outlines the results of the TR-20 routing for this watershed for 2 year, 10 year, and 25 year storm events using a Type 3 storm. The peak flows and runoff volumes for each of these storms generated in each drainage area are summarized with the TR-20 output in Appendix F. As shown, this TR-20 routing generates very significant flows for this watershed. For example, the peak storm flow at the Highland Avenue Bridge would range from 858 cubic feet per second for a 2 year frequency storm to 1828 cubic feet per second for a 25 year frequency storm. However, it should be noted that this analysis did not address detention effects in the watershed. These detention effects could not be considered due to a lack of information necessary to develop accurate discharge and storage curves. As a result, these flows are conservatively high and would in reality be lower. The following outlines areas where significant detention would be expected.

- Shallow Pond in *Study Area*: Study area 1 drains to a shallow pond just north of the AMTRAK embankment. This pond outlets into a 30 inch culvert which drains through the AMTRAK embankment to Fenger Brook. Much of this culvert was observed to be

TABLE 4.2

SUBWATERSHED SUMMARY

FENGER BROOK STORMWATER MANAGEMENT STUDY
DECEMBER 1995

Study Area[1]	Drainage Area (acres)	SCS Curve Number	Time of Concentration (hours)
1	59.8	83	0.34
2	234.5	84	0.92
3	54.5	81	0.23
4	37.2	85	0.21

1) Study areas for the TR-20 evaluation are not the same as the defined subwatersheds.

TABLE 4.3

SUMMARY OF TR-20 EVALUATION

FENGER BROOK STORMWATER MANAGEMENT STUDY DECEMBER 1995

Study Area[1]	2 Year Storm (3.4 inches)		10 Year Storm (5.0 inches)		25 Year Storm (5.7 inches)	
	Peak Flow (cfs)	Runoff Volume (acre-ft)	Peak Flow (cfs)	Runoff Volume (acre-ft)	Peak Flow (cfs)	Runoff Volume (acre-ft)
1	199	22	352	39	420	47
2	518	90	912	159	1088	190
Subtotal (To Niles Hill Road Bridge)	620	112	1099	198	1313	238
3	179	18	321	34	386	41
Subtotal (To Glenwood Ave. Bridge)	738	131	1322	232	1583	279
4	143	15	246	26	292	31
Subtotal (To Highland Ave. Bridge)	858	145	1528	258	1828	309

1) Study areas for the TR-20 evaluation are not the same as the defined subwatersheds.

obstructed with debris, so in its current condition this pond could provide a significant amount of detention during major storm events. Regardless of the debris blockage, this pond is anticipated to provide significant stormwater detention.

- Main Stem Wetlands in *Study Area*: In Study area 2, Fenger Brook drains through a relatively large wooded wetland system. This wetland is approximately 160 acres in size and is generally located in the center of the sub-watershed. During smaller storm events, Fenger Brook would likely stay within its banks and thereby would receive little benefit from detention in the wetlands, with the exception of some "wide spots" which likely exist in the brook. During larger storm events when Fenger Brook would rise above its banks, some detention would be provided in the wetland floodplain.

- Upper and Middle Coves in *Study Areas* 3 and 4: The Upper and Middle Coves would be expected to provide significant detention of large storm events due to their ability to provide a significant amount of storage volume with relatively small increase in water depth.

5.0 POLLUTANT LOADING ASSESSMENT

A pollutant loading assessment was performed to identify and quantify potential non-point source pollutants to Alewife Cove from the surrounding watershed. The approach undertaken was to obtain pollutant loading factors, sometimes referred to as runoff coefficients, from the literature and apply these factors to the Watershed to quantify potential loads and the sources of these loads. The factors reported in the literature are typically based on stormwater sampling events and are a function of the land use within the drainage area. Based on these loading factors and current Fenger Brook Watershed features and stormwater management practices, loadings to the Upper and Middle Coves for the defined drainage areas within the watershed were calculated. The objective was to determine what areas should be targeted for best management practices for the pollutants of concern.

A GIS database was developed based on watershed mapping and land uses. The land uses described in Section 2 were delineated in the database. The pollutant runoff coefficients were then applied to the land uses and the GIS database was used to develop total loads to Alewife Cove.

It should be noted that the use of loading factors does not provide absolute pollutant loads expected to Alewife Cove. However, loading factors can provide a relative comparison of the source of loads to the Cove with respect to the whole watershed. Although not based on actual sample results from the Cove, this information can be used to delineate those areas and land uses with the greatest pollutant generating potential.

5.1 Literature Review of Pollutant Load Factors

As stated above, an extensive literature review was performed to obtain applicable loading factors for land uses in the watershed. Appendix G provides a compilation of the literature values obtained, references, and other pertinent information. It should be noted that for most studies referenced, little or no information was provided regarding sample techniques, land use definitions, existing management practices, and time of year in which sampling was performed. As such, it was necessary to make assumptions in order to use this information.

The data in Appendix G was arranged into a format where similar or same land uses were grouped to match given land use categories utilized within the Fenger Brook watershed. The range of loadings, i.e. upper and lower values, were defined for each parameter available. Using the upper and lower values, an "average" was established for each land use. The average loading was used in the pollutant loading evaluation. A summary of the average loading factors and associated land uses for TSS and total nitrogen is provided in Table 5.1. As indicated in Appendix G, for some land uses, loading factors were not available for certain constituents. For these constituents, values were interpolated from values for similar land uses and similar parameters. It is important to note that the nitrogen compounds, i.e. kjeldahl nitrogen, nitrate/nitrite and ammonia, do not add up to the total nitrogen loading factors given. This is due to obtaining the range from several different data sources. As such, total nitrogen is the sole parameter used for further evaluation below.

Waterford and New London provided information on land uses within the Watershed. Table 5.2 lists the land uses provided by Waterford and New London and the categories in which the land uses are grouped. (Note, the land use locations are provided in Figure 2.1.) Figure 5.1 shows the land use classes, or categories, within the watershed.

5.2 Loading Scenarios

Several loading scenarios were evaluated, using the GIS database, based on the pollutants of concern in the watershed. The following steps were undertaken to develop the loading scenarios.

1. Identification of the pollutant(s) resulting in the degradation of the Cove's water quality.

2. Determination of what measures, either natural or man produced, would reduce pollutant loading to the Cove and adjust the literature loading values to reflect this.

3. Calculate the total loads of pollutants to the Cove based on the adjusted loading factors and the area of each land use.

Based on the water quality characterization of Alewife Cove, the major pollution problems were identified. These were nitrogen inputs to the Upper Cove, sediment input to both the Upper and Middle Coves, and elevated fecal coliform bacteria in the Middle Cove and lower reach. Little information is available in the literature regarding bacterial loadings. Therefore, the loading evaluations do not include coliforms. As such, fecal coliform will be addressed qualitatively as opposed to quantitatively in this study. Nitrogen and suspended solids were targeted for further evaluation in the loading assessment. Nitrogen in the Upper Cove was detected at levels which would result in eutrophication. The Middle Cove did not exhibit high levels of nitrogen nor signs of eutrophication. Therefore, only the Upper Cove was evaluated for nitrogen loadings. Total suspended solid loads were evaluated for both the Middle and Upper Coves. For this exercise, an average of the upper and lower loading factor values was used to estimate the annual load.

Table 5.3 lists the drainage area sizes and calculated pollutant loads of total nitrogen and total suspended solids, without reductions, for each drainage area as shown in Figure 4.1, within the Fenger Brook Watershed. The loads are based on the loading factors detailed above. The drainage areas are shown on Figure 5.2. (Section 4.0 provides a description

TABLE 5.1

SUMMARY OF POLLUTANT LOADING FACTORS FOR TSS AND TOTAL NITROGEN *

FENGER BROOK WATERSHED MANAGEMENT STUDY DECEMBER 1995

Landuse	TSS (kg/ha/yr)	Total Nitrogen (kg/ha/yr)
Low-Med Density Residential	274	5.24
High Density Residential	1,055	11.5
Commercial/Industrial	1,050	9.1
Parks & Playgrounds	16.6	0.33
Parking Lots/Roads	441	15
Agriculture	1,375	21.3
Forest	25.1	3.9
Pasture	187	3.1

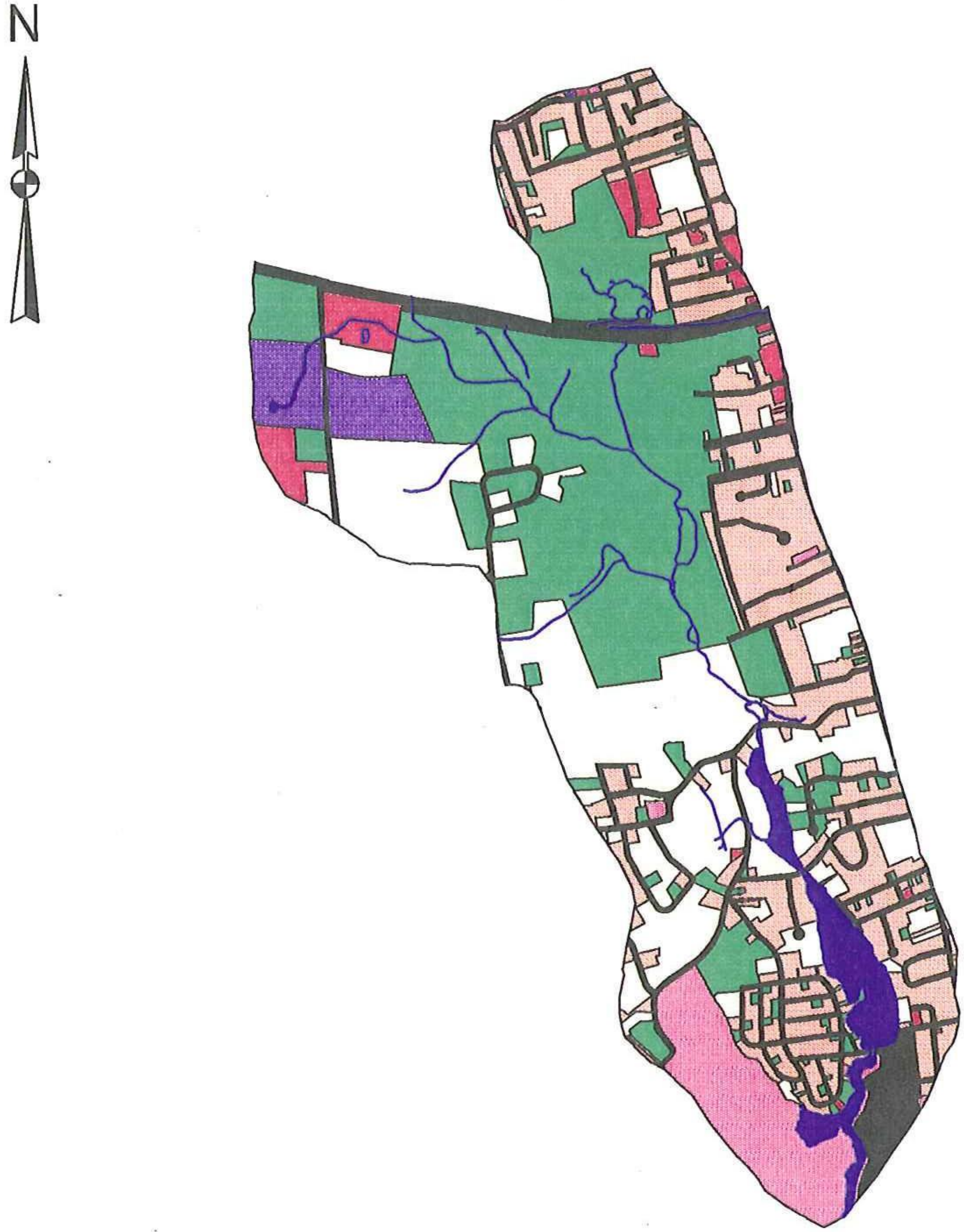
*See Appendix G for source of values.

TABLE 5.2

LAND USE CATEGORIES AND ASSOCIATED LAND USES FOR WATERFORD/NEW LONDON, CONNECTICUT

FENGER BROOK WATERSHED MANAGEMENT STUDY DECEMBER 1995

Land Use Category	Land Uses
Low/Medium Density Residential	Residential - Single Family > 0.5 Acres
	Residential - Single Family < 0.5 Acres
High Density Residential	Residential - Two Family
	Residential - Three Family
	Residential - Four to Six Family
	Residential - More Than Six Family
Commercial/Industrial	Commercial - General Retail and Service
	Commercial - Automotive Sales and Service
	Commercial - Office
	Commercial - Marine Sales and Service
	Commercial - Wholesale and Storage
	Institutional - Public and Private
	Industrial
	Utilities
Parking Lots	Large Parking and Roads
Parks and Playgrounds	Park, Recreation, and Open Space - Public
	Park, Recreation, and Open Space - Private
Agriculture	Farms (Includes Piggery)
	Residential Farms
	Open Space - Nursery
Forest	Forested Areas and Vacant Land



LEGEND

Surface Water Features

Landclass Legend

- Low to Medium Density Residential
- Urban / High Density Residential
- Commercial / Industrial
- Parks & Playgrounds
- Parking Lots
- Agriculture
- Forest
- Water

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FENGER BROOK WATERSHED MANAGEMENT STUDY

Land Use Classes Within The Watershed

PROJECT NO.: 92603A1 | FILE NAME: J:FENGER.APR | SCALE: 1" = 2000' | DATE: MAR. 1995 | FIGURE 5.1

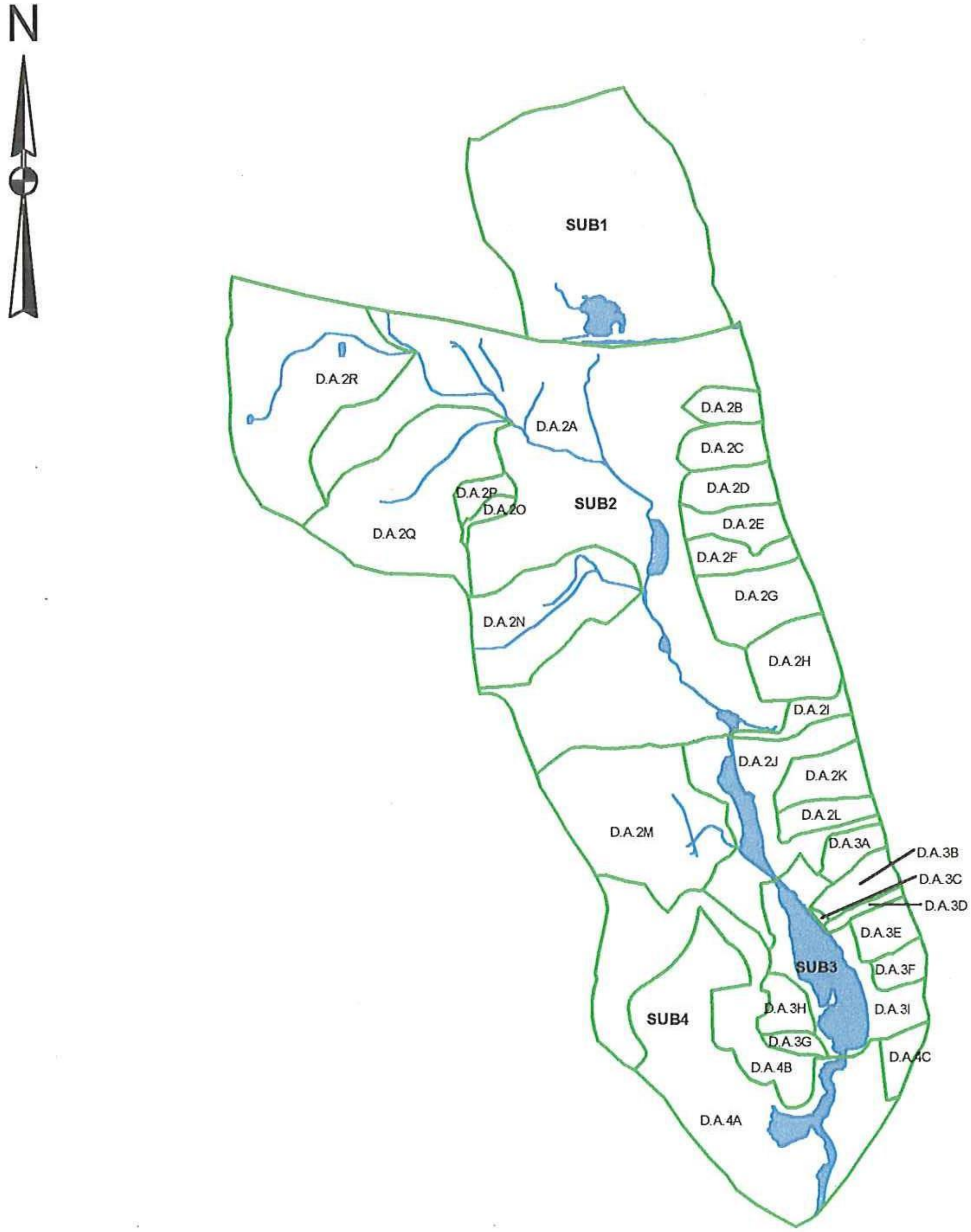
TABLE 5.3

DRAINAGE AREA SIZES AND ASSOCIATED ESTIMATED POLLUTANT LOA
WITHOUT REDUCTION

FENGER BROOK WATERSHED MANAGEMENT STUDY
DECEMBER 1995

Watershed/ Drainage Area	Area (Ha)	Average TSS (kg/yr)	Average TN (kg/yr)
Watershed 1	59.8	36698	559
Watershed 2			
D.A.2A	115.5	22013	655
D.A.2B	3.0	2684	35
D.A.2C	4.4	3014	48
D.A.2D	4.6	3505	55
D.A.2E	4.4	4106	52
D.A.2F	3.9	3812	44
D.A.2G	8.7	7681	103
D.A.2H	8.0	5307	74
D.A.2I	2.7	2182	32
D.A.2J (1)	17.4	8507	141
D.A.2K	5.2	2381	41
D.A.2L	3.4	2465	37
D.A.2M	26.0	9965	184
D.A.2N	17.5	1712	77
D.A.2O	1.1	252	9
D.A.2P	2.0	369	14
D.A.2Q	26.0	5559	135
D.A.2R	32.7	24388	379
Watershed 3			
D.A.3A	2.8	1771	25
D.A.3B	3.8	2898	40
D.A.3C	0.2	129	3
D.A.3D	1.1	915	14
D.A.3E	3.6	2439	36
D.A.3F	2.4	2073	31
D.A.3G	1.4	1035	16
D.A.3H	3.1	2461	36
D.A.3I (1)	10.8	8204	108
Watershed 4			
D.A.4A	43.5	13317	224
D.A.4B	24.5	6308	160
D.A.4C	2.5	21837	415

(1) Area does not include water surface area of Alewife Cove.



LEGEND

Drainage Area Boundary

River or Stream

Water Bodies

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FENGER BROOK WATERSHED MANAGEMENT STUDY

Drainage Area Locations

PROJECT NO.: 92603A1	FILE NAME: J:FENGER.APR	SCALE: 1" = 2000'	DATE: DEC. 1995	FIGURE 5.2

of the drainage areas.) Further evaluation of the nitrogen and total suspended solids loads is provided below. Appendix G provides the average loading factors as well as a table summarizing the calculated loading of TSS and total nitrogen for each drainage area.

As indicated above, it was assumed the loading factors obtained from the literature did not account for stormwater management practices. Therefore, adjustments were applied to loading factors for those areas where natural or man-made features/practices were anticipated to reduce pollutant loadings. The adjustments included reductions that are based on literature values for removal efficiencies of similar management practices. These reductions, associated drainage areas, and reason for including a reduction are listed in Table 5.4.

Sub-Watershed 1 drains to a pond north of the railroad. The pond is assumed to act as a detention pond with no net reduction in total nitrogen since the greatest percentage of nitrogen is in the soluble form. From Table 5.4, a reduction of nitrogen from Sub-Watershed 1 was not applied. For those drainage areas discharging stormwater to the forested wetlands areas as a diffuse source, or "sheet-flow," a nitrogen reduction of 50 percent was applied. This reduction was applied due to anticipated nitrogen removal from overland flow, assuming that little to no channelization occurs in these areas. The percent reduction reflects cited removal efficiencies of forested filter strips (Schueler, 1987).

As with the nitrogen loading assessment, reductions were applied to the TSS loadings for those areas where natural features or management practices were anticipated to reduce pollutant loadings. The reductions for TSS and associated drainage areas are also summarized in Table 5.4. From this table, it is seen that a reduction of 85% is applied to Sub-Watershed 1. Again, this is due to the natural drainage pond north of the railroad tracks which would function as a wet detention pond. For those areas which generate sheet flow to the wetlands, a reduction of 50% in TSS was applied. Additionally, a reduction of 7.5 percent was applied to those areas with catch basins that are maintained on a routine basis in Waterford. For the Middle Cove, TSS loads for drainage areas leading to the Upper Cove were reduced by an additional 85% to account for removal in the Upper Cove itself.

