

Peconic Estuary Stormwater Assessment and Planning Tool

Final Report

October, 2003



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Prepared for:

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Prepared for:
Peconic Estuary Program
Suffolk County Department of Public Health Services
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This report was prepared for the Peconic Estuary program with funding provided by the U.S. Environmental protection Agency under assistance agreements Nos. CE992424-01, X992713-02-0, and CE992002-06 to the Peconic Estuary Program through the Suffolk County Department of Health Services. The mention of trade names or commercial products does not in any way constitute an endorsement or recommendation for use.



ACKNOWLEDGEMENTS

Horsley & Witten, Inc. would like to thank the Peconic Estuary Program for guidance, information collection, and useful comments during the preparation of this document. We thank the Suffolk County Soil and Water Conservation District and the USDA, Natural Resources Conservation Service for their invaluable assistance in this project. In addition, we thank the Peconic Estuary Bay Keeper for assistance in collecting field data that was integral to the accuracy of this report. We would also like to thank the US EPA and New York State Department of Environmental Conservation for comments on the final draft of this document.

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1.0 EXECUTIVE SUMMARY

Horsley & Witten, Inc. was contracted by the Peconic Estuary Program to create a Regional Stormwater Runoff Management Plan designed to mitigate loadings of fecal coliform bacteria and nitrogen to the Peconic Estuary. This document is the result of the first phase of this effort. The purpose of this study is to further ongoing efforts toward achieving two specific goals outlined within the Peconic Estuary Program's Comprehensive and Conservation Management Plan (CCMP): 1) to reopen shellfishing areas historically closed due to unacceptable concentrations of bacteria in overlying waters, and 2) to decrease loads of nitrogen to the estuary. The study uses existing information from local, county, and state agencies to build a quantitative model for predicting loads of each pollutant to small embayments within the region. The model was incorporated into a Geographic Information System (GIS) so that local agencies could use existing data to determine the impacts to other embayments on a subwatershed basis.

The interactive model created by Horsley & Witten performs two fundamental calculations: runoff volume and total pollutant load by subwatershed. The overall watershed to each embayment was divided into smaller subwatersheds based on field surveys performed by local Natural Resource Conservation Service (NRCS) and Suffolk County Soil and Water Conservation District (SCSWCD) personnel. The volume of runoff is calculated using the NRCS TR-55 equation. This volume is then multiplied by a series of fecal coliform (FC) bacteria or nitrogen loading coefficients to determine the total pollutant load. Each coefficient is expressed as a concentration of the specified pollutant within a fixed amount of runoff. Currently there are no available runoff sampling data for any of the watersheds contributing runoff to the embayments chosen for this study. As a result, Horsley & Witten designed the preliminary bacteria model to provide results for a range of loading values taken from scientific literature and sampling in other areas of Long Island. The values available to the user are a minimum, maximum and average value adapted from this research. Research in the area of nitrogen loading coefficients reveals a much more consistent set of values in the literature. As a result, it was not necessary to model a range of coefficients.

A preliminary pilot study for a single embayment, Hashamomuck Pond, was performed by Horsley & Witten using the fully integrated GIS-based pollutant loading model. The model was used to quantify and map the distribution of FC bacteria and nitrogen loadings to Hashamomuck Pond. Horsley & Witten calibrated the results of the FC bacteria loading model by calculating the resultant concentrations within five transects of the embayment. The predicted concentrations were compared with the historic adverse weather pollutant sampling data provided by the New York State Department of Environmental Conservation (NYSDEC). The comparison from these preliminary results suggested that the minimum coefficients applied to the model produced the most accurate results for Hashamomuck Pond.

Following the preliminary report, Horsley & Witten enhanced the calculations performed within the model on two levels. First, adjustments were made to the TR-55 calculations

to account for potential discrepancies in small storm runoff volume calculations. Research has demonstrated that the conventional TR-55 equation is prone to underestimating runoff volumes for storms smaller than two inches (Pitt, 1987). Comparing the results of the preliminary runoff volume calculations with the observed land use characteristics surrounding Hashamomuck Pond confirmed this discrepancy. Several subwatersheds that showed no runoff for modeled storms as high as 1.3 inches would clearly be generating runoff in reality because of directly discharging lawn or paved areas. To account for this discrepancy, modifications were made to the equation that changed NRCS curve numbers based on the level of rainfall specified in the model. These modifications produced significantly higher levels of runoff and subsequent higher levels of bacteria loading throughout the watershed.

The second set of adjustments applied to the model entailed creating a more complete picture of the watershed hydrology on a quantitative level. In the preliminary report, only the volume of the embayment was used to dilute the loading of bacteria for calibration purposes. In the following adjusted analysis, daily recharge from groundwater, the volume of stormwater runoff, and tidal flushing were also used to dilute the loads. Flushing calculations were performed using a tidal prism method (Dyer, 1997). These calculations account for the complete hydrologic system affecting each embayment during and shortly after a rain event. The resulting concentration represents an average bacteria concentration throughout the embayment. This value was calculated on a daily basis over a four-day period and compared to the average of measured FC concentrations taken from NYSDEC adverse weather sampling. The comparison indicates that the model is