In addition to the load reductions due to management practices, forested areas were assigned a loading value of zero. The purpose of assigning a value of zero to forested areas was two-fold. The first was to identify the significant sources of pollutants associated with anthropogenic activities (discounting atmospheric deposition) within the watershed. The second was to identify pollutant loadings that are "controllable" via appropriate BMPs by screening out natural or "background" sources. (It was felt that contributions from forested areas would be considered natural background and would not be expected to be controlled.) Forested areas are ultimately assigned pollutant load values for the BMP evaluation presented within the loading assessment Section 5.2.1. An example of the method used in calculating the adjusted load is provided in Example 1. This shows the adjusted load calculation for subwatershed 1.

5.2.1 Loading Assessment - Upper Cove

Nitrogen

TABLE 5.4

POLLUTANT LOADING ADJUSTMENTS FOR EXISTING MANAGEMENT PRACTICES/WATERSHED FEATURES

FENGER BROOK WATERSHED MANAGEMENT STUDY DECEMBER, 1995

Subwatershed/ Drainage Area	Load Reduction Feature/Practice	TSS Reduction (%)	Total Nitrogen Reduction (%)
Watershed 1	Natural Pond	85	0
2A, 2N, 2Q, 2R	Sheet Flow to Wetlands	85	50
2B, 2C, 2D, 2E, 2F, 2G, 2H, 2O, 2P	Point Source to Wetlands	50	0
All Subwatersheds Discharge to the Upper Cove	All Sources to the Upper Cove	85	0
2M, 3H, 3G	Catch Basin Maintenance	7.5	7.5

EXAMPLE 1

DETERMINATION OF ADJUSTED TSS LOAD FOR SUBWATERSHED 1

FENGER BROOK WATERSHED MANAGEMENT STUDY DECEMBER 1995

The following example is provided to show the method of calculating loading from the individual drainage areas. A loading summary table is provided in Appendix G.

Subwatershed 1

Landuse	*Area (ha)*	*TSS Load Factor (kg/ha-yr)*	*TSS Load (kg/yr)*
Low/Medium Density Residential	3.63	273.5	992
High Density Residential	25.19	1,055	26,575
Commercial/Industrial	4.05	1,050	4,253
Parks	0.37	16.6	6.1
Parking Lots/Roads	9.84	440.5	4,335
Agricultural	0.09	1,375	124
Forest	16.64	25.05	417
			36,702 *

Adjusted Load

Reduction due to Natural Feature.

The additional reduction due to natural features is as follows, excluding load due to forested areas:

Adjusted Load = (Total Load - Forest Load) x (1 - Reduction Factor)
*= (36,702 - 417) (1-0.85) = 5,443 kg/yr **

From Table 5.4, the reduction factor in this case is 0.85.

* *Note: Values differ slightly from those reported in Tables 5.3 and 5.5 due to rounding of the land areas. (The GIS database carries out calculations with a greater number of significant digits than provided in this example.)*

Table 5.5 provides a summary of the adjusted nitrogen loads for each drainage area to the Upper Cove. The loads from these drainage areas are also depicted on Figure 5.3. From this table, it is seen that the major drainage areas which contribute nitrogen to the upper cove are Sub1, 2A, 2M, and 2R. Sub1 contributes a significant quantity due to the fact that the majority of this drainage area is densely developed and no net reduction of nitrogen is anticipated before entering the Cove. Drainage areas 2A, 2M, and 2R are high contributors of nitrogen due to their large areas.

The loading of nitrogen to the Upper Cove was also evaluated by land use and by drainage area groups. Tables 5.6 and 5.7 show these breakdowns. Table 5.6 shows both the original loads for the watershed based on the loading factors and the reduced loads. The adjusted loads account for the reductions applied to the original loads as discussed above. From Table 5.6 it is seen that the main source of nitrogen is contributed by residential areas, more than 60 percent of the total adjusted load. The drainage area groups provided in Table 5.7 are grouped as follows: areas that flow directly to the Cove, point stormwater discharges to wetlands north of the Cove, diffuse source discharges to the wetlands north of the Cove, and discharges to wetlands north of the railroad (Sub-Watershed 1). These groups were developed to identify the significant areas where pollutants are generated. Table 5.7 indicates that the contribution of nitrogen to the Upper Cove is generated from all drainage area groups in equivalent magnitude. The loading percentages by drainage area are depicted in Figure 5.3. Figure 5.4 shows the nitrogen loads to the Upper Cove by drainage area groups. The percentages shown in this figure are given in Table 5.7.

Total Suspended Solids

TSS loading scenarios were developed for the Upper Cove. The loading of TSS to the Upper Cove by drainage area is provided in Table 5.5 and shown in Figure 5.5. This loading assessment shows that the majority of TSS is generated from drainage areas 2J, Sub 1, and 2M. Solids generated from the other drainage areas are significantly reduced due to removal by the wetlands. It should be noted that Sub 1 is a significant contributor of TSS even with reductions provided by the wetlands.

As with nitrogen, TSS loadings were grouped by both land use and drainage area groups. Tables 5.6 and 5.7 show these breakdowns for the Upper Cove. The percentages by drainage area groups are also depicted in Figure 5.6. From Table 5.6 it is seen that the majority of TSS is generated from residential areas, over 75 percent for the loads. In Table 5.7, the TSS loads to the upper cove area are broken down as described above for the drainage area groups. Most of TSS contributed to the Cove is generated from areas that flow directly to the Cove and point source discharges to the wetlands.

5.2.2 Loading Assessment - Middle Cove

As stated above, only TSS to the Middle Cove was evaluated. Table 5.8 shows the TSS load to the Middle Cove by drainage area. This Table shows that much of TSS is generated from drainage area 3I, which is immediately adjacent to the Middle Cove. This is expected as a large portion of TSS load is assumed to be removed in the Upper Cove. Additional large contributors of TSS are drainage areas Sub 1, 2A, and 2R. The percentage of TSS contributions by drainage area are depicted in Figure 5.7.

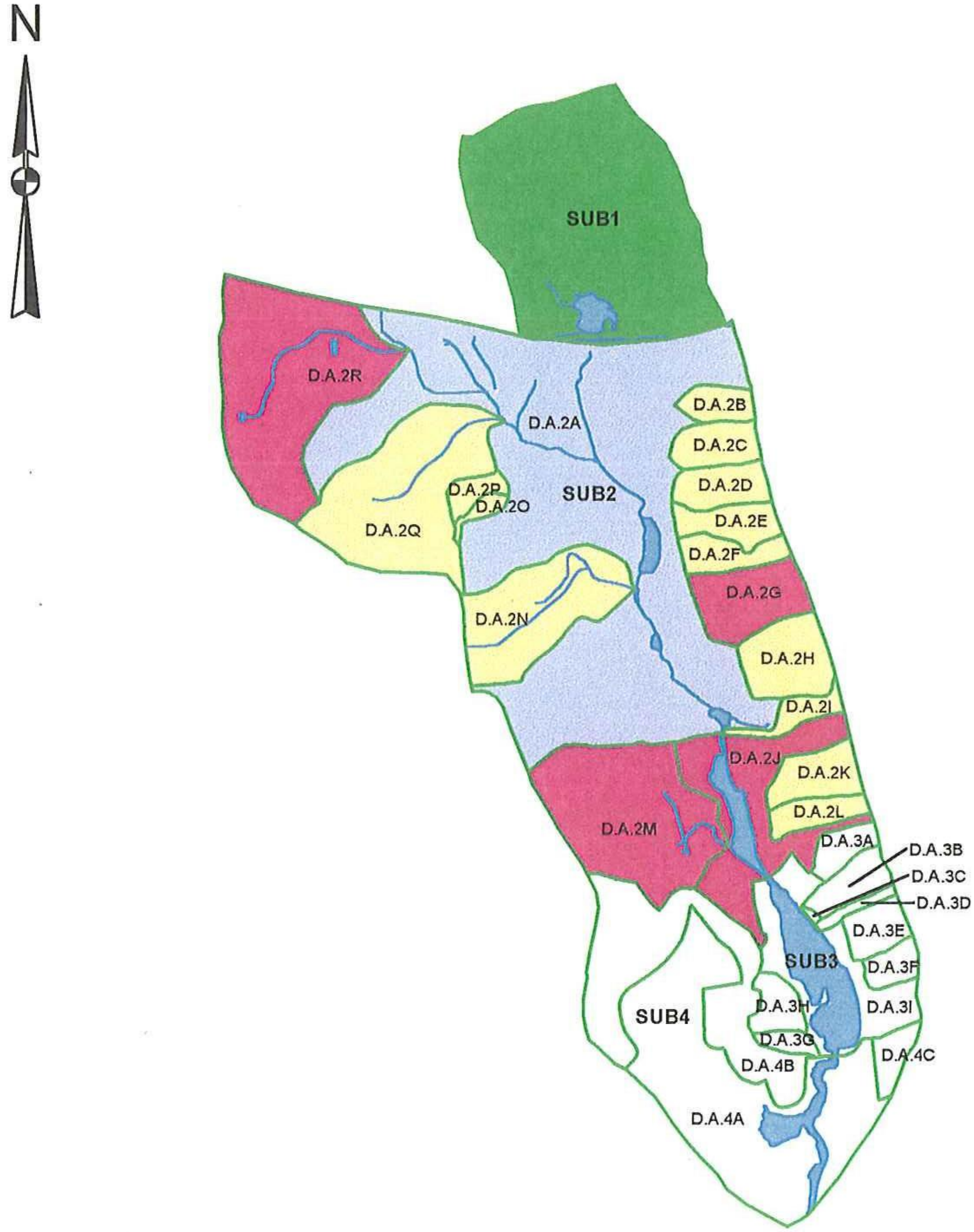
TABLE 5.5

POLLUTANTS LOADINGS TO UPPER COVE BY DRAINAGE AREA (1)

FENGER BROOK WATERSHED MANAGEMENT STUDY
DECEMBER, 1995

Drainage Area	Area (Ha)	TSS Reduction Factor (%)	Nitrogen Reduction Factor (%)	TSS		Total Nitrogen	
				Load (kg/yr)	% of Total	Load (kg/yr)	% of Total
D.A.2A	115	85	50	3019	6.2	182	10.4
D.A.2B	3.0	50	0	1342	2.7	35	2.0
D.A.2C	4.4	50	0	1504	3.1	47	2.7
D.A.2D	4.6	50	0	1749	3.6	54	3.1
D.A.2E	4.4	50	0	2053	4.2	52	3.0
D.A.2F	3.9	50	0	1906	3.9	44	2.5
D.A.2G	8.7	50	0	3838	7.9	103	5.9
D.A.2H	8.0	50	0	2648	5.4	72	4.1
D.A.2I	2.7	0	0	2182	4.5	32	1.9
D.A.2J (2)	17.4	0	0	8475	17.3	136	7.8
D.A.2K	5.2	0	0	2347	4.8	36	2.1
D.A.2L	3.4	0	0	2451	5.0	35	2.0
D.A.2M	26.0	7.5	7.5	4962	10.2	168	9.6
D.A.2N	17.5	85	50	210	0.4	14	0.8
D.A.2O	1.1	50	0	119	0.2	7	0.4
D.A.2P	2.0	50	0	171	0.4	10	0.6
D.A.2Q	26.0	85	50	803	1.6	51	2.9
D.A.2R	32.7	85	50	3627	7.4	173	9.9
Sub 1	59.8	85	0	5442	11.1	495	28.3
TOTAL	346			48847	100	1749	100

Note: (1) Forested area loadings are set to 0.0 for this assessment.
(2) Area listed for D.A.2J does not include the surface area of Alewife Cove.



LEGEND

- Drainage Area Boundary
- River or Stream
- Water Bodies

Percent of Total Nitrogen to Upper Cove by Drainage Area

- Not Applicable
- 0% - 5%
- 5% - 10%
- 10% - 15%
- > 15%

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FENGER BROOK WATERSHED MANAGEMENT STUDY

Percentage of Nitrogen Contributed to the Upper Cove by Drainage Area

PROJECT NO.: 92603A1 | FILE NAME: J:FENGER.APR | SCALE: 1" = 2000' | DATE: DEC. 1995 | FIGURE 5.3

TABLE 5.6

LOADINGS TO UPPER COVE GROUPED BY LAND USE

FENGER BROOK WATERSHED MANAGEMENT STUDY
DECEMBER 1995

Land Use	Area (Ha)	TSS Original Load (kg/yr)	TSS Original Load (%)	TSS Reduced Load (kg/yr)	TSS Reduced Load (%)	Total Nitrogen Original Load (kg/yr)	Total Nitrogen Original Load (%)	Total Nitrogen Reduced Load (kg/yr)	Total Nitrogen Reduced Load (%)
Low/Med. Dens. Resid.	87	23,843	16.3	8,241	16.9	456.9	17.1	319.2	18.2
High Density Residential	66	69,704	47.5	29,516	60.4	760.2	28.4	738.7	42.2
Comm./Ind.	13	14,161	9.7	2,360	4.8	122.8	4.6	82.6	4.7
Parks	1	18	0.0	7	0	0.4	0.0	0.3	0
Park. Lots/Roads	35	15,472	10.6	5,697	11.7	526.8	19.7	451.3	25.8
Agriculture	15	20,178	13.8	3,027	6.2	312.6	11.7	157.3	9.0
Forest	129	3,223	2.2	0	0	495.2	18.5	0	0
Pasture	0	0	0	0	0	0	0	0	0
Total	346	146,599	100	48,847	100	2675	100	1749	100

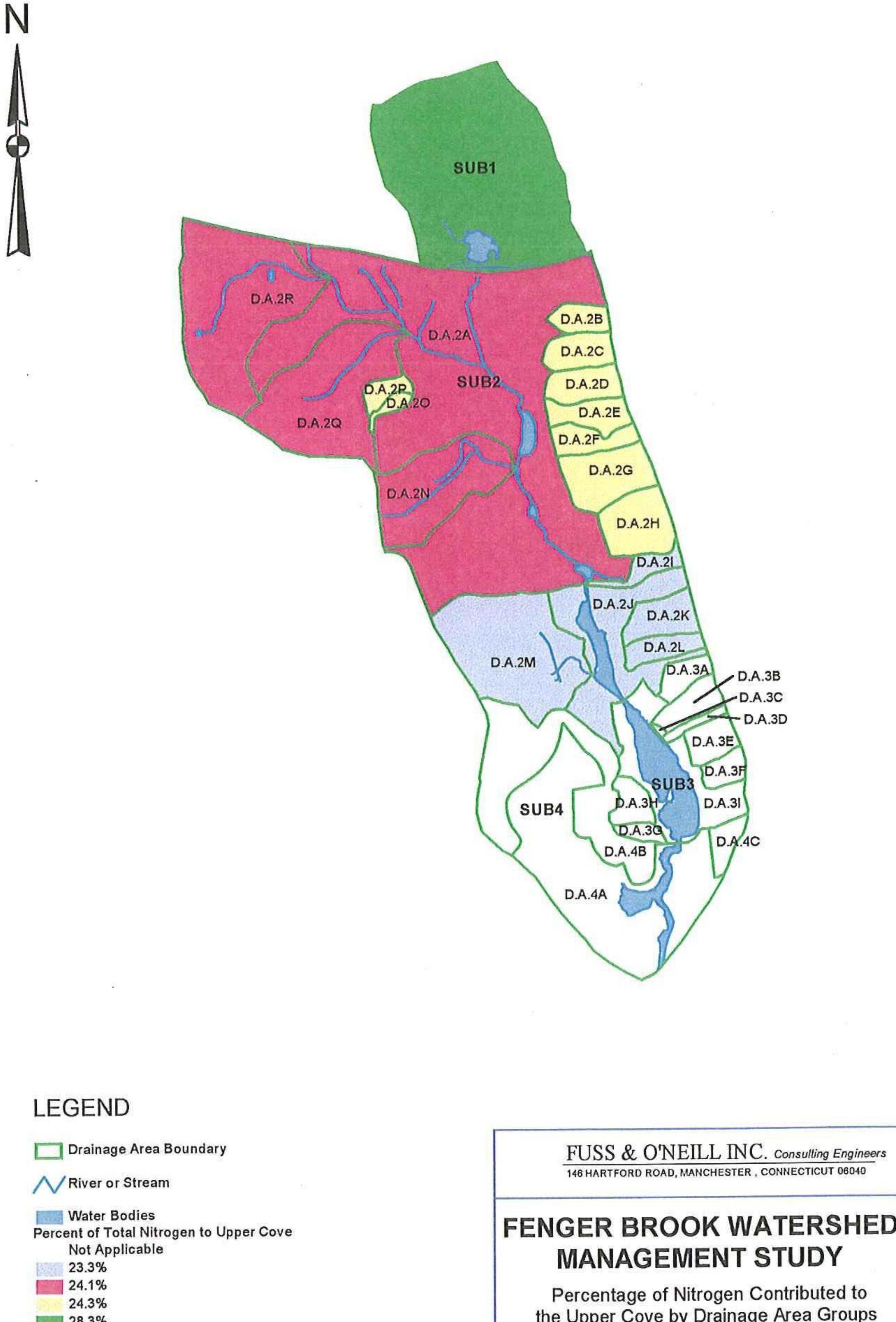
TABLE 5.7

DRAINAGE AREA GROUP BASED LOADINGS

FENGER BROOK WATERSHED MANAGEMENT STUDY
DECEMBER 1995

Group	Area (Ha)	% of Total	TSS Load (kg/yr)	TSS % of Total	Total Nitrogen Load (kg/yr)	Total Nitrogen % of Total	Reduced TSS Load (kg/yr)	Reduced TSS % of Total	Reduced Total Nitrogen Load (kg/yr)	Reduced Total Nitrogen % of Total
1	55	16	25500	17	435	16	20417	42	408	23
2	40	12	30729	21	436	16	15329	31	425	24
3	192	55	53672	37	1244	47	7659	16	421	24
4	60	17	36698	25	559	21	5442	11	495	28
Total	346	100	146599	100	2675	100	48847	100	1749	100

KEY:
1 - Land use areas that flow directly to Cove.
2 - Point source stormwater discharges to the wetlands north of the Cove.
3 - Diffuse source discharges to the wetlands north of the Cove.
4 - Discharges to the wetlands north of the railroad (Sub-watershed 1).



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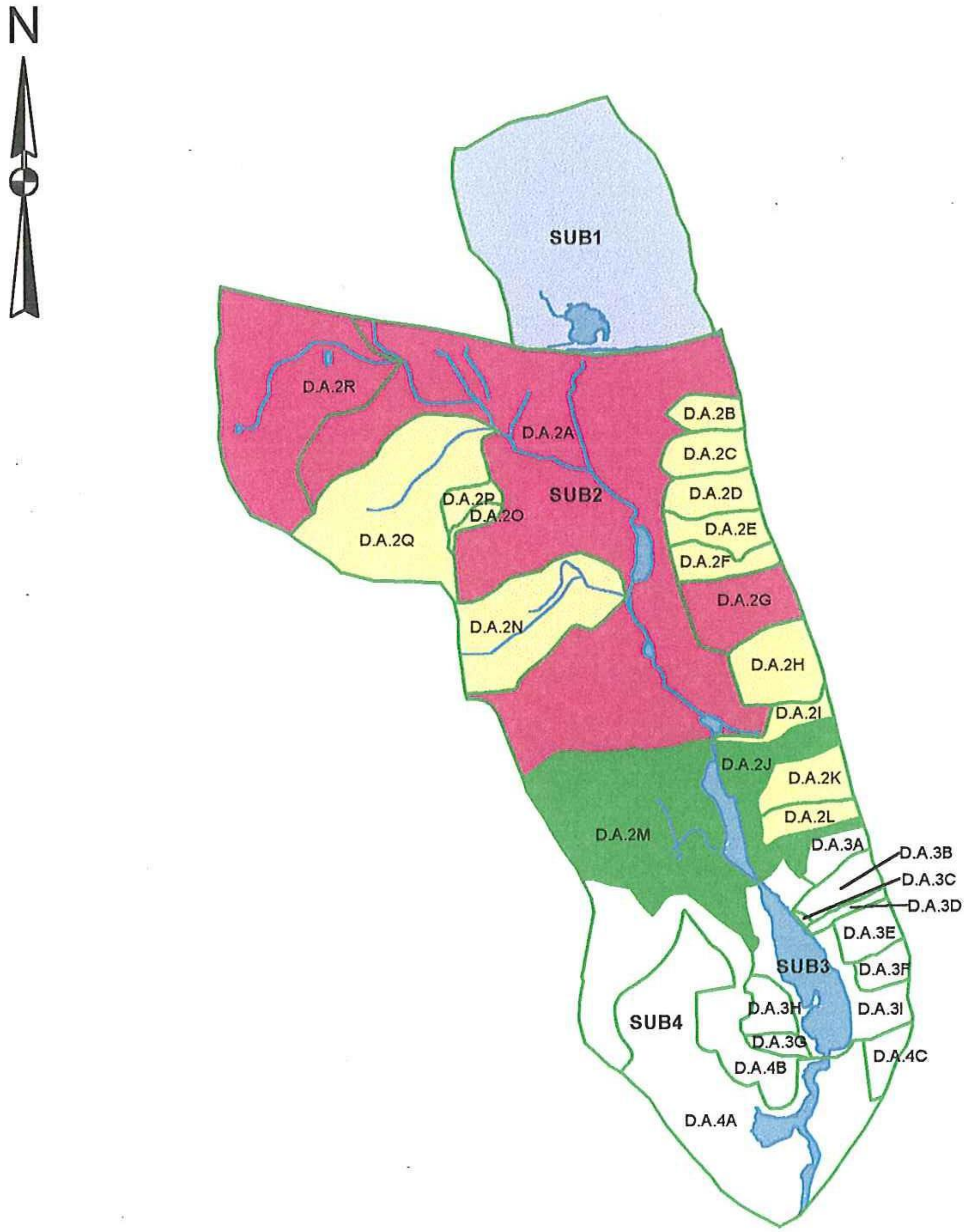
FENGER BROOK WATERSHED MANAGEMENT STUDY

Percentage of Nitrogen Contributed to the Upper Cove by Drainage Area Groups

PROJECT NO.: 92603A1 | FILE NAME: J:FENGER.APR | SCALE: 1" = 2000' | DATE: DEC. 1995 | FIGURE 5.4



LEGEND

Drainage Area Boundary

River or Stream

Water Bodies

Percent of TSS to Upper Cove by Drainage Area

Not Applicable

0% - 5%

5% - 10%

10% - 15%

> 15%

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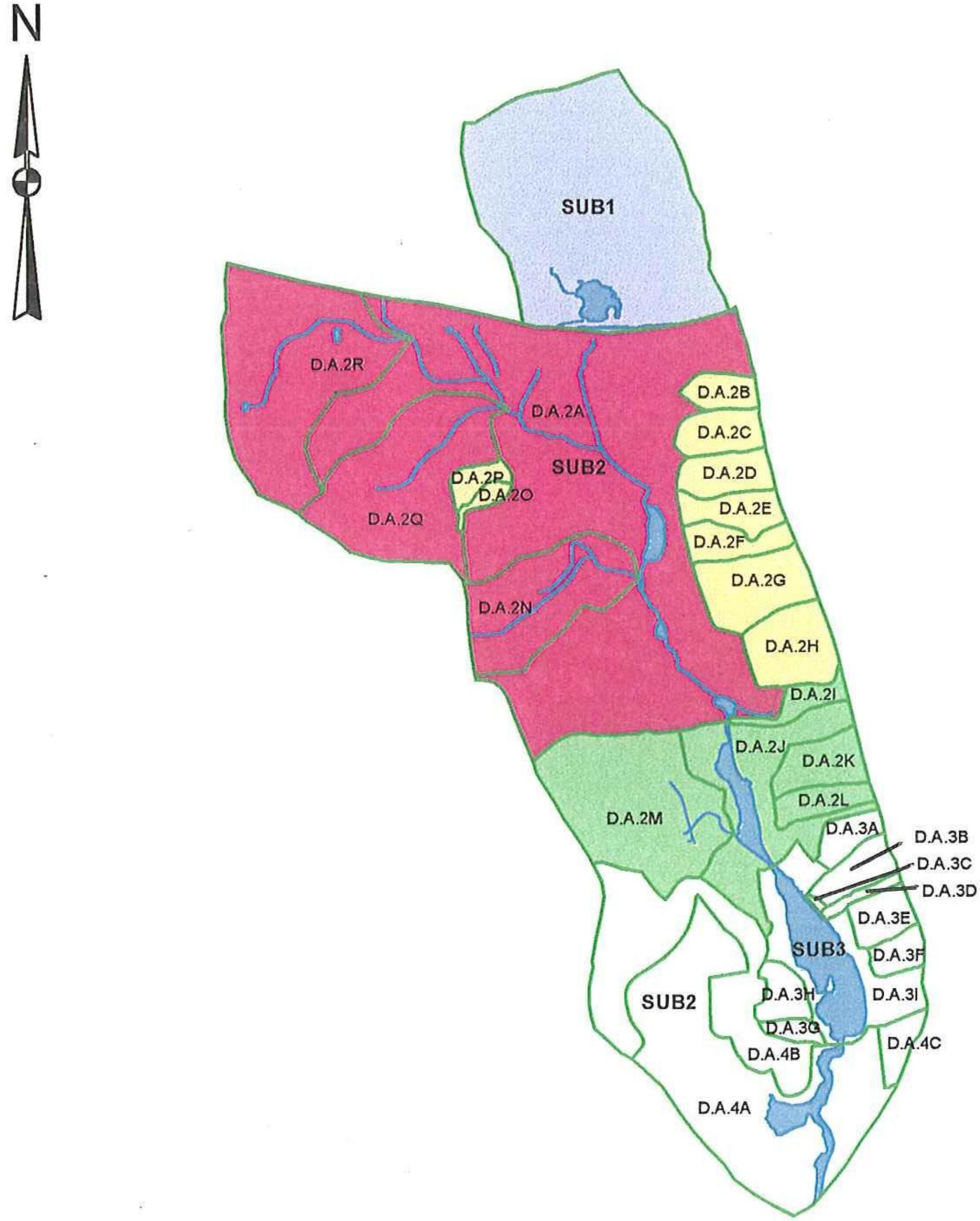
FENGER BROOK WATERSHED MANAGEMENT STUDY

Percentage of TSS Contributed to the Upper Cove by Drainage Area

PROJECT NO.: 92603A1 FILE NAME: J:FENGER.APR

SCALE: 1" = 2000' DATE: DEC. 1995 FIGURE 5.5



LEGEND

Drainage Area Boundary

River or Stream

Water Bodies

Percent of TSS to Upper Cove

Not Applicable

10.3%

14.4%

28.9%

46.4%

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FENGER BROOK WATERSHED MANAGEMENT STUDY

Percentage of TSS Contributed to the Upper Cove by Drainage Area Groups

PROJECT NO.: 92603A1 FILE NAME: J:FENGER.APR

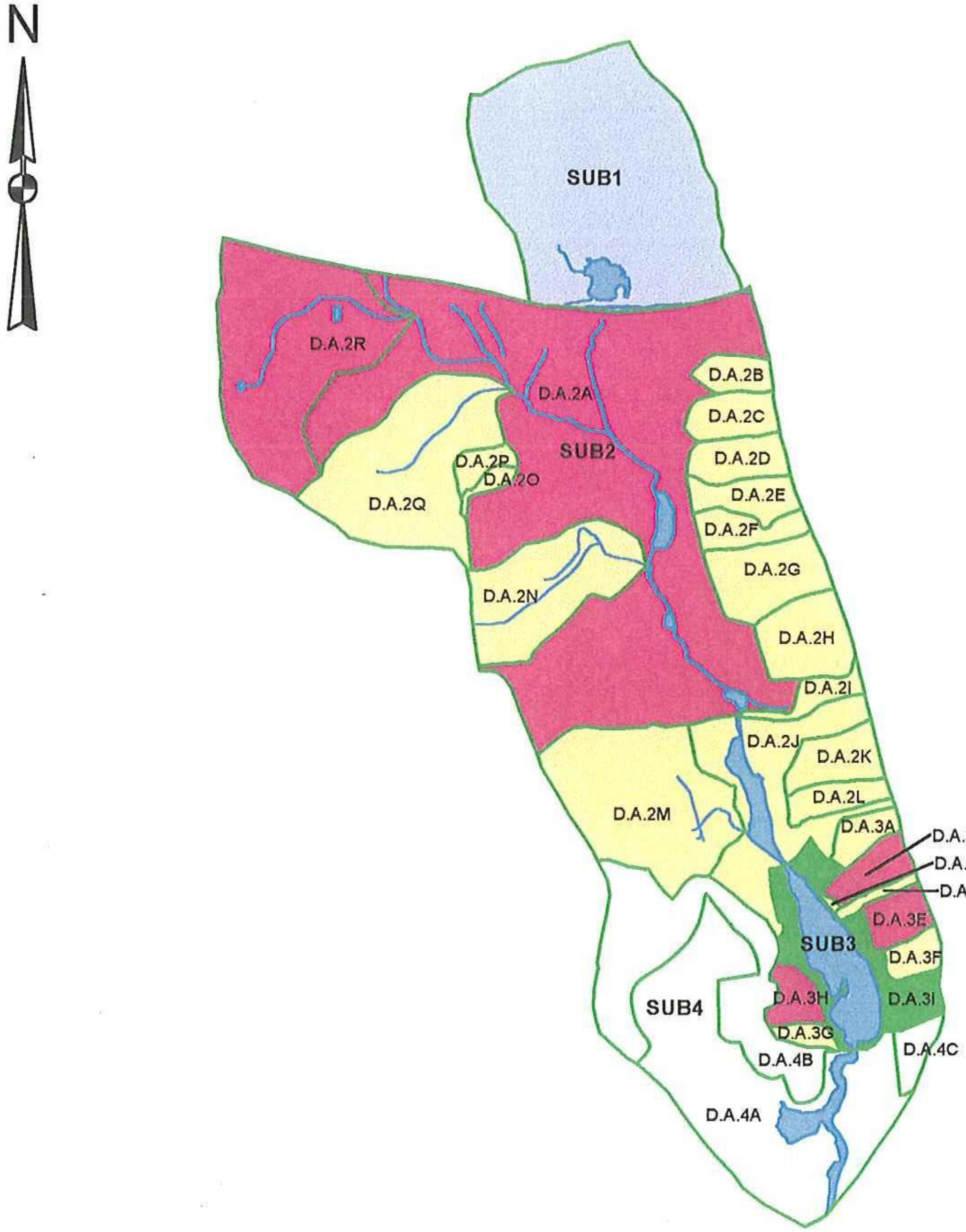
SCALE: 1" = 2000' DATE: DEC. 1995 FIGURE 5.6

TABLE 5.8

TOTAL SUSPENDED SOLIDS LOADING TO THE MIDDLE COVE FENGER BROOK WATERSHED MANAGEMENT STUDY DECEMBER 1995

Drainage Area	Area (Ha)	TSS Reduction Factor (%)	TSS Load (kg/yr)	TSS % of Total
D.A.2A	115	85	3019	7.2
D.A.2B	3.0	85	403	1.0
D.A.2C	4.4	85	451	1.1
D.A.2D	4.6	85	525	1.3
D.A.2E	4.4	85	616	1.5
D.A.2F	3.9	85	572	1.4
D.A.2G	8.7	85	1151	2.8
D.A.2H	8.0	85	794	1.9
D.A.2I	2.7	85	327	0.8
D.A.2J (1)	17.4	85	1271	3.1
D.A.2K	5.2	85	352	0.8
D.A.2L	3.4	85	368	0.9
D.A.2M	26.0	85	1495	3.6
D.A.2N	17.5	85	210	0.5
D.A.2O	1.1	85	36	0.1
D.A.2P	2.0	85	51	0.1
D.A.2Q	26.0	85	803	1.9
D.A.2R	32.7	85	3627	8.7
D.A.3A	2.8	0	1771	4.3
D.A.3B	3.8	0	2892	6.9
D.A.3C	0.19	0	129	0.3
D.A.3D	1.1	0	915	2.2
D.A.3E	3.6	0	2433	5.8
D.A.3F	2.4	0	2072	5.0
D.A.3G	1.4	50	515	1.2
D.A.3H	3.1	50	1227	2.9
D.A.3I (1)	10.8	0	8196	19.7
Sub 1	59.8	85	5442	13.1
TOTAL	376		41663	100

(1) Area does not include water surface area of Alewife Cove.



LEGEND

Drainage Area Boundary

River or Stream

Water Bodies

Percent of TSS to the Middle Cove by Drainage Area

Not Applicable

0 to 5%

5% to 10%

10% to 15%

> 15%

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FENGER BROOK WATERSHED MANAGEMENT STUDY

Percentage of TSS Contributed to the Middle Cove by Drainage Area

PROJECT NO.: 92603A1 FILE NAME: J:FENGER.APR

SCALE: 1" = 2000' DATE: DEC. 1995 FIGURE 5.7

5.3 Loading Assessment Summary

A review of the loading scenarios described above for screening purposes indicates the following items of significance.

1. The main source of nitrogen generated in the Watershed is from residential areas.

2. The urban sub-watershed north of the railroad (Sub 1) is a significant source of the total nitrogen from the Watershed to the Cove.

3. Residential areas within the Watershed generate as much as 75 percent of the TSS contributed to the Cove.

4. Drainage areas adjacent to the Cove generate the largest percentage of the TSS contributed to both the Upper and Middle Coves.

6.0 BEST MANAGEMENT PRACTICES (BMP) EVALUATION

In order to address the non-point source pollution to Alewife Cove, an evaluation of potential best management practices (BMPs) that can be implemented in the watershed has been performed. The significant non-point source pollutants have been identified in Sections 3 and 5 as excess nitrogen to the upper cove, sediment build-up in both the Upper and Middle Coves and elevated fecal coliform counts in the Upper and Middle Coves.

The goal of the BMP evaluation was to develop a cost effective approach to reduce the non-point source pollutants of concern to the Cove and to prioritize effective BMPs. As discussed in the loading evaluation in Section 5.0 of this report, the pollutant loads generated in the watershed are based on the results of other studies. As such, the loadings presented in this report are hypothetical and provide a general indication of the relative magnitude and source of non-point pollution generated in the watershed. In this sense, the loading assessment provides a valuable tool for selecting and evaluating potential BMPs.

The approach in assessing BMPs for the Watershed was as follows:

1. An initial screening of several BMPs to eliminate BMPs not appropriate for implementation in the Watershed;

2. Development of costs and efficiencies for the screened BMPs;

3. Evaluation of the BMP cost/benefits to compare the effectiveness and cost of each BMP in the watershed;

4. Prioritizing the BMPs based on the cost/benefit; and

5. A review of the advantages and disadvantages of the screened BMPs.

It should be noted that there are many non-point source management measures that can be employed in the watershed to potentially improve the water quality of Fenger Brook and Alewife Cove. For many of the measures, however, the benefit and cost are difficult to calculate. Such non-quantifiable measures include enhancing existing regulations, such as zoning regulations, to improve management of existing land resources and remediating natural resources such as wetlands. Keeping this in mind, the BMP evaluation has been separated into two categories. The first involves an analysis of BMPs for which costs and improvements to water quality can be quantified, such as structural measures. The approach for this evaluation is described and detailed in Sections 6.1 through 6.4 below. The second part of the evaluation identifies those BMPs that are recommended to be implemented in the watershed, without identifying or quantifying the specific costs and benefits associated with such BMPs. A summary of these potential measures is provided in Section 6.5.

6.1 Existing Best Management Practices

As discussed in Section 2.0 of the report, some BMPs are currently implemented in the Watershed. These BMPs include the following:

Street Sweeping
Catch Basin Maintenance (Waterford only)
Leaf and Yard Waste Collection
New Sanitary Sewers (Septic System Abandonment)
Pump Station Removal (Sanitary Sewers)

As described in Section 2.0, street sweeping practices in the New London portion of the watershed consist of sweeping roads several times per year. Sweeping is performed in the spring, end of fall, and several times during the summer. Street sweeping, however, is not coordinated with parking bans within the watershed. Parked cars prevent access to gutters where the majority of pollutants accumulate. Considering this, for conservative purposes, it is assumed that current pollutant removal is negligible; although New London's existing street sweeping likely has benefits in reducing stormwater pollutants. As such, for purposes of this evaluation, it is assumed that current street sweeping practices could be improved by implementing a parking ban to enhance pollutant removal.

In Waterford, street sweeping is performed annually in the spring. Additional water quality benefits are likely if this program was expanded to include fall sweeping following leaf collection.

Catch basin cleaning is performed regularly in Waterford. The loading evaluation discussed in Section 5.0 accounts for a reduction in pollutants for this catch basin maintenance program. According to City personnel, New London does not maintain catch basins located within the Watershed. Leaf and yard waste collection is performed by both New London and Waterford.

As noted in Section 2.0, the Town of Waterford installed three grit/gross particle separators in the Ridgewood portion of the watershed. Installation of these systems was performed after completion of this study and, therefore, were not accounted for in the BMP evaluation presented in the following sections.

Also discussed in Section 2.0 is the fact that Waterford is in the process of replacing septic systems in the area of the Cove with a sanitary sewer collection system. Additionally, the pump station in New London, which has exhibited periodic failures, will be replaced with an interceptor sewer and tied into a pump station in Waterford. These two measures may reduce potential septic/sanitary sewer inputs to the Cove.

6.2 Initial BMP Screening

An initial list of potential BMPs was developed for consideration within the Fenger Brook Watershed. The BMPs considered are listed as follows:

Porous Asphalt Pavement
Concrete Grid Pavers
Impervious Surfaces Reduction
Swales with Check Dams
Roof Runoff Dry Wells
Infiltration Basins
Infiltration Trenches
Sand Filters
Off-line Trenches
Vegetation/Buffer Strip/Gardening Practices
Perforated Stormwater Pipes
Wet Ponds
Gross Particle Separators
Fertilizer Management
Yard Waste Collection
Pet Waste Management
Erosion Control
Housekeeping/Street Sweeping
Street Perimeter Trench
Runoff Distribution (Level Spreader)
Stormwater Detention/ Retention Basins
Stream/Wetland Buffers
Septic Maintenance
Wetland Enhancements

These BMPs were screened to identify the practices which have the most potential to address the non-point source impacts associated with the Watershed. The screening criteria included the following:

- Applicability: Most BMPs target specific pollutants or stormwater related problems. Therefore, only those BMPs with the potential for reducing the pollutants of concern for this watershed were considered further.

- Implementability: The ability to implement a BMP based on site conditions.

- Reliability: The ability to provide consistent and reliable removal/treatment in the Watershed.

- Land Requirements: The land area required to implement the BMP.

Cost and efficiencies of the BMPs were used to further evaluate the screened alternatives as discussed below. Appendix H provides a discussion of the screening for each BMP in the initial list above. A summary of the BMPs evaluated in the screening, including potential effects and significant factors, is provided in Table 6.1. Based on this screening, several BMPs were considered for further evaluation. These BMPs were evaluated to address existing conditions in the watershed. Other BMPs can be considered for areas of new development. These include the following:

Lot Based BMPs	Structural BMPs	Non-Structural BMPs
Roof Runoff Dry Well	Level Spreaders	Street Sweeping
Infiltration Trench	Gross Particle Separators	Fertilizer Management
	Sand Filters	Catch Basin Maintenance
	Constructed Wetlands	

TABLE 6.1

POTENTIAL BEST MANAGEMENT PRACTICES

FENGER BROOK STORMWATER MANAGEMENT STUDY
DECEMBER 1995

PRACTICE	POTENTIAL EFFECTS	COMMENTS
Current Watershed Practices		
· Street Sweeping*	Remove solids which accumulate in street gutters.	Conducted only annually in Waterford. Not coordinated with parking bans.
· Catch Basin Cleaning *	Solids removed in maintained sumps. Also maintain drainage system.	Not conducted in New London.
· Leaf and Yard Waste Collection *	Remove source of potential solids and nutrient loads.	Improper disposal still occurs in watershed.
· Erosion Control	Minimize solids loading from new construction.	Both towns have adopted erosion control regulations.
· New Sewers	Remove failing septic systems as potential source of fecal coliform and nutrients.	Waterford plans to hook-up any remaining septic system in developed parts of watershed.
· Pump Station Repair	Remove potential source of fecal coliform and nutrients.	Scheduled to be completed in the near future.

* BMPs to be considered for further evaluation.

TABLE 6.1
(continued)
POTENTIAL BEST MANAGEMENT PRACTICES

FENGER BROOK STORMWATER MANAGEMENT STUDY
DECEMBER 1995

PRACTICE	POTENTIAL EFFECTS	COMMENTS
Potential Structural Measures		
· Infiltration Basins	Reduce freshwater storm flows as well as solids, nutrients and fecal coliform loads.	Little space in urban areas as well as poor soils.
· Grass Ditch Street Drainage	Reduce freshwater storm flows as well as solids, nutrients and fecal coliform loads.	Inappropriate for existing urban areas.
· Pervious Storm Drain	Reduce freshwater storm flows.	Limited potential due to poor soils and slopes in urban areas. Would require replacing existing storm sewer.
· Retention Basin	Reduce solids and nutrient loads.	Little space in urban areas.
· Detention Basin	Reduce solids and nutrient loads.	Little space in urban areas.
· Wet Ponds	Reduce solids and nutrient loads.	Little space. Potential to disturb wetlands.
· Constructed Wetlands*	Reduce solids and nutrient loads. Potential to enhance wildlife habitat.	Little space. Potential to disturb existing wetlands.
· Level Spreaders/Buffer Strips *	Reduce freshwater storm flows as well as solids, nutrient and fecal coliform loads.	Significant buffer system available above upper cove.
· Gross Particle Separators *	Reduce solids and nutrient loads.	Can be constructed in-line with existing drains.
· Sand Filters *	Reduce solids, nutrient and fecal coliform loads.	Can be constructed in-line with existing drains but requires significant maintenance.

* BMPs to be considered for further evaluation.

TABLE 6.1
(continued)
POTENTIAL BEST MANAGEMENT PRACTICES

FENGER BROOK STORMWATER MANAGEMENT STUDY
DECEMBER 1995

PRACTICE	POTENTIAL EFFECTS	COMMENTS
Potential Non-Structural Measures		
· Lawn Maintenance * - Fertilizer Management - Yard Waste Collection - Pet Waste Management	Reduce solids, nutrients and fecal coliform loads.	Largely consist of public education campaign. Can include "test plots" and free soil analysis. Can include ordinances.
· Improved Street Sweeping *	Further reduce solids.	Coordinate spring and fall sweeping with parking bans.
· Catch Basin Cleaning in * New London	Further reduce solid loads and maintain existing drainage system.	Existing New London system is no longer operational in places due to accumulated material.
· Improved Leaf and Yard Waste * Collection	Further reduce solids and nutrient loads.	Public education campaign and enforcement of existing laws.
Potential Lot Based Measures		
· Porous Asphalt Pavement	Reduce freshwater storm flows.	75% failure rate. Requires significant maintenance.
· Concrete Grid Pavers	Reduce freshwater storm flows.	Difficult to maintain and keep clear of snow.
· Swales with Check Dams	Reduce freshwater storm flows, solids and nutrient loads.	Inappropriate for urban areas.
· Roof Run-Off Dry Wells*	Reduce freshwater flows.	Poor soils in watershed.
· Infiltration Trenches*	Reduce freshwater flows, solids and nutrient loads.	Poor soils in watershed.
· Vegetative Buffers	Reduce solids and nutrient loads.	Existing lawns likely provide best buffer.

* BMPs to be considered for further evaluation.

The following sections provide a description of these BMPs and the mechanisms responsible for reducing the pollutants.

6.3 *Description* of Screened BMPs

Table 6.2 is provided as a summary of advantages and disadvantages of the BMPs. These measures should be fully evaluated by the municipalities before implementation. In some circumstances, the advantages or disadvantages of a specific BMP may be more critical than the cost/benefit of that BMP. For example, sand filters may prove to be more effective in removing pollutants at a lower overall cost than another BMP; however, the increase in labor required to maintain a sand filter may make it less preferable. Public Works Directors should partake in decisions associated with implementing BMPs. The following provides a description of each of the screened BMPs.

6.3.1 Lot Based BMPs

Lot based BMPs are structural measures or retrofits that could be implemented on individual lots, including residential, commercial and industrial, within the watershed. The lot based measures to be evaluated in the watershed include roof runoff dry wells and infiltration trenches. Although there are a number of disadvantages to such measures, such as gaining public support and actual construction on private property, these measures are further evaluated to compare the feasibility with more "traditional" BMPs.

Roof Runoff Dry Wells

Roof runoff dry wells would consist of installing a dry well system to collect stormwater from roofed areas within the watershed. The dry wells would serve to infiltrate stormwater, thereby reducing runoff during rain events which would reduce or attenuate pollutants associated with rainwater and atmospheric deposition. The dry wells would consist of prefabricated concrete units. Crushed stone and filter fabric would be placed around the perimeter of the units to prevent clogging from the surrounding soils. It is assumed that each lot would require two infiltration units as most roofs are pitched in two directions. Dry wells would be most effective in areas where soils are well drained. As such, a disadvantage of such a measure within the Fenger Brook Watershed is that the majority of soils are poorly drained.

Infiltration Trenches

Infiltration trenches are measures that can be employed to infiltrate stormwater and thereby, reduce runoff. It has been reported that trenches are most practicable for sites less than 5 to 10 acres; therefore, these measures are appropriate for small individual lots. An infiltration trench basically consists of a shallow excavated trench that has been backfilled with stone. Runoff is diverted to the trench where it is exfiltrated to underlying subsoils. Runoff to infiltration trenches should be directed through a vegetated filter strip to remove sediment. Trench sizes are a function of quantity of runoff and rate of exfiltration.

The major advantages of infiltration are the reduction of surface runoff and removal of soluble pollutants. It has been reported that an 80 to 100 percent reduction in coliform bacteria can be achieved by infiltration trenches (Shueler, 1987).

TABLE 6.2

ADVANTAGES AND DISADVANTAGES OF SCREENED BEST MANAGEMENT PRACTICES

FENGER BROOK WATERSHED MANAGEMENT STUDY
DECEMBER, 1995

BEST MANAGEMENT PRACTICE	ADVANTAGES	DISADVANTAGES
Sand Filters	· High potential to remove solids. · Does not require large area for installation · Can be installed in-line with existing storm drains	· Significant maintenance required
Level Spreaders	· Convert point discharges to sheet flow to remove nutrients and solids · Will allow some downstream infiltration · Could utilize existing vegetation/wetlands for stormwater treatment	· Topography and available space must maintain down gradient sheet flow through buffer areas
Constructed Wetland	· Potential for significant solids and nutrients removal	· Significant capital and O&M costs · Requires a large area · Large peak flows may flush system · Will likely result in some disturbance of existing wetlands
Gross Particle Separators	· Does not require large area for installation · Would remove solids and floatables from discharge · Can be installed on-line with existing storm drains	· Little to no nitrogen removal · Requires periodic cleaning
Fertilizer Management	· Potential to reduce significant source of nitrogen · Public education campaign could address pet waste management, yard waste disposal, and over-watering	· Public participation necessary for a successful program.

* BMPs to be considered for further evaluation.

TABLE 6.2
(continued)
ADVANTAGES AND DISADVANTAGES OF SCREENED BEST MANAGEMENT PRACTICES

FENGER BROOK WATERSHED MANAGEMENT STUDY
DECEMBER, 1995

BEST MANAGEMENT PRACTICE	ADVANTAGES	DISADVANTAGES
Street Sweeping	· Municipalities currently own street sweeping equipment	· Parking ban necessary for effective street sweeping in urban areas
Catch Basin Cleaning	· Allow catch basin sumps to remove coarse solids · Maintain existing drainage system; many catch basins in New London are not functional	· Maintenance requirements.
Roof Runoff Dry Wells	· Reduce storm water runoff · Some nitrogen reduction	· Poor soils in watershed for infiltration · High groundwater in much of watershed · Must be installed/maintained by individual lot owners
Lot Base Infiltration Trenches	· Allow runoff from lots to infiltrate · Some reduction of nitrogen, solids and coliform bacteria	· Poor soils on watershed for infiltration · High groundwater in much of watershed · Must be installed by individual lot owners · Pretreatment required to minimize potential for clogging

* BMPs to be considered for further evaluation.

A significant disadvantage to trenches is sedimentation/clogging. If clogging of such trenches occurs, partial or complete replacement of the trench must be performed. Another disadvantage of such measures is that they are most effective in well drained soils. As with roof runoff dry wells, such measures would be less effective in the Fenger Brook Watershed due to the poorly drained soils. Additionally, areas with steep slopes may limit the use of infiltration trenches.

6.3.2 Structural BMPs

For many structural measures, storm sewers can be configured such that only the first flush is diverted to the control structure. The first flush is generally considered to be the runoff generated by the first 0.5 inches of rainfall over a one-hour period and has been found to wash about 90% of the pollutants from paved surfaces. By only diverting first flush flows to a control structure and bypassing larger flows, a structure could serve relatively large drainage areas but be sized to treat smaller flows that convey most of the pollutants.

Gross Particle Separator

A gross particle separator (also call an oil/grit separator) generally consists of a buried concrete tank that is baffled to provide a solids settling zone as well as to remove floatables from the discharge.

A number of criteria have been suggested for designing gross particle separators. Typically, these structures are sized to remove solids that have a particle size equivalent to fine sand during peak flows. Smaller particles would be settled during smaller storms. Sufficient volume must also be provided to store sand and floatables.

These tanks must be periodically pumped to remove accumulated grit and floatables. Typically, tanks are scheduled for annual clean-outs. Manholes should be provided for access to the tank.

Gross particle separators typically have the lowest pollutant removal rates as they rely on gravity settling of solids to remove pollutants. As a result, only a fraction of nutrients and metals are removed that are in particulate form. Turbulence during high flows can also significantly reduce settling efficiencies.

Level Spreader/Filter Strip

A level spreader is a structure which converts a point discharge to sheet flow. Once in sheet flow, stormwater runoff can be allowed to drain across a vegetated filter strip before entering a watercourse. The filter strip could consist of planted grass but is usually found to be more effective in a natural wooded area with grass, humus, leaf litter, brush and other plants. This vegetation promotes infiltration as well as trapping of solids. Humus is also effective in binding some soluble pollutants. As a result, simply converting an existing point discharge and allowing the discharge to sheet flow across existing vegetation could provide significant water quality benefits. A vegetated filter strip has significantly more potential to remove solids as well as other particulate and soluble pollutants. By converting stormwater into sheet flow and allowing it to drain across a vegetated strip, the stormwater is filtered by vegetation and other natural litter. Sheet flow also promotes infiltration.

A level spreader could be as simple as constructing a level "ditch" at the discharge of a storm sewer. The downgradient edge of this ditch must be level to allow water from the discharge to sheet flow across the length of the ditch into a stable vegetated area which then drains to the receiving watercourse. In general, an existing vegetated area/filter strip would not have to be enhanced, but backfill and seeding of any eroded channels would be recommended to maximize sheet flow through the vegetated area. A concrete lip is usually provided at the downgradient edge of the level spreader to minimize erosion which could affect performance by concentrating or re-channeling flows.

Little maintenance is required for a level spreader. Maintenance would likely include periodic inspections and repairing sections in which channeling may have occurred.

<u>Sand Filter</u>

A sand filter has greater potential to remove solids than conventional settling. A stormwater treatment sand filter typically consists of a structure with two chambers. Stormwater would first drain into a sedimentation chamber to remove coarse solids and reduce clogging of the sand filter. This sedimentation chamber would then overflow into the sand filter. The overflow should be baffled or hooded to capture floatables in the sedimentation chamber. The stormwater overflow would infiltrate through the sand filter to the outfall pipe. An emergency bypass would be recommended to prevent flooding in case of clogging. Sand filters have very good potential to remove solids as a result of the filtering provided. Sand filters can trap fines which are not typically settled. As these fines bind with pollutants more readily than coarse solids, there is also increased potential to remove other particulate pollutants. However, there is little potential to remove soluble pollutants.

Maintenance requirements include periodic pumping of floatables and sediments from the sedimentation chamber. Also, the first few inches of the sand filter will clog over time. As a result, the sand must be periodically replaced.

<u>Constructed Wetlands</u>

Wetland systems have significant potential to remove solids as well as nutrients and other pollutants. While natural wetlands should be preserved, a wetland system can be constructed to treat stormwater runoff. In general, a constructed wetland consists of two systems. Stormwater would first drain into a pond, allowing coarse solids to settle. This pond would then overflow into the constructed wetlands. Constructed wetlands have significant potential to remove particulate and soluble pollutants. These systems utilize a number of treatment processes which include settling, vegetative uptake, filtration, microbial action and adsorption to sediments and plants. Treatment performance is dependent on hydraulic loading and wetland age. Performance is also dependent on time of year, improving during the growing season and declining in the fall and winter.

Maintenance would be required to periodically remove accumulated sediment and repair erosion. In some cases, maintenance of the wetland areas include harvesting of vegetation. In addition, semiannual inspections would be recommended to confirm that the wetland is operating properly and is flourishing. Reinforcement plantings may be needed if some areas become unvegetated due to drought and other factors.

For this study, the constructed wetland option evaluation consists of a single wetland installed upstream of the discharge of Fenger Brook to the Upper Cove. A constructed wetland at this location was evaluated for the following reasons:

1. A wetland at this location would capture a significant portion of the flow generated in the watershed.

2. Portions of the existing wetlands were identified as having channelization and, therefore, nutrient uptake by the existing wetlands was felt to be less than the potential uptake if channelization wasn't present. By creating a wetland above the inlet to the Cove, a significant portion of the freshwater from the watershed could be captured thereby maximizing the potential for nutrient uptake.

It should be noted that implementation of in-stream measures such as this are typically difficult due to local, State and Federal permitting requirements.

To treat stormwater from a drainage area by the use of a constructed wetland, 0.01 acres of constructed wetlands per acre of drainage area served should be created (Schueler, 1992). This would result in an 8.5 acre constructed wetland to serve the watershed area above the Cove inlet.

6.3.3 Non-Structural BMPs

Non-structural alternatives consist of practices which reduce sources of pollutants in the watershed. These practices can either be applied across the watershed or can be focused in specific areas of concern. While these practices do not require new construction, there are generally some costs to implement and maintain a program to reduce pollutant sources.

The following paragraphs outline these programs and associated benefits.

Street Sweeping

The existing street sweeping program could be enhanced to remove additional solids that accumulate in street gutters before they are washed-off by a storm event. The following outlines several improvements to the existing street sweeping program that could potentially be implemented.

- Enforce parking ban on urban streets where street sweeping is now conducted. Parked cars prevent access to gutters where most of the pollutant load from streets is stored. During spring and fall cleaning, a one day temporary parking ban coordinated with the street sweeping program should be adequate. This temporary parking ban could be advertised in the newspaper, signs could be posted, or direct mailings could be made to notify the public when the parking ban is in place and when their streets will be swept.

- As Waterford performs street sweeping only in the spring, it is recommended that Waterford expand their street sweeping program to include annual fall sweeping in residential neighborhoods. Leaves and grass can make up as much as 20% of the total solids load stored in gutters in residential areas (Bannerman and Hughes, 1983). This

- Street sweeping performance is dependent on operator skill. Sweeper speed, brush adjustment, rotation rate and sweeping pattern all affect pollutant removal. It is recommended, if not already performed, that operators be trained by a qualified professional. This likely would improve the efficacy of existing programs.

Fertilizer/Lawn Management

Program Description

Fertilizer is a likely significant source of nitrogen in this watershed. Homeowners in general over-apply fertilizers as a result of following the application instructions provided with commercial fertilizers. These instructions often specify heavier than required application rates in order to cover worst-case conditions. The Northern Virginia Soil and Water Conservation District found that up to 2/3 less fertilizer can be applied than is typically recommended by manufacturers (NVPDC, 1992). Excess nitrogen and phosphorous in fertilizer that is not used by plants either infiltrates into the ground or is swept by runoff to receiving waters.

In order to reduce fertilizer use, a public education campaign could be directed to homeowners about proper fertilizer application. In addition, this campaign could be used to further reduce other sources of stormwater pollutants from existing homes and businesses. This campaign could increase the public's awareness and concern about non-point source pollution by educating the public on stormwater impacts to their ponds, wetlands and watercourses as well as the public's role in reducing these impacts. This campaign could be used to convey the following information to the public:

- Current non-point source pollution impacts and the goals to reduce these impacts.

- General education about fertilizer overuse and associated nitrogen and phosphorous impacts.

- Typical recommended nitrogen requirements for lawns and suggested fertilizer application rates.

- Information on soil testing offered by the University of Connecticut Cooperative Extension System to determine fertilizer requirements. Typical cost is $5.50 per soil sample delivered. This could be made a "free" testing program if a source of funding could be established.

- Use of alternative "fertilizers" such as compost that provide slow release of nitrogen and other nutrients, thereby contributing less nitrogen to stormwater.

- Fertilizer application practices that reduce the potential to contribute to stormwater loadings. These practices would include multiple application of fertilizers and use of dry versus liquid fertilizers.

- Use of lawn clippings to create a mulch that retains water and pollutants in runoff.

- Pet waste contributions to bacteria, solids, and nitrogen loads and suggestions on proper pet waste management and disposal.

- Impacts from improper leaf disposal and reminders of how leaf waste is properly disposed.
- Impacts from over-watering lawns such as increased runoff and suggestions on proper watering for best effects.
- Landscaping techniques which can reduce fertilizer, pesticides and water use as well as reduce runoff.
- Proper disposal of waste oil and household hazardous waste.
- Storing potential sources of stormwater pollutants indoors such as paints, pesticides, herbicides and metallic materials, for example.

A public education campaign could consist of a newsletter or bulletins periodically sent to residences and businesses within the watershed. This newsletter should be updated to include current information on measures to reduce pollution. It should be noted that the University of Connecticut Cooperative Extension System has already developed fact sheets on non-point source pollution and lawn care impacts. Initially, a series of news releases to local newspapers would also be recommended to raise public awareness and interest on non-point source impacts. These news releases should first focus on stormwater quality impacts identified by this study and the likely sources of these impacts from homes and businesses. Later releases could include the municipalities' role in reducing non-point source pollution and the recommended plan to reduce stormwater pollution. Periodic news releases would also be recommended to update the public on the effects on the water quality of the Cove.

At least part-time staffing would be necessary to implement this program to prepare newsletters, answer questions from the public, and keep up-to-date on stormwater issues. This staff person could also get more involved in developing other components of the public education campaign as well as reviewing best management practices proposed for new developments as part of their site plan review. A volunteer association also could be created to continue education and management of this program, eventually replacing the paid staff.

Another component of a long-term public education campaign could be to educate schoolchildren on non-point source pollution as well as the public's role to reduce it. Lesson plans could be prepared for teachers to teach classes on non-point source pollution. This would improve long-term awareness as well as improve overall community support.

The municipalities also could manage several demonstration lawns to show residents in the watershed how the recommended fertilizer and lawn management program works. This would consist of coordinating the efforts of four or five volunteers managing lawns in the watershed which residents would be able to visit. Note that this could potentially be performed on public lawns. In addition, if desired, alternative landscaping could also be demonstrated. This program also could include classes on lawn care and fertilizer use which reinforces minimizing non-point source impacts and would also provide the public the opportunity to ask experts about lawn care problems.

The fertilizer/lawn maintenance program could also incorporate a pet waste management program. Pet wastes are potentially a significant source of bacteria in stormwater runoff.

It should be noted that a study by the Nassau-Suffolk Regional Planning Board in 1978 found that pet droppings in runoff were responsible for shellfish bed closures in New York and Massachusetts (Koppleman, 1978). Pet wastes also contribute to solids and nitrogen loadings. In order to reduce this potential source of stormwater pollutants, pet wastes should be collected by pet owners and disposed of properly. Several alternatives can be implemented to encourage proper disposal as follows.

- Public education on water quality impacts from pet wastes and encouraging pet owners to pick up pet droppings. The watershed-wide public education campaign described above would include information on water quality impacts from pet wastes and direction on proper disposal. This approach would rely on voluntary compliance and "neighborhood enforcement" as opposed to ordinances and fines.

- An ordinance could be adopted requiring pet owners to clean up after their pets when in public areas, such as sidewalks, roadsides and parks, and to properly dispose of droppings. Police could be empowered to ticket and fine offenders to enforce the ordinance.

- "Scooper" dispensers in areas where pets are walked frequently, such as in public parks, also could be provided. This provides a convenient way for pet owners to collect pet wastes in public places.

Catch Basin Maintenance

As indicated in Section 2.3, little maintenance of the catch basins within New London is performed. Recommended maintenance typically consists of annual cleaning of catch basins and catch basin sumps to remove accumulated solids. The sumps can then function to remove gross particulates, such as sand and grit, reducing the amount of sedimentation that can occur in downstream surface waters. The catch basin maintenance developed for New London would involve annual clean-out of catch basins annually. Clean-out should be scheduled in the late spring to remove sand and grit accumulated from street sanding performed in the winter.

6.4 Cost/Benefit Evaluation

To identify which BMPs would be most cost effective in reducing the pollutants of concern in Alewife Cove, a cost/benefit analysis was performed for each of the screened BMPs. The analysis consisted of developing opinions of cost and removal efficiencies for each BMP. The benefit is a measure of the amount of pollutants removed by each BMP.

6.4.1 BMP Costs

Opinions of the capital costs and annual operation and maintenance costs were developed for each of the BMPs considered. Table 6.3 provides a summary of these costs as well as the total 20-year present worth costs. The 20-year present worth costs are based on an annual rate of return of 8 percent. A breakdown of the cost is provided in Appendix I. These costs were based on estimates provided in the reference section of this appendix and best engineering judgement. It is important to note that these costs are estimates and should not be used for construction budgeting purposes. It should also be noted that the opinion of costs do not include land acquisition costs or costs associated with obtaining drainage

TABLE 6.3

SUMMARY OF REMOVAL POTENTIAL AND ESTIMATED UNIT COSTS FOR SCREENED BMPS

FENGER BROOK WATERSHED MANAGEMENT STUDY
DECEMBER 1995

Best Management Practice	Solids Removal Efficiency (%)	Nitrogen Removal Efficiency (%)	Capital Cost Per Unit ($)	Annual Operation and Maintenance Cost Per Unit ($)	Total Operation and Maintenance Cost ($)	20 Year Present Worth for O&M ($)	20 Year Present Worth (1) ($)
NON-STRUCTURAL CONTROLS							
Fertilizer Management	0	15 to 25	$25,000 Lump Sum	$14,000	$14,000	$137,000	$162,000
Street Sweeping	5 to 10	0	$0	$30/curb-mile	$570	$6,000	$6,000
Catch Basin Maintenance	5 to 10	5 to 10	$0	$150 ea.	$16,800	$165,000	$165,000
STRUCTURAL CONTROLS							
Gross Particle Separator	20 to 40	5 to 10	$28,000	$1,000	$1,000	$10,000	$38,000
Level Spreader (to Forested Area)	80 to 100	40 to 60	$16,000	$600	$600	$6,000	$22,000
Sand Filter	70 to 90	30 to 45	$33,000	$1,600	$1,600	$16,000	$49,000
Constructed Wetland (8 Acres)	55 to 85	20 to 40	$837,000	$88,000	$88,000	$864,000	$1,701,000
Dry Well Installation							
Residential	0	1 to 2 (2)	$2,100	$150	$150	$1,500	$3,600
Urban	0	2 to 5 (2)	$2,100	$150	$150	$1,500	$3,600
Commercial/Industrial	0	3 to 6 (2)	$4,200	$300	$300	$2,900	$7,100
Infiltration Trenches							
Residential	60 to 100	40 to 80	$13,500	$950	$950	$9,300	$23,000
Urban	60 to 100	40 to 80	$9,000	$600	$600	$5,900	$15,000
Commercial/Industrial	60 to 100	40 to 80	$13,500	$950	$950	$9,300	$23,000

(1) Based on an 8% rate of return.
(2) Rounded to nearest percent.

easements as these would vary as a function of location. In addition, the costs are typical for these measures and, with the exception of the constructed wetland, are not a function of drainage area size. The cost opinions can be used for planning purposes.

From Table 6.3 it should be noted that the capital cost for street sweeping is not included in the present worth evaluation. The reason for this is that both Waterford and New London currently maintain a street sweeping program and no capital costs above what is currently expended for these programs is necessary. The street sweeping operation and maintenance costs are based on sweeping an additional 19 curb-miles. This represents the additional amount of road surface that should be swept in Waterford annually because currently Waterford performs a single street sweeping event in the spring. It should be noted that although capital costs were not included in the cost assessment, the additional street sweeping would result in increased wear and tear on the street sweeping equipment. For purposes of this evaluation it is assumed that the low number of additional miles would not result in a noticeable increase in capital expenditures. However, for informational purposes, the cost break-down in Appendix I includes capital cost estimates for street sweeping programs. Additional street sweeping in New London is not recommended as the frequency of street sweeping currently performed should be adequate.

As with street sweeping, catch basin maintenance requires no additional capital expenditures. It is assumed that both New London and Waterford have the necessary equipment to clean catch basin sumps.

It should also be noted that a structural stormwater system for Drainage Area 2C does not exist at this time. All drainage from this area is surface run-off. To implement a structural BMP for this drainage area, a central collection system must be created. As such, BMPs evaluated in this drainage area include the cost of constructing a subsurface drainage system. A central collection system would also serve to eliminate ponding and runoff in the road. The cost for installing a drainage system in Area 2C is estimated to be $52,000. (See Appendix I for calculation.)

6.4.2 BMP Removal Efficiencies

In addition to costs, Table 6.3 provides a summary of the removal efficiencies of the BMPs for both nitrogen and TSS. Removal efficiencies for each of the selected BMPs were obtained from several references. A summary of the references from which the efficiencies were obtained is provided in Appendix J. The references are based on evaluations of typical systems. A range of the removal efficiencies was used in this study based on an evaluation of values reported in the literature. Best engineering judgement was also used in selecting the removal efficiencies where literature values were unavailable. A summary of the development/application of some BMP removal efficiencies is provided in the following paragraphs. Table 6.3 is separated into structural BMPs and non-structural BMPs. Structural BMPs involve treatment of stormwater at the "end-of-pipe" or before stormwater enters a water body. Non-structural BMPs involve source reductions and watershed wide implementation of specific measures.

To estimate the effectiveness of several measures in reducing pollutant loads to surface waters, a review of available literature was performed to identify relative pollutant contributions. Specifically, the review targeted references for sources of nitrogen from residential and other applicable land uses. Kopplemen (1978) provides a summary of sources and fate of nitrogen for Long Island. A review of this summary indicates that as much as 46 percent of nitrogen, discounting the contribution from on-site septic systems, is from fertilizer application for turf management of households and golf courses. A technical bulletin on nitrogen loading in Cape Cod indicates that as much as 47 percent of nitrogen generated from a typical residential home is from lawn areas, i.e. fertilizer application (Eichner and Cambareri, 1992). Again, this percentage is based on the total anticipated load less the load generated from on-site waste disposal. In a study of nitrogen loadings to Buttermilk Bay, Massachusetts, Whitten et al. (no date) report that 57 percent of the nitrogen load to Buttermilk Bay, excluding sewage, is a result of lawn fertilizers. (It should be noted that these examples are for areas of sandy soils in which infiltration is an important factor.)

Although nitrogen contributions to surface waters from lawn fertilizers vary depending on soil type, vegetation and other factors, the above sources give an overall relative understanding of the potential and relative percentage of nitrogen loading from fertilizer use. In developing the removal efficiency for fertilizer management, it was assumed that an effective fertilizer management program would reduce nitrogen from turf management/gardening practices by one-third to one-half. Based on the above studies, this would result in a total reduction in nitrogen loading from residential areas of approximately 15 to 25 percent.

Street sweeping practices were assumed to result in reduced loadings from those land uses associated with roadways, i.e. residential, commercial/industrial, and roads/parking lots. Catch basin maintenance was evaluated in the same manner.

Roof runoff dry wells involve diverting the downspouts from roofed areas to dry wells. This would reduce nitrogen associated with precipitation and dry deposition from roof areas. In developing the removal efficiencies for nitrogen, it was assumed that 20 percent of the nitrogen from residential, and commercial/industrial land use areas is associated with precipitation. (The Long Island Sound Study (1994) indicates that as much as 24 percent of non-point nitrogen for the Sound's watershed is from the atmosphere. As a conservative measure, 20 percent is used herein.) Additionally, typical lots as described by the zoning regulations were used to determine the percent of roof area within these areas. Finally, it was assumed that the dry wells would act as infiltration trenches in terms of nitrogen removal efficiencies. For infiltration trenches, it was assumed that 100 percent of the runoff from a lot would be captured within the trench. Nitrogen would be expected to travel through groundwater to surface water with some reductions. Although this is unlikely, this assumption was used to simplify the evaluation. The removal efficiencies presented in Table 6.3 represent typical values reported in the literature. Realistically, dry wells and infiltration basins would be located in areas with soils that have adequate drainage. However, to simplify the evaluation, it was assumed that these measures could be implemented watershed-wide.

The constructed wetland option involves locating a single man-made wetland upstream of the outlet of Fenger Book to the Cove. This wetland would intercept stormwater drainage from both Sub-watersheds 1 and 2. The cost represents that for a wetland sized to detain runoff generated by a drainage area of this size. The 20-year present worth cost includes yearly operation and maintenance which entails vegetation harvesting necessary to reduce total nitrogen.

6.4.3 BMP Prioritization

The objective of prioritizing, or ranking, the screened BMPs is to identify the BMPs that most effectively reduce the problem non-point source pollutants to the Cove at the lowest cost. Prioritizing the BMPs assessed in this evaluation included the following:

1. Determining the potential locations to implement the BMPs;

2. Developing cost/benefit ratios for each of the screened BMPs using the costs and pollutant removals identified in the section above; and

3. Prioritizing/sorting each BMP on a drainage area or land use basis from the best cost/benefit ratio to the worst.

In selecting appropriate locations for the BMPs, a review of the watersheds was performed to determine the drainage areas in which the potential BMPs could be implemented. The criteria used in the location of BMPs were as follows:

1. Structural Drainage Systems: Several of the BMPs can only be located in drainage areas served by an existing structural system (i.e. culverts, catch basins, etc.).

2. Discharge Location: The location of the discharge with respect to the Cove was also considered in locating BMPs, such as level spreaders which require an area where stormwater can be diffused before entering a water body.

In the cost/benefit analysis, the non-structural BMPs were evaluated by land use; in effect reductions and costs were applied to each land use such as residential areas. The purpose of evaluating non-structural measures this way was that the effects would be a function of the land use. Structural measures were evaluated by drainage area as the effects would be drainage area wide regardless of the land uses. Some non-structural measures, such as catch basin maintenance, were evaluated on the same basis as structural measures as the benefits would be seen on a drainage area wide basis. Similarly, some structural measures were evaluated on the same basis as non-structural BMPs. These included the lot based BMPs; dry wells and infiltration trenches. The purpose of evaluating these measures as such is that the costs and benefits are a function of the land use for which they are applied.

For each BMP, a table was developed to show the drainage area, or land use, where the BMPs could be applied, the respective TSS and nitrogen loadings for these land uses, costs associated with each BMP, and estimated percent total reduction in pollutant loads. These tables are provided in <u>Appendix K</u>. These tables show both the average anticipated pollutant load and respective total reduction in loads. Also provided in <u>Appendix K</u> are tables showing the cost/benefit (represented by cost/removal) for each BMP. Separate cost/benefits were developed for both nitrogen and total suspended solids. The cost/benefit represents the cost in 1994 dollars per kg/yr removal of pollutants. The lower the ratio, the more cost effective the BMP.

To prioritize the BMPs, the cost/removal ratios were ranked from the lowest to highest by drainage area or land use, whichever applies to the BMP. This shows which drainage areas/land uses should be targeted first by a specific BMP to provide the most cost effective improvement to the Cove system. The cost versus removal for the ranked BMPs were graphed in Figures 6.1 through 6.4. Average load reductions are shown in these figures. Separate figures were developed for both total nitrogen and TSS. The graphs represent the cumulative cost and removals for the BMPs from the most cost effective to the least. Each symbol on the graph represents the additional costs and removal for each subsequent BMP addition.

Structural Measures

Figure 6.1 shows a comparison of average nitrogen removal versus cost for the structural BMPs. This figure reveals that level spreaders are the most cost effective means of reducing total nitrogen to the Upper Cove. This is represented by the curve with the steepest slope. Sand filters provide the next best level of treatment followed by the constructed wetland. As anticipated, gross particle separators do not provide an effective means of reducing nitrogen as the measures are mainly targeted at reducing solids. As indicated in this graph, the lot based measures, dry wells and infiltration trenches, are not a cost effective means of reducing nitrogen. For the lot based BMPs, each point represents the cost/removal associated with a land use, i.e., residential and commercial/industrial. For the other structural measures, each point represents an individual structure at a specific drainage area.

The cost/benefit curves for TSS reductions via structural BMPs are provided in Figure 6.2. This figure shows that both level spreaders and sand filters are the most cost effective BMPs in reducing TSS loads to the Cove. Neither gross particle separators nor the constructed wetland are as cost effective as sand filters or level spreaders. Lot based infiltration trenches are the least effective. (Note dry wells are not included in this figure as the contribution of TSS from roof areas is assumed to be insignificant and thus dry wells will not provide TSS reduction.)

Non-Structural BMPs

The cost versus removal efficiencies for non-structural BMPs were graphed and are provided in Figure 6.3 for nitrogen removal. The curves shown in this figure represents the cost/removal for implementing the BMPs in Sub-watersheds 1 and 2. (Street sweeping is not provided in the graph as it was assumed that this measure would provide little to no nitrogen reduction.) This figure shows that fertilizer management is a more cost effective means of reducing nitrogen in the watershed than catch basin maintenance.

Figure 6.4 shows the cost/benefit of non-structural measures for TSS removal. (Fertilizer management is not shown in the graph as this measure would provide no TSS reduction.) Note that based on the curves shown in the graphs, street sweeping is more cost effective in reducing TSS than catch basin maintenance. Both measures are limited in reducing the TSS load to the Cove by a small fraction of the total load.

6.4.4 BMP Selection

Based on the above evaluation, it is apparent that the lot based BMPs, infiltration trenches and dry wells, are not cost effective measures relative to the watershed based, structural and non-structural, BMPs. Therefore, these were eliminated from further evaluation. The above evaluation also indicates that catch basin maintenance is not as cost-effective as other

Figure 6.1 Cost vs. Nitrogen Removal
Structural BMPs

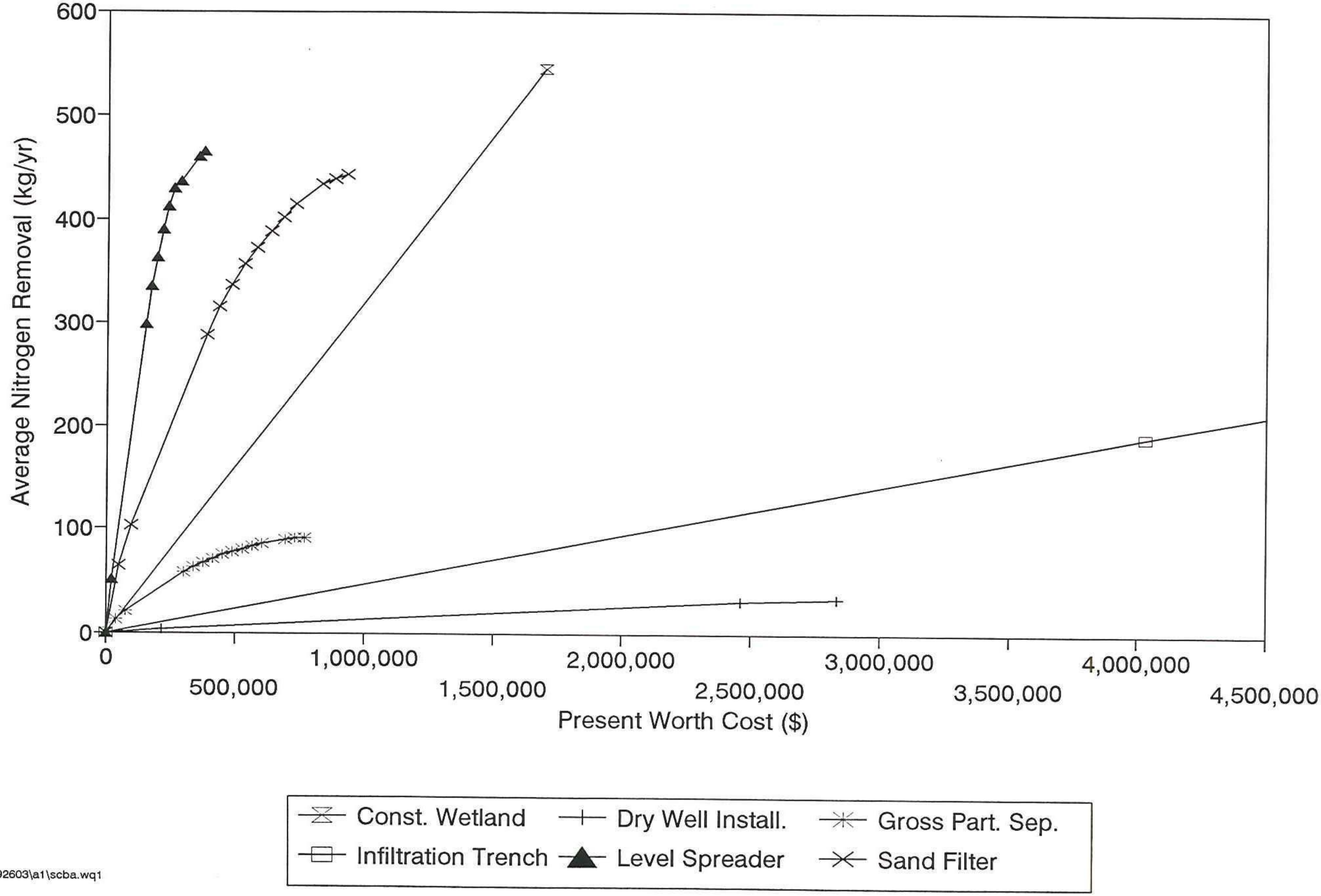

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Figure 6.2 Cost vs. TSS Removal
Structural BMPs

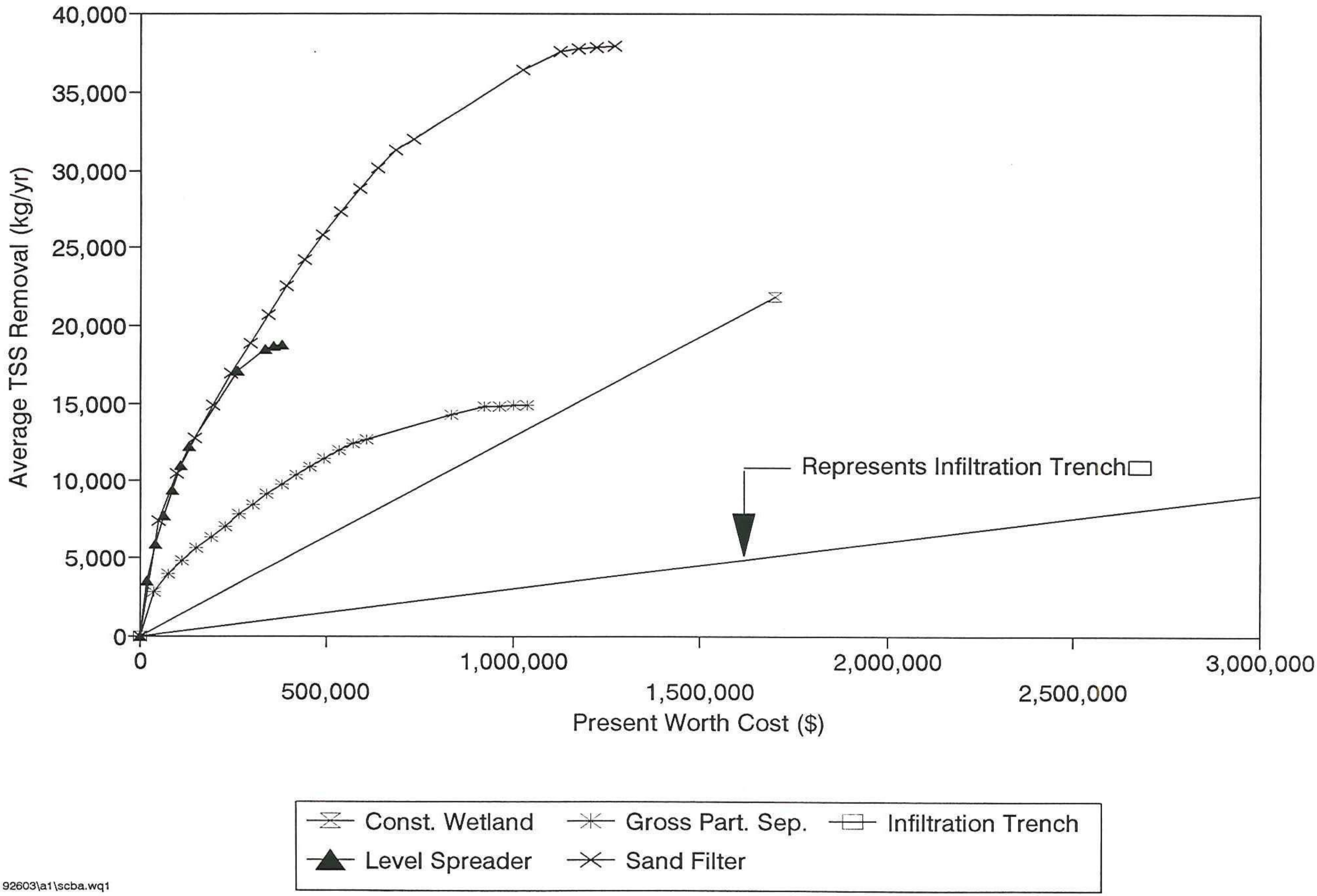

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Figure 6.3 Cost vs. Nitrogen Removal
Non-Structural BMPs

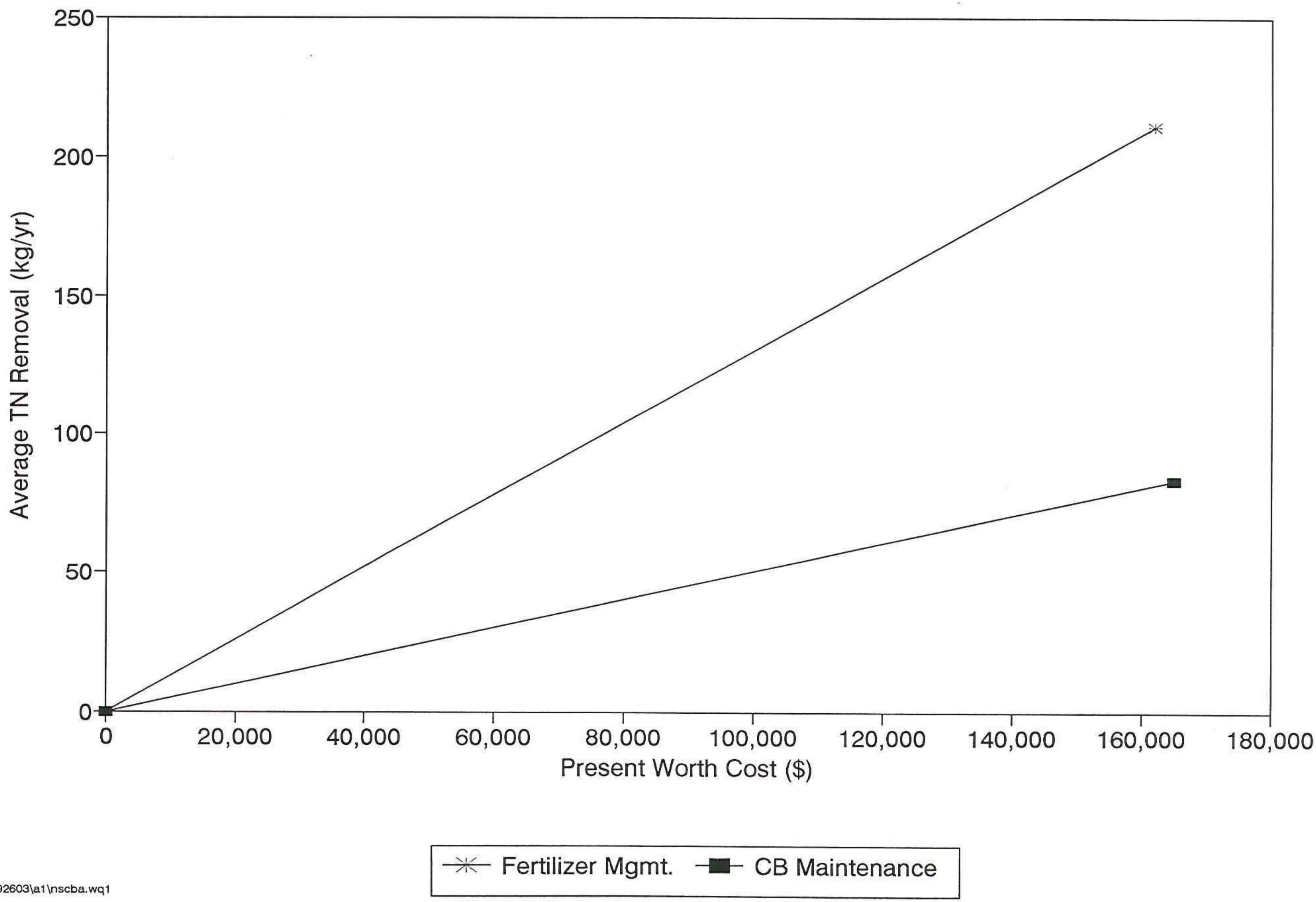

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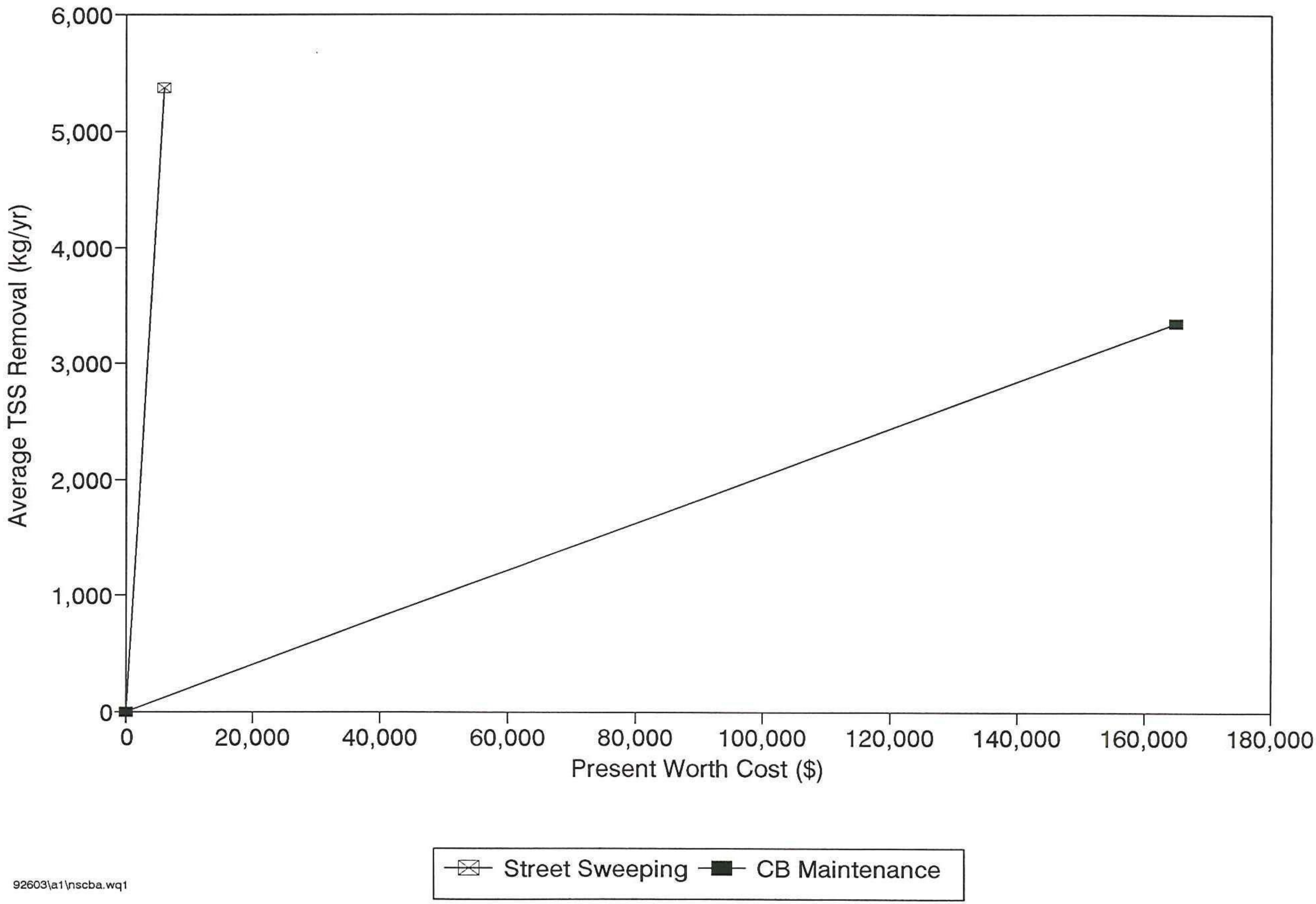
Figure 6.4 Cost vs. TSS Removal

Non-Structrual BMPs



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measures; however, catch basin maintenance is considered further as a potential BMP as it should be performed for proper operation of New London's drainage system.

A comparison of the most cost effective structural BMPs to non-structural BMPs is provided in Figures 6.5 and 6.6 for total nitrogen and TSS, respectively. Figure 6.5 indicates that level spreaders are the most cost effective measure for reducing total nitrogen. The next cost effective BMP for nitrogen removal is fertilizer management followed by sand filters. Catch basin maintenance is the least effective practice for nitrogen removal. Figure 6.6 indicates that an effective street sweeping program is the most cost effective measure for reducing TSS; however, this is limited to a small fraction of the TSS load to the Cove. The next most effective measures are a combination of level spreaders and sand filters. The figure shows catch basin maintenance to be the least effective measure.

The next step in the cost/benefit analysis of the BMPs was to identify the most cost effective structural BMP for each drainage area and optimize their locations. This was performed by further sorting the cost/benefits for all BMPs from the most cost effective to the least by drainage area. The data set was further sorted by grouping all BMPs and identifying the most cost effective BMPs throughout the watershed. Tables 6.4 and 6.5 provide summaries of the prioritized BMPs for total nitrogen and TSS, respectively. The tables show structural and non-structural BMPs as separate measures. The order of BMPs is from the most cost effective to the least and represents the order in which the BMPs should be implemented. The tables show the selected BMP, drainage area location, and anticipated pollutant removal. Also provided in the tables are the cumulative removal, with represents the removal for each additional BMP, percent of the total load to the watershed, the present worth cost and cumulative present worth cost, and the cost/benefit for each BMP.

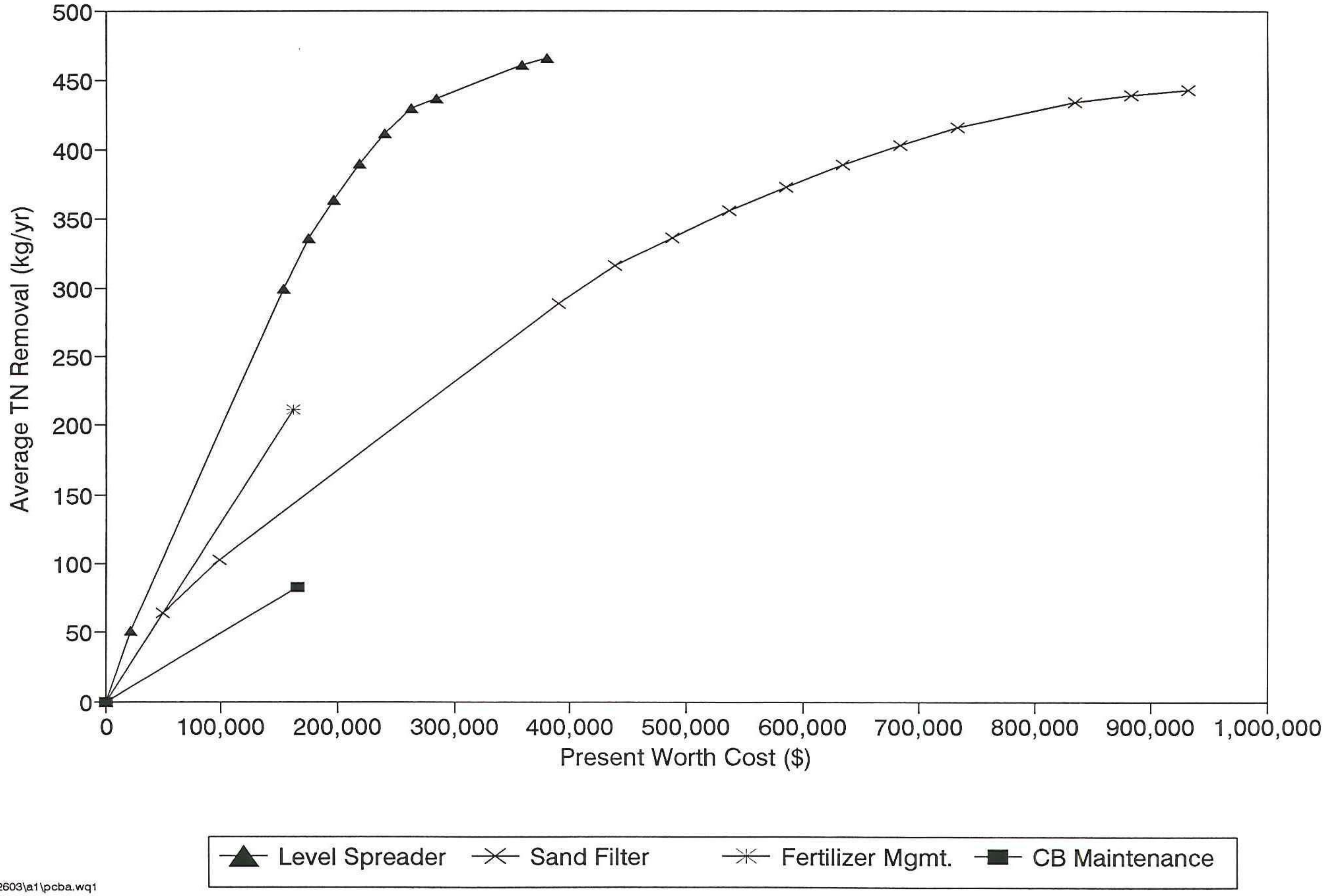
As indicated in Table 6.4, the first measure to reduce nitrogen loads to the Upper Cove is the installation of level spreaders. The table shows that by installing level spreaders in drainage areas 2G, 1, and 2H total nitrogen loads can be reduced by as much as 15 percent. The next most effective measure would be implementing a fertilizer reduction program. This measure alone would reduce nitrogen by 9.5 percent. By implementing all the structural BMPs listed, total nitrogen can be reduced by as much as 25%. Non-structural measures would reduce total nitrogen by as much as 13.2 percent.

It should be noted that implementation of the non-structural and structural BMPs will not give a combined removal of 38.2 percent. Implementation of the non-structural BMPs will reduce the load of nitrogen before reaching the structural BMPs. Assuming the removal efficiency remains constant, the amount of nitrogen removed by the structural BMPs will be reduced. However, since fertilizer management is watershed wide and may be implemented in areas where structural BMPs do not apply, such as sheet flow drainage areas, an estimate of reduction for combined measures would be difficult to quantify.

Table 6.5 shows the list of selected BMPs for TSS removal. This table shows that street sweeping is the most cost effective measure followed by several structural BMPs. The table also shows that a combination of level spreaders and sand filters will effectively reduce TSS loadings to the Cove. The implementation of non-structural BMPs could reduce TSS by as much as 6.4 percent and the listed structural BMPs could reduce TSS by as much as 48.9 percent for a total reduction of 55.3 percent. However, as with nitrogen, implementing structural and non-structural measures will not provide a combined removal of 55.3 percent

Figure 6.5 Cost vs. Nitrogen Removal

Potential BMPs



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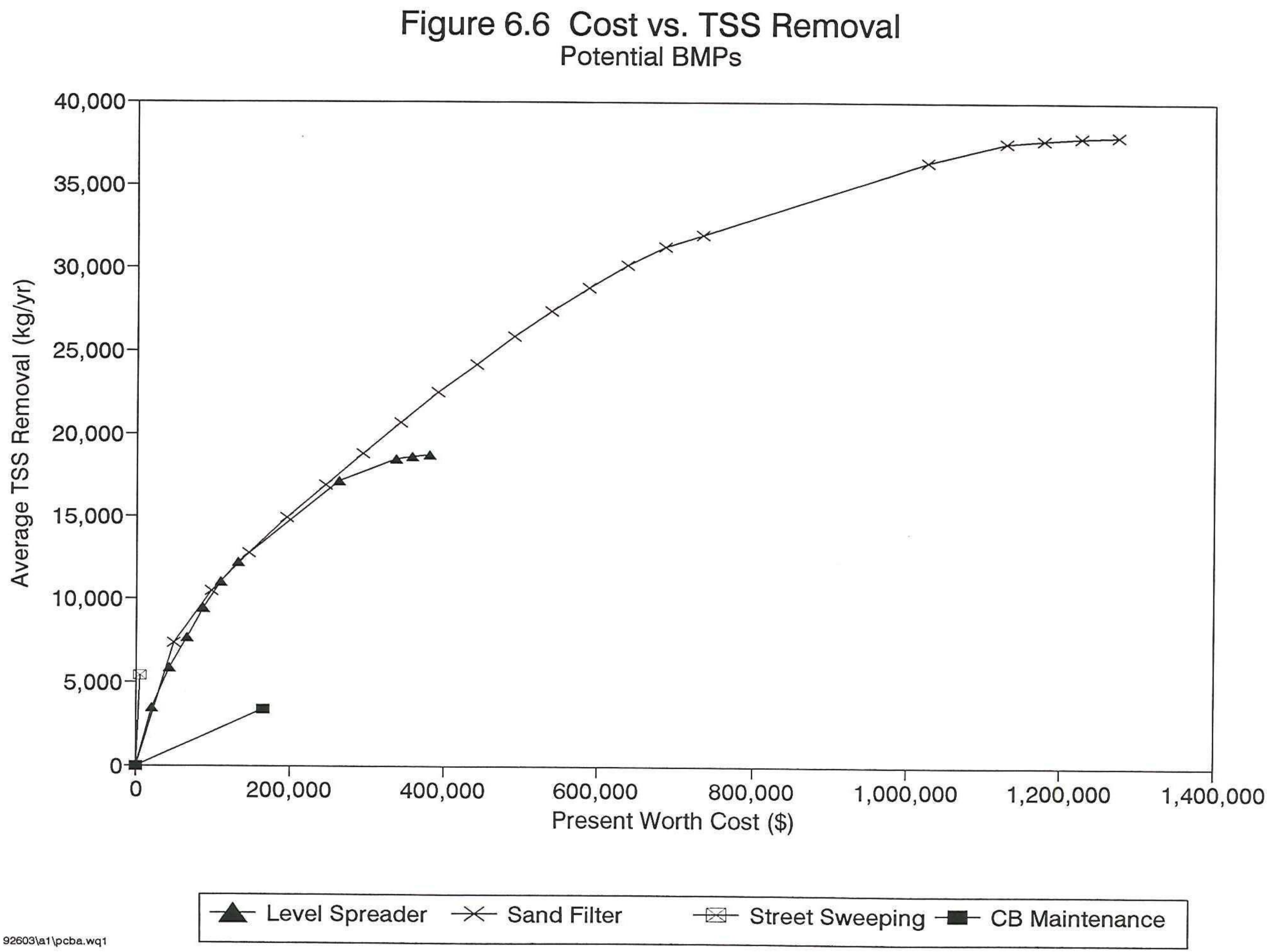

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TABLE 6.4

BMP PRIORITIZATION FOR TOTAL NITROGEN REMOVAL

FENGER BROOK WATERSHED MANAGEMENT STUDY
DECEMBER 1995

BMP	Location	Nitrogen Removal (kg/yr)	Cumulative N Removal (kg/yr)	Cumulative Percent of Total Nitrogen Load	Present Worth Cost* ($)	Cumulative PW Cost ($)	Cost/Benefit ($/(kg/yr))
Non-Structural							
Fertilizer Reduction	Watershed	211	211	9.5%	$162,000	$162,000	$768
Catch Basin Cleaning	New London	83	294	13.2%	$165,000	$327,000	$1,488
Level Spreader	D.A.2G	51.7	52	2.3%	$22,000	$22,000	$426
Level Spreader	D.A.1	248	299	13.4%	$131,000	$153,000	$529
Level Spreader	D.A.2H	37.1	336	15.1%	$22,000	$175,000	$593
Sand Filter	D.A.2M	63.9	400	17.9%	$49,000	$224,000	$767
Level Spreader	D.A.2D	27.8	428	19.2%	$22,000	$246,000	$793
Level Spreader	D.A.2E	26.2	454	20.3%	$22,000	$268,000	$841
Level Spreader	D.A.2F	22.1	476	21.3%	$22,000	$290,000	$994
Level Spreader	D.A.2B	17.1	493	22.1%	$22,000	$312,000	$1,284
Level Spreader	D.A.2P	7.2	501	22.4%	$22,000	$334,000	$3,043
Sand Filter	D.A.2K	15.5	516	23.1%	$49,000	$383,000	$3,155
Sand Filter	D.A.2L	13.8	530	23.7%	$49,000	$432,000	$3,546
Level Spreader	D.A.2C	23.8	554	24.8%	$74,000	$506,000	$3,107
Level Spreader	D.A.2O	4.7	559	25.0%	$22,000	$528,000	$4,661

* Based on 20 years of operation and an 8% rate of return.

TABLE 6.5

BMP PRIORITIZATION FOR TSS REMOVAL

FENGER BROOK WATERSHED MANAGEMENT STUDY
DECEMBER 1995

BMP	Location	TSS Removal (kg/yr)	Cumulative TSS Removal (kg/yr)	Cumulative Percent of Total TSS Load	Present Worth Cost* ($)	Cumulative PW Cost ($)	Cost/Removal ($/(kg/yr))
Non-Structural							
Street Sweeping	Watershed	1623	1623	2.1%	$6,000	$6,000	$3
Catch Basin Cleaning	New London	3348	4971	6.4%	$165,000	$171,000	$74
Structural							
Level Spreader	D.A.2G	3459	3459	4.5%	$22,000	$22,000	$6
Sand Filter	D.A.2M	7377	10836	14.0%	$49,000	$71,000	$7
Level Spreader	D.A.2H	2393	13229	17.0%	$22,000	$93,000	$9
Level Spreader	D.A.2E	1845	15074	19.4%	$22,000	$115,000	$12
Level Spreader	D.A.2F	1715	16789	21.6%	$22,000	$137,000	$13
Level Spreader	D.A.2D	1580	18369	23.7%	$22,000	$159,000	$14
Level Spreader	D.A.2B	1208	19577	25.2%	$22,000	$181,000	$18
Sand Filter	D.A.3B	2319	21896	28.2%	$49,000	$230,000	$21
Sand Filter	D.A.2L	1972	23868	30.8%	$49,000	$279,000	$25
Sand Filter	D.A.2K	1904	25772	33.2%	$49,000	$328,000	$26
Sand Filter	D.A.3H	1822	27594	35.6%	$49,000	$377,000	$27
Level Spreader	D.A.1	4898	32492	41.9%	$131,000	$508,000	$27
Sand Filter	D.A.3F	1525	34017	43.8%	$49,000	$557,000	$32
Sand Filter	D.A.3A	1417	35434	45.7%	$49,000	$606,000	$35
Level Spreader	D.A.2C	1359	36793	47.4%	$75,000	$681,000	$55
Sand Filter	D.A.3G	766	37559	48.4%	$49,000	$730,000	$64
Level Spreader	D.A.2P	159	37718	48.6%	$22,000	$752,000	$138
Level Spreader	D.A.2O	106	37824	48.7%	$22,000	$774,000	$208
Sand Filter	D.A.3C	103	37927	48.9%	$49,000	$823,000	$476

* Based on 20 years of operation and an 8% rate of return.

as the non-structural measures will provide some removal before the loads reach the structural measures. Again, the actual reduction would be difficult to quantify.

It is interesting to note that for both nitrogen and TSS loads, the same BMP is selected for each drainage area. The order of implementation, however, is different. This makes selecting BMPs for each location an easier process. However, to select the order in which the BMPs should be implemented, a choice between targeting total nitrogen or TSS should be made.

6.5 Additional BMPs

6.5.1 Regulatory Measures

Future development in the watershed has the potential to increase non-point source pollutant loadings to Fenger Brook and Alewife Cove. Zoning, subdivision and wetland regulations are now used to control impacts from new developments. Additionally, the municipalities rely on staff reviews to determine the need for non-point source pollution controls. As detailed in Section 2.4, the local regulations can be revised to reduce the impacts of non-point source pollution associated with future development. The following sections provide specific recommendations to enhance the local regulations to reduce the impact of the existing and new development. It is recommended that an evaluation of the impacts, such as economic and social, of proposed changes in the regulations should be performed before any changes are enacted.

Train Municipal Staff and Commissions

Training municipal staff and land development commission members on non-point source impacts and methods to control impacts could provide the decision making ability to significantly reduce stormwater pollution from new development. The University of Connecticut Cooperative Extension System has developed a non-point source pollution education program for municipal officials (NEMO program) in order to protect water quality from environmental impacts arising from new development near estuaries. This project includes a series of fact sheets that are presented to municipal officials on sources of stormwater pollution and how new developments can be regulated to control impacts. A copy of this information can be obtained from the University of Connecticut Cooperative Extension System.

Improve Existing Regulations

Land development regulations could be amended to further regulate new developments to control stormwater pollution, as well as require improvements during new construction at currently developed property. The following are areas in the regulations which would, if enacted, help to improve future water quality in the watershed. Some of these recommendations would, however, impact the character of the future developments, i.e. housing setbacks, sidewalk widths, street widths, and cluster developments, and as such, should be given careful consideration before implementation.

1. Amend zoning regulations to require new multi-family, commercial and industrial sites to incorporate "best management practices" (BMPs) at all stormwater point discharges. BMPs for new developments should be focused on solids, nutrients and bacterial

loadings. The regulations also should stipulate that BMPs be maintained by their private owners in accordance with an approved maintenance schedule.

2. Zoning and subdivision regulations could also be amended to minimize impervious areas. This would minimize runoff from new developments and promote infiltration. In order to minimize impervious areas the following alternative amendments should be considered.

   - Reduce sidewalk widths. New London's regulations require sidewalk widths of five feet. The subdivision regulations for Waterford provide details indicating sidewalk widths of 4' 6". Reducing sidewalk widths to four feet along roads would reduce total impervious area. Reduced sidewalk widths should be considered for future residential areas.

   - Reduce building setbacks. Large building setbacks result in long driveway and walkway lengths. Most zones in New London require minimum setbacks of 25 feet. Minimum setbacks in Waterford are typically 50 feet for town roads and 75 feet for state roads. Both Waterford and New London should consider stipulating maximum setbacks. In addition, Waterford should consider reducing the minimum setbacks for residential zones. A recommended minimum setback is 25 feet.

   - Recommend infiltration of roof runoff from "clean roofs" on new commercial buildings.

   - Naturally vegetated buffers could be required to be left at the downgradient borders of properties to allow interception and treatment of sheet flow from developed properties.

   - Cluster residential development to limit impervious area and maximize open space. The zoning regulations for Waterford currently allow cluster subdivisions in residential zones (R-20, R-40, R-120). The Waterford subdivision regulations require a minimum of 20 percent of the parcel be permanently reserved as open space. It is recommended that the open space requirement be increased to 40 to 50 percent, as open space is the major benefit of cluster developments. The New London subdivision regulations have open space requirements as deemed appropriate by the planning and zoning commission. Minimum open space requirements should be stipulated in these regulations for cluster and residential development.

   - Reduce paved street width requirements. Current street width requirements for Waterford in the subdivision regulations are generally consistent with standards in other municipalities. However, Waterford should consider reducing road widths for secondary low-density roads and in industrial areas. This would reduce the amount of impervious area for new development areas.

3. In addition to reducing paved areas, the zoning and subdivision regulations could be amended to reduce runoff. In order to minimize runoff the following alternative amendments should be considered.

- New residential developments could be directed to drain roof drainage to infiltration chambers and driveway runoff across the lawn areas to maximize infiltration.

- Revise the sub-division regulations to encourage new roads to be constructed without curbs. Eliminating curbs along low traffic roads would allow runoff to sheet flow off of the road into vegetated areas thereby promoting some treatment and infiltration of stormwater. As a result, minimizing curbing requirements along secondary low-density roads may be appropriate.

- New development could also significantly increase off-site peak flows. While detention basins may not be appropriate for every development, zoning regulations could be amended to require new drainage systems be designed to not exceed pre-development peak flows. Current regulations do not require any peak flow controls. Such measures would also provide treatment of stormwater runoff.

- Driveways, where practical, could be required to be graded to drain to naturally vegetated areas and drainage depressions as opposed to public roads.

4. A current study, being performed by the Connecticut Department of Environmental Protection Inland Water Resource Wetlands Program, will provide a technically defensible methodology for regulating activities adjacent to wetlands and watercourses. When such criteria are issued under this program, it is recommended that both New London and Waterford adopt these criteria.

5. Wetland regulations of both municipalities could also be amended to prohibit new point discharges to wetlands. Instead, a level spreader could be used to convert a point discharge to sheet flow. A sufficient set back should be required to allow for adequate filter strip length. This measure would also reduce the potential for long term erosion at point discharges.

6. The wetland regulations for both New London and Waterford permit as of right grazing and farming operations in wetlands where these activities are essential to the farming activities. The wetland evaluation detailed in Section 3.2 indicated that grazing and farm activities caused degradation to one of the wetlands. A potential beneficial measure would be to incorporate policies recommending fencing around wetland areas within grazing areas where these wetland areas are not essential to the agricultural activities. Alternatively, a program can be established to educate local farmers on the importance of wetlands and practices that can be implemented to reduce potential impacts from farming activities.

7. The subdivision regulations of New London should be amended to specifically require sumps for each catch basin which are now not explicitly called for. The details provided in Waterford's regulations indicate that two foot deep sumps are to be required on catch basin. Similar guidelines could be provided in New London's regulations.

8. The zoning regulations could be revised to require street sweeping and catch basin cleaning for large private parking lots. It should be noted that the DEP has recently

issued a general stormwater permit for specific commercial activities. The general permit specifically requires street sweeping of parking lots and inspections of the stormwater generating activities. The zoning regulations of the municipalities could be expanded to adopt similar provisions. Such provisions could reduce solids, nutrient, and bacterial levels contributed to the watercourses within the Watershed.

9. Provisions could be implemented in the zoning regulations to require adequate maintenance of garbage dumpsters in business and apartment areas. During the field survey, a dumpster in a New London apartment complex was noted to be overflowing and had garbage scattered on the ground. Municipal solid waste that is exposed to stormwater has the potential to contribute bacteria and other pollutants to surface waters. Maintaining "clean" refuse collection areas could reduce this contribution.

6.5.2 Retrofit Existing Wetlands

As indicated in the wetland report (Appendix E) approximately 233 acres of wetlands were identified in the Fenger Brook watershed. These wetlands included both freshwater (220 acres) and tidal (13 acres). All of these wetland areas have reportedly been impacted by development in one manner or another. Surrounding development has impacted and reduced the size of the wetlands. In addition, runoff from these developed areas has increased stormwater flow to the wetlands as well as increased pollutant loadings. These increased flows have led to erosion and channelization through the wetlands which has reduced the potential for these wetland systems to attenuate peak flows and reduce pollutant loadings.

Natural wetland systems have significant potential to remove solids as well as other stormwater pollutants via a number of processes including sedimentation, filtration, vegetative uptake and microbial actions. Natural wetlands can also provide attenuation of peak flows by providing storage in low points. In order to take advantage of these attributes as well as reduce erosion, channelized flows through the wetlands must be minimized. Distributing stormwater flows diffusely across the wetlands would minimize short circuiting through existing channels and maximize detention within the wetlands.

The following paragraphs outline several restoration techniques which could potentially be implemented in the existing wetland areas in the Fenger Brook wetlands. These techniques should be selected for specific areas based on local conditions. It should be noted that the techniques outlined include both techniques to "unchannelize" flow as well as to "repair" eroded areas in the wetlands.

- Level Spreaders: A level spreader is a structure which converts a point discharge to sheet flow. These structures are described in detail in Section 6.3.2. Once in sheet flow, stormwater would be allowed to drain across the wetland in sheet flow. This would provide the opportunity for the stormwater to be filtered as well as provide some attenuation of flows by storage in low points, infiltration and evapotranspiration. Existing drainage channels should be backfilled to a point so as not to allow re-channelization. Level spreaders have been recommended for the retrofit of existing storm sewer discharges from existing developed areas in this watershed. Some stable bypass should be considered for larger flows to prevent erosion during extreme storm events.

- Check Dams: Check dams have been recommended in other watersheds in order to reduce stormwater velocities and potentially provide some out-of-bank distribution of flow. The check-dams consist of a dam placed across an existing channel. These dams cause water to pond behind the dam, thereby flattening the hydraulic gradient of the channel which results in reduced channel velocities and erosion potential. During a storm event, water would overtop the check dam. Much of the water overtopping the check dam would likely drain directly into the channel, however, some out-of-bank flow could be created depending on channel geometry which would provide some attenuation of flow and removal of pollutants.

  For proper long-term operation, sediment may need to be periodically removed from check dam pools. Also, wooden check dams would require periodic replacement. As a result, this alternative would result in direct impacts to the wetlands system for construction as well as long-term maintenance. Stone gabion check dams may require less long term maintenance but would cause greater initial disturbance to wetlands for construction. In order to control in-stream erosion, check dams should be spaced to allow ponding throughout the reach between each dam or in reaches with historic erosion problems. Otherwise, velocities would return to existing conditions just downstream of the check dam as velocity is only dependant on hydraulic gradient, surface conditions, geometry and flow rate. Check dams may have limited potential to create out-of-bank flow as water may tend to overtop the dam directly into the existing channel during storms. Check dams should be located only in stabilized areas where out-of-bank flow would not create erosion.

- Stabilize Stream Banks: Without attenuation of peak flows or redistribution of flows to minimize channel flow, existing eroding channels will likely continue to erode in the future. These eroding stream banks can be stabilized with a number of vegetative techniques and products. In extreme cases, riprap could also be used to stabilize problem banks. This approach should first be targeted in areas with severe erosion. Redistribution of stream flows would likely be a more cost effective technique to provide long-term erosion control in the minor channels created by erosion in these wetlands.

- Enhance Channel Geometry: Existing eroded channels can be enhanced by reconstructing the channel to control erosion and allow the channel to meander. This approach could consist of improving the existing channel geometry to control erosion (i.e. flatten vertical slopes) or creating a more natural meander pattern that would also slow velocities and enhance storage. This technique could require significant work in a wetlands and has significant permitting requirements. The channel must also be stabilized to prevent the channel from "realigning" itself.

- Create Channel Pools: Pools could be excavated in existing channels to provide some attenuation of peak flows and thereby reduce velocities and erosion potential. Similar to check dams, sediment could build-up on channel pools requiring periodic sediment removal for proper operation.

In order to minimize disturbance to wetlands and permitting requirements, level spreaders should first be considered to redistribute flows. This technique would enhance wetland pollutant removal as well as limit the potential for channel erosion by providing some attenuation of peak flows. The remaining measures could be considered for other problem channels depending on site conditions.

6.6 Recommended Approach

Based on the results of the BMP cost/benefit evaluation, it is recommended that a phased approach be used in implementing BMPs in the watershed. Such an approach would involve implementing the most cost effective BMPs, as summarized above, and monitoring the Cove for improvements. A phased approach would achieve two goals:

1. Improve the quality of the Cove; and

2. Minimize costs associated with implementing BMPs.

Monitoring of the Cove before and after implementation of the BMPs would provide information as to whether the quality of the Cove has been improved.

The recommended order for BMP implementation is provided in Table 6.6. As a first step before implementation or coincident with these measures, the recommended regulatory revisions could be implemented at a low cost to the municipalities. It should be noted that although catch basin maintenance does not provide a significant reduction in pollutants, it is recommended to be implemented in New London to improve the hydraulic capabilities of the storm drainage system. Table 6.6 is ordered such that nitrogen reduction, overall, is of higher priority than solids reduction. The phased approach assumes that the most benefit will be received in nitrogen reduction for the money spent. The diminishing returns in the effectiveness of nitrogen removal for BMPs in some drainage areas make them less attractive and therefore are toward the bottom of the list.

6.7 Rediversion of the Upper Fenger Brook Watershed

As discussed in Section 3.0 of this report, a significant portion of the apparent Fenger Brook watershed as depicted on USGS topographic mapping has been bisected by a railroad embankment. This appears to have resulted in the diversion of a segment of Fenger Brook to Jordan Cove, a nearby estuarine watershed. It is unclear whether the watershed north of the railroad actually ever flowed to Fenger Brook since the grades in this area are relatively flat and flow could have gone either south or west. A possible result of the railroad construction has been to cut-off a significant freshwater source to Alewife Cove; however, this diversion, if it occurred, was implemented over 140 years ago (CAS, 1978). To improve the quality of Alewife Cove, it has been suggested that upper Fenger Brook be rediverted to the main stem Fenger Brook by constructing a culvert through the railroad embankment. Such a diversion could be beneficial; however, such benefits could be more than off-set by detrimental impacts. The following is a discussion of the potential benefits and impacts of diverting upper Fenger Brook.

The most significant benefit of the rediversion would be to restore the watershed to its "original" hydrologic state. This would increase the freshwater flow to the Cove which in turn has the potential to improve flushing to remove "trapped" nutrients and sediment. However, an increase of freshwater flow would be accompanied by higher stormwater flows and associated pollutant loads. This could possibly intensify eutrophication and sediment build-up. This upper watershed area appears to be as heavily developed as the current

TABLE 6.6

RECOMMENDED BMP IMPLEMENTATION PRIORITIZATION

FENGER BROOK WATERSHED MANAGEMENT STUDY
DECEMBER 1995

Location	Best Management Practice	Present Worth Cost*
Watershed Wide	Street Sweeping	$6,000
New London	Catch Basin Cleaning	$165,000
Drainage Area 2G	Level Spreader	$22,000
Drainage Area 1	Level Spreader	$22,000
Drainage Area 2H	Level Spreader	$22,000
Watershed Wide	Fertilizer Management	$162,000
Drainage Area 2M	Sand Filter	$49,000
Drainage Area 2D	Level Spreader	$22,000
Drainage Area 2E	Level Spreader	$22,000
Drainage Area 2F	Level Spreader	$22,000
Drainage Area 2B	Level Spreader	$22,000
Drainage Area 2P	Level Spreader	$22,000
Drainage Area 2K	Sand Filter	$49,000
Drainage Area 3B	Sand Filter	$49,000
Drainage Area 3H	Sand Filter	$49,000
Drainage Area 3F	Sand Filter	$49,000
Drainage Area 3A	Sand Filter	$49,000
Drainage Area 3G	Sand Filter	$49,000
Drainage Area 2L	Sand Filter	$49,000
Drainage Area 2C	Level Spreader	$22,000
Drainage Area 2O	Level Spreader	$22,000
Drainage Area 3C	Sand Filter	$49,000

* Based on 20 years of operation and a rate of return of 8 percent.

* BMPs to be considered for further evaluation.

Fenger Brook watershed. Rediverting the upper Fenger Brook to the Cove would result in increasing both the base flow and stormwater flow of Fenger Brook. This would likely reduce the long-term salinity of Alewife Cove. Additionally, the stormwater flushing of the Cove would likely increase which would exacerbate the wide variability of salinity currently occurring in the Cove. If the re-diversion could be accompanied by adequate detention of stormwater in the upper watershed, the stormwater flush relative to stream base flow could potentially be reduced resulting in a decrease in the dramatic variability of the Cove's salinity. Detention of stormwater flows could be increased by implementing BMPs such as level spreaders. However, the duration of detention may not be enough to reduce the impact of the salinity variation.

A significant potential disadvantage of rediverting the flow is the immediate impact to Jordan Cove. The habitat of Jordan Cove has likely adapted to the upper Fenger Brook diversion. Rediverting this watershed could prove harmful to the biota of Jordan Cove. Additionally, there exists the potential of draining wetlands north of the railroad and thereby damaging a valuable resource. The benefits of the rediversion to Alewife Cove could be outweighed by impacts such as increased pollutant loads and potential to introduce additional pollutants of concern. If such a diversion were performed, the extent of BMP implementation, as described in the sections above, would likely need to be extended to the upper watershed.

The above discussion addresses only some of the potential impacts of rediverting upper Fenger Brook. To adequately assess all of the benefits/drawbacks of the rediversion, a complete environmental impact study should be performed.

6.8 BMP Funding

Funding for the BMPs referenced in the above sections may be provided through a number of mechanisms. Such mechanisms include obtaining federal grants, applying a user or polluter fee for the Cove, and full funding by the State or local municipalities. Stormwater runoff programs are typically implemented at the local level. Local municipalities generally have limited budgets and staffing. Federal and State programs can provide some relief; however, such funding can be limited and uncertain and should not be anticipated to provide complete BMP funding. The following is a discussion of each of the funding options including the advantages and disadvantages of each.

6.8.1 Non-Point Source Pollution Grants

The Environmental Protection Agency (EPA) has developed grant programs to provide funding for non-point source pollution reduction projects. Some of the grant programs include: 1) the 319 Non-Point Source Pollution Grant Program (as established under Section 319(h) of the Clean Water Act), 2) Section 104b(3) of the Clean Water Act, and 3) Section 309 of the Coastal Zone Management Act (CZMA). This listing is not intended to be all inclusive as there may be additional programs that provide funding for non-point source pollution funding. The following is a brief summary of the above grant programs.

<u>319 Grant Program</u>

The 319 Grant program requires the following:

- Must be linked to the Connecticut Non-Point Source (NPS) Assessment and Management Plan.

- Target the major statewide NPS categories of pollution or high priority impaired or threatened water bodies or water resources.

- Directed at achieving, encouraging or requiring implementation of identified BMPs or directed at preventing identified NPS categories of pollution through land use controls.

- Feasible, practical, cost effective and likely to be successful with measurable results.

- Directly related to water quality improvement or pollution prevention.

The major advantage of such a program is that the BMPs recommended for Fenger Brook meet these requisites. Additionally, matching funds can be in forms other than cash such as labor. Disadvantages of such a program are: 1) the potential for limited funding and 2) the fact that the Grant provides only 60 percent of the total project cost.

Section 104b of Clean Water Act

Section 104b of the CWA includes provisions for funding non-point source pollution programs. There is no strict guidance under this program. The criteria for obtaining funds under this program include:

- support of the program by the State,

- the program must be in accordance with National and Regional water quality goals,

- a proposal for funding must be submitted to the EPA by the State, and

- the project must be technology transferable and not for long-term continuous programs.

According to EPA sources (Telecon with Jay Brolin of EPA Region 1 on February 9, 1995), a program such as the Fenger Brook Watershed Management Study would be required to be an "innovative technology" project. The use of GIS in the evaluation of such a project could be considered innovative technology.

Coastal Zone Management Act

The Coastal Zone Management Act (CZMA) of 1972 was enacted to preserve, protect, restore, or enhance the Nations coastal waterways. Section 6217 of the Coastal Zone Act Reauthorization Amendments includes provisions for grants to States for coastal zone management programs. The requirements for grants include the following:

- An application for a grant must be developed by the State as part of the State's development and implementation of coastal zone enhancement objectives; and

- The State must complete all the application requirements and have an approved program under the Coastal Zone Management Act.

Federal grants under this CZMA fund up to 50 percent of the program costs. As the Fenger Brook/Alewife Cove Watershed falls within a coastal zone, the CZMA grant program may apply.

6.8.2 Flood and Erosion Control Board Sponsorship

Municipal Flood and Erosion Control Boards are authorized by State statute to enter into cost sharing agreements with the State of Connecticut for such projects as flood control, beach erosion control and dam repairs. The legislation would have to be amended to allow application of this program to non-point source watershed management projects. The basis of the existing legislation is that municipalities share costs with the State in a pro-rated fashion calculated upon the ownership types of properties benefitted by the works of improvements. Generally, if all property benefitted is municipally owned, the State's share would be approximately two thirds of the total project costs. If all property benefitted is privately owned, the State's share would be one third. If all of the property benefitted is State owned then the State would pay the full cost. The share of total project costs is then calculated based upon the types of ownership of the properties benefitted by works of improvements. The legislation further allows the Flood and Erosion Control Boards to enter into agreements or levy the property owners a tax or fee to cover a certain percentage of the Town's share of the project costs. The legislation also allows the State to enter into agreements with the Federal government to provide funds for construction of improvements under this agreement.

For flood control projects, the properties benefitted could be properties fronting a watercourse which are subject to flood damage. Similarly, for a beach erosion control project, the properties fronting the beach would be benefitted by erosion control improvements. In both cases, the linear extent of property fronting the watercourse or beach would be the basis for calculating the cost share ratio. For dam repair projects, it is the linear extent of properties fronting the waterbody created by the dam.

For a non-point pollution watershed protection project the cost sharing ratio could be based upon properties fronting a waterbody to be improved, such as the Cove. In this case since most of the property is private, the States share could be 33% while the municipalities could be responsible for the balance. The municipalities could levy a fee or tax from the properties benefitted in order to cover a portion or all of the costs.

The advantage of a program such as this is that it provides a legal mechanism for the municipalities to fund projects with both State and property owner involvement. It can provide an equitable manner in which to distribute financial liability to those who clearly benefit from improvements and it provides a method for equitable subsidy from the Federal Government to State, municipality and private entities. The disadvantage is that this does require political action by both the State and local governments to authorize funds for these works of improvements. There may be resistance from citizens who do not receive direct benefit from the improvements yet ultimately pay with their tax dollars for the municipalities' share.

6.8.3 Resource Restoration Act

The State legislature recently enacted legislation in 1994 which provides funds for the restoration of rivers and tidal wetlands. These funds can be used as matching funds for

Federal riparian zone restoration projects. It is unclear whether these funds can be used for a project such as non-point source watershed management and should be evaluated further.

The obvious advantage is that if in fact State funds are available as matching funds to federal funds, there may be minimal need for a municipal share for the initial project implementation.

6.8.4 State Funding

Opportunities to fund nonpoint source management practices exist through Connecticut's Clean Water Fund, the state revolving fund that is used primarily to fund sewage treatment plant and sewerage projects. Up to One Million Dollars per year is available by state law to fund municipally-sponsored projects that address nonpoint and stormwater sources of pollution that impact Long Island Sound. The funds are to be used for construction projects that make meaningful differences in water quality, not for planning or study. Similarly, state law has provided up to $1 million each year for stream restoration projects through the Clean Water Fund. Projects that improve water quality, as well as habitat, are eligible and projects that address nonpoint sources of pollution through application of BMPs fit well within the designs of the program.

The State legislature can authorize funds for a specific project such as this either to be implemented under an existing legislative program or as an outright grant to a State agency or municipality. Such funding could take the form of a State revolving loan fund (EPA, 1994). The Fenger Brook project could potentially receive funding in such a fashion with effective sponsorship. The project could be funded as a pilot project related to the Long Island Sound programs in the State of Connecticut Office of Long Island Sound.

6.8.5 User/Polluter Fees

User and polluter fees would include charging a fee to either those who utilize the Cove or those who generate non-point source pollution to the Cove. Potential users of the Cove include those residents immediately adjacent to the Cove, shell-fishers and other fishers and other recreational users. Non-point source polluters would include those land users in the watershed identified as contributing higher loads of pollutants. A stormwater utility could be established to develop a fee structure similar to sewage or water utilities (EPA, 1994). Such a utility could also be responsible for construction, operation, and management of stormwater systems and programs.

The advantage of either of these programs is that the cost for improving water quality is applied to either those who benefit directly or those who impart the impacts. A major disadvantage of levying such fees is collection. It could be problematic in establishing a fee schedule and an adequate collection system. Additional disadvantages include whether such a system is equitable and the public resistance to paying these fees.

6.8.6 Municipal Funding

A potential funding mechanism would be to fund such projects via the subject municipalities; New London and Waterford. An advantage of such a program would be to spread funding out over a broader base of resources. An increase of the municipal property tax rates would likely provide sufficient funding for the project. Significant disadvantages to such a program would be public opposition and question of inequity to Town and City residents who don't use the Cove.

7.0 APPLICATION TO OTHER COASTAL WATERSHEDS

The following section is a discussion of the approach used in for the Fenger Brook Watershed Management Study. The discussion provides a summary of the recommended approach as well as an evaluation of some of the items used in this study and the appropriateness for application in other coastal watersheds.

It should be noted that every watershed is unique and, therefore, the approach detailed herein is not intended to be all inclusive. The steps described below are intended to be used as a framework and guideline for future watershed studies. Additionally, it is not the only approach that can be used in a watershed management study. The following sources offer additional guidance for watershed management:

1. Connecticut Department of Environmental Protection's Office of Long Island Sound and Bureau of Water Management.

2. University of Connecticut Cooperative Extension System.

3. Center for Watershed Protection, Silver Spring, Maryland.

4. U.S. Environmental Protection Agency's Center for Environmental Research Information in Cincinnati, Ohio, and Office of Water, Washington, D.C.

5. Metropolitan Washington Council of Governments, Washington, D.C.

6. Northern Virginia Planning and District Commission, Annadale, Virginia.

This list of sources is provided as a guide for further information and is not intended to be all inclusive.

7.1 <u>Recommended Study Approach for Other Watersheds</u>

The approach used for the Fenger Brook Watershed Management Study can be used to evaluate similar watersheds. However, the measures identified for improving the water quality of Alewife Cove should not be indiscriminately applied to other watersheds. The specific BMPs evaluated and recommended for implementation in the Fenger Brook Watershed may not be applicable for other coastal watersheds within Connecticut. The main reason for this is that each watershed is different. Significant potential differences include pollutants responsible for degrading the water system, configuration or physiography of the watershed, and land uses within the watershed. In terms of pollutants of concern, some coastal watersheds may exhibit stress due to high metal loads. In such a case, different BMPs might apply. The physiography of the watershed is important in consideration of such factors as slope, soils, and land available for BMP selection. Such considerations are important in identifying potential BMPs that can be located within the watershed. Finally, the major land uses within the watershed will drive the type of watershed management strategy necessary for reducing non-point source impacts. For example, Fenger Brook Watershed consists mainly of medium and high density residential areas, whereas another watershed may contain large areas of industrial or commercial uses. Such land uses contribute significantly different types and quantities of pollutants and therefore management strategies would be different. Although such differences would change the management measures and strategies implemented in a watershed, a similar approach to develop such measures could be used.

Keeping the above in mind, the recommended approach to be used in evaluating a watershed is as follows:

1. Perform on-site evaluations/surveys of the watershed. Such surveys can provide information on land uses, areas of significance, current management practices and other useful information. Meetings with appropriate town officials are strongly encouraged. Additionally, although not undertaken as part of this study, a review or audit of a specific activity or project may provide information as to the effectiveness of local regulations and implementation thereof by local officials.

2. Identify the specific non-point source impacts to the coastal waterbody. This would include monitoring of the waterbody to identify the pollutants of concern and the stresses to the watershed. Alternatively, a review of existing studies concerning the water system can be performed to identify the impacts if such studies provide adequate information.

3. Determine the major sources or potential major sources of the non-point pollutants of concern. Such a determination can be performed in one of the following ways. The first is to assign pollutant loads to the land uses within the watershed. The second would be to monitor stormwater throughout the watershed. The first method is a less expensive means of assessing non-point pollution in the watershed; however, the second will likely provide more accurate data.

4. Evaluate the natural features of the watershed that would affect BMP effectiveness such as slopes, soils, etc., as well as the effectiveness of existing BMPs and apply reductions to predicted loads as appropriate.

5. Screen potential BMPs to reduce/control the non-point pollutants of concern.

6. Evaluate the cost and effectiveness of BMPs within the watershed. Select the most cost-effective BMPs for implementation within the watershed.

7. Upon implementation of the BMPs, perform monitoring of the water quality of the coastal waterbody to evaluate the effectiveness of the BMPs.

A GIS database can be used to facilitate the loading assessment and BMP evaluation. As with the recommended strategy for Fenger Brook, the BMP strategy can be implemented in a phased approach. A phased approach would allow the capital cost of measures to be spread out, and allow a determination of the effectiveness of the measures in achieving the water management goals.

7.2 Evaluation of Study Approach

The following serves as a critique of the approach used in the Fenger Brook Watershed Management Study. This critique is provided as useful information for development of similar watershed management studies or plans.

The following are some of the useful tasks performed in the Fenger Brook Watershed Study as well as a discussion of the value for other watershed studies.

1. Interviews with Municipal Personnel - Interviews with municipal personnel provide useful information regarding existing management practices, such as street sweeping, refuse collection, etc., watershed-wide land uses, existing non-point pollution sources and future plans that might impact non-point pollution.

2. Regulatory Review - A review of existing regulations of the local governments could provide information on what regulatory controls may be lacking and what is recommended for implementation. Generic guidelines should be developed against which regulatory controls can be measured for adequacy.

3. Site Survey/Field Reconnaissance - One or more surveys of the watershed provides information on land uses, efficiency of existing management practices and whether local regulations are being effectively implemented.

4. Loading Assessment - A pollutant loading assessment, based on either values reported in the literature or on stormwater monitoring, can be used to identify significant potential sources of non-point source pollution. Such an assessment can be used to target specific areas for management practices.

5. Identification of BMPs and BMP Cost/Benefit Evaluation - Based on the loading assessment and other information obtained in the study, potential BMPs can be selected for the watershed. A cost/benefit evaluation, such as the one performed in this study, will provide a prioritization of the most cost effective measures to be employed in the watershed.

6. Zoning Data - Although the incorporation of zoning data within the GIS database did not provide necessary information in the Fenger Brook study, it could be useful in other watershed management programs. The study could define whether incorporating zoning would be useful in future evaluations. For the Fenger Brook study, pollutant loadings were based entirely on current land use data and not on future development as exhibited by the specific development zones of the watershed. Change of zoning was not evaluated as a potential means of reducing future pollutant loads. It was recognized that any further development should incorporate proper BMPs to minimize the potential contribution of non-point source pollution. However, zoning information could be used to evaluate the impacts of future growth in the watershed. Pollutant loading factors can be applied to areas slated for development to determine the impact on water quality. The loading factor would be representative of the land uses allowed in the zoned area.

Some of the tasks performed in this study are not recommended for other studies. The information provided by these tasks proved to be either burdensome or of less value than originally anticipated. Tasks not recommended for other watershed studies include the following:

1. Assessing the Watershed by Lot - The GIS database was set up to evaluate each individual lot within the watershed. Evaluating the watershed on such a "micro-scale" proved to be cumbersome in evaluating pollutant loads and BMP effectiveness. Creating lot-base data was very time consuming as electronic lot base data was not available. Alternatively, it is recommended that a watershed be separated and evaluated by major land uses as a opposed to a "lot-by-lot basis." The land use categories could be grouped by larger areas and provide the ability to evaluate BMPs on a land use type basis such as residential versus commercial, but without having to create a detailed lot boundary data layer.

2. Watershed Hydrology - The TR-20 modeling portion of this study provided minimal information in assessing the impacts to the Cove. TR-20 computes the peak flow from one described storm event and cannot easily compute annual runoff or pollutant loads. TR-20 can be used to calculate pollutant loads for the storm event evaluated if the runoff concentrations are known. Calculating annual pollutant loads would require data on average stormwater pollutant concentrations and computing annual runoff by tabulating runoff for each storm event over a year. The peak flows generated from TR-20 simulations can be used to determine the potential for erosion of a channel. However, detailed information would be required on the channel geometry. *A TR-20* analysis becomes important in the actual design stage where BMP sizing would require knowledge of actual flow magnitude and runoff volume for a specific area.

3. Storm Drainage System Detail - The development of a detailed storm drainage system data layer for the GIS database proved to be very time consuming and did not measurably improve the ability to evaluate the watershed. Understanding in a generic sense which watersheds are served by drainage networks and which flow over land directly to the Cove or brook proved to be more important. A simple identification of watersheds as to type of drainage would have sufficed for the purposes of this study in lieu of the detailed field review and transformation of hard copy drainage system data to the electronic database. However, the storm drain details could provide information useful to the municipalities for other purposes, such as scheduling maintenance.

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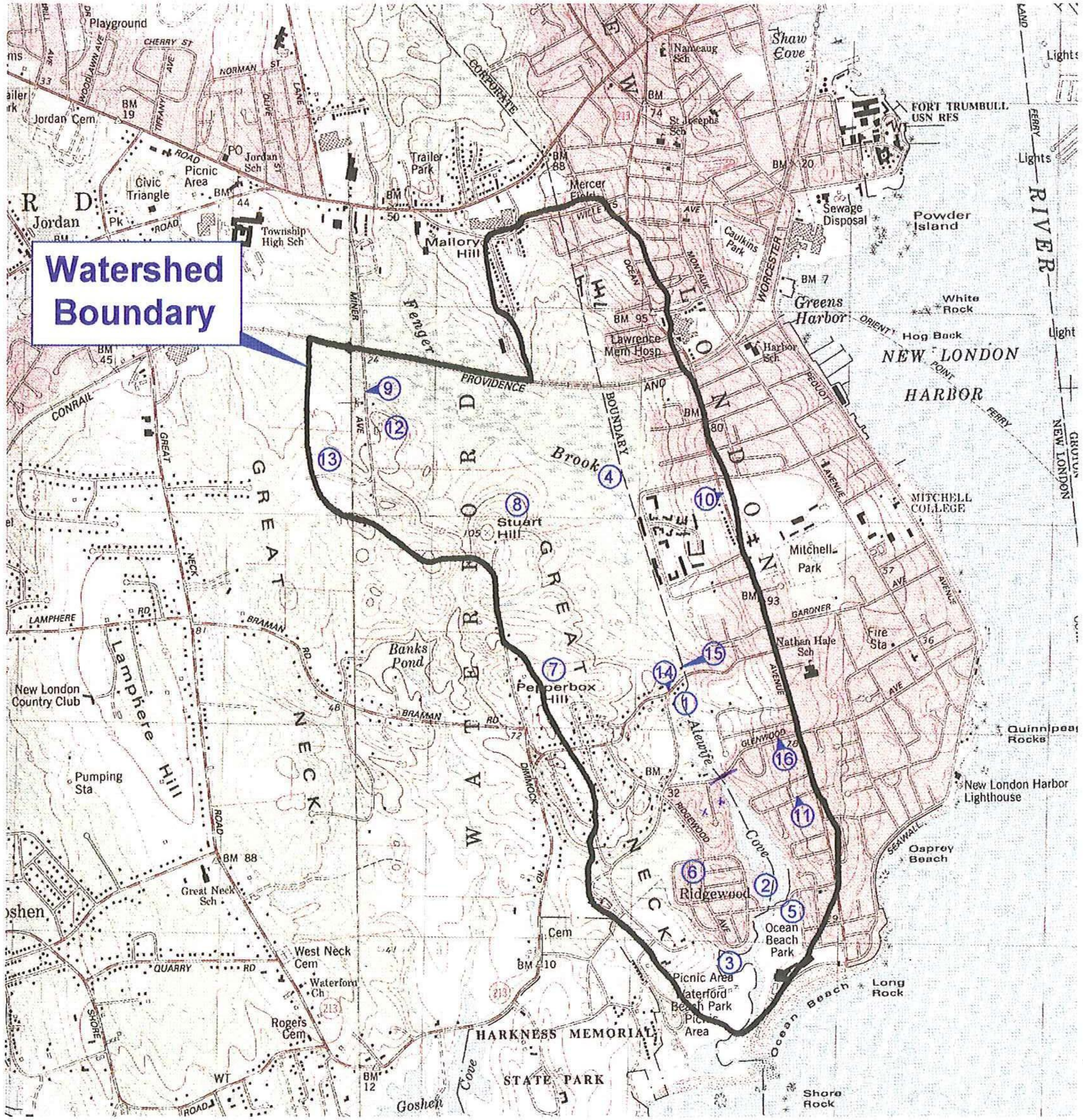


LEGEND

1. Upper Alewife Cove
2. Middle Alewife Cove
3. Lower Reach
4. Fenger Brook
5. Ocean Beach Park
6. Ridgewood
7. Pepperbox Hill
8. Stuart Hill
9. Miner Lane
10. Ocean Avenue
11. Greenway Road
12. Piggery
13. Waterford Landfill
14. Niles Hill Road
15. New London Pump Station
16. Glenwood Avenue

MAP REFERENCE:
THIS MAP IS PREPARED FROM 7.5 MINUTE SERIES TOPOGRAPHIC MAP QUADRANGLES NIANTIC (1983), CONNECTICUT-NEW YORK AND NEW LONDON (1984), CONNECTICUT-NEW YORK.

CONNECTICUT
QUADRANGLE LOCATION

NOT RELEASED FOR CONSTRUCTION

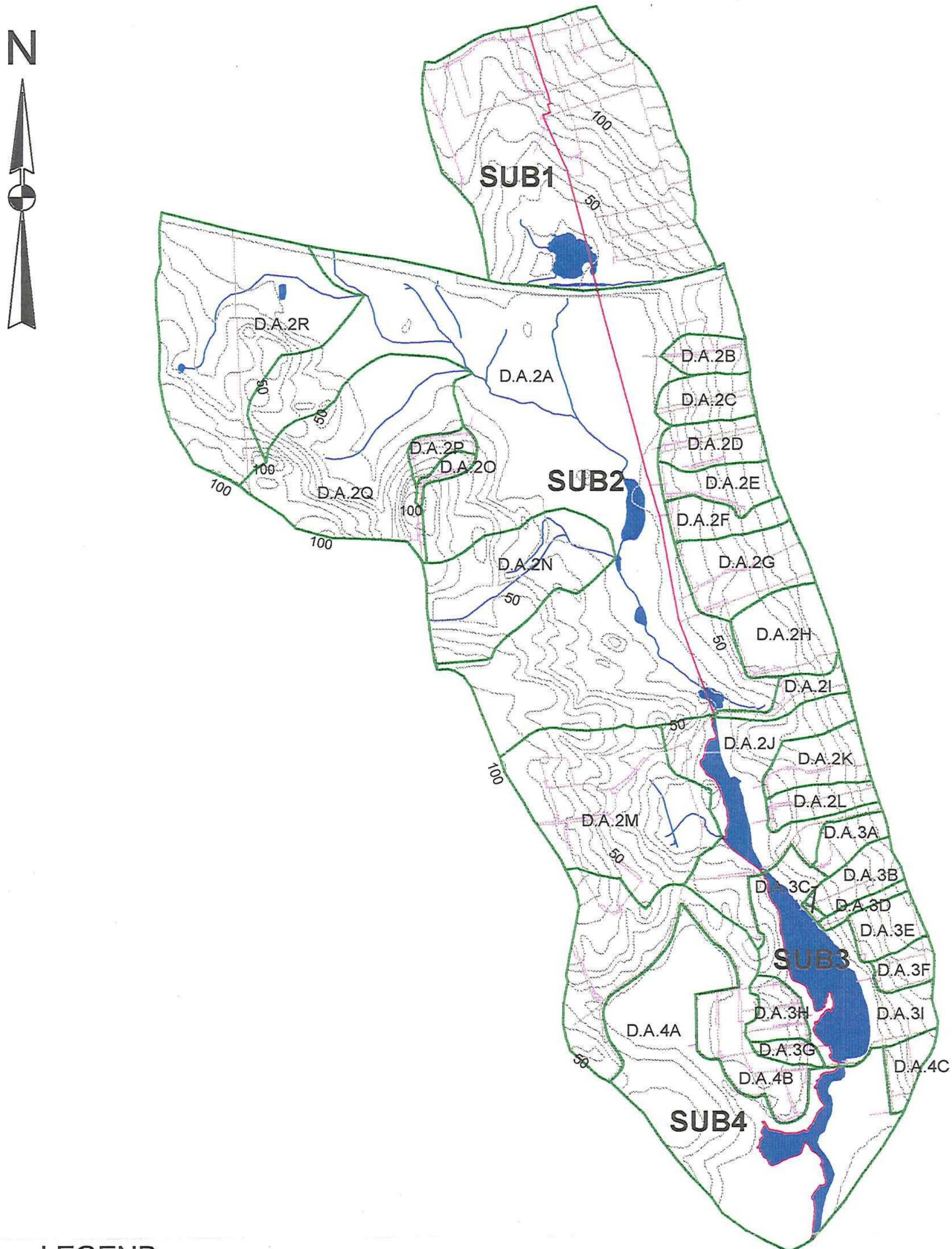
FIGURE NO. 1.1

FUSS & O'NEILL INC. Consulting Engineers
146 HARTFORD ROAD, MANCHESTER, CONNECTICUT 06040
(203) 646-2469

PROJ. MGR.:
CHIEF DSGNR.:
FN: NEW LONDON/WATERFORD
PPP:

SITE LOCATION MAP
FENGER BROOK WATERSHED MANAGEMENT STUDY

CONNECTICUT
DATE: MARCH 1995
JOB NO: 92-603A1



LEGEND

- Drainage Area Boundary
- Town Line
- Stormwater System
- Contours
- Roads
- River or Stream
- Water Bodies

SOURCE CREDIT: CONTOURS DIGITIZED FROM THE WATERFORD QUADRANGLE

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FENGER BROOK WATERSHED MANAGEMENT STUDY

Subwatersheds, Drainage Areas and Topography

PROJECT NO.: 92603A1 FILE NAME: J:FENGER.APR

SCALE: 1" = 1200' DATE: MAR. 1995 FIGURE 4.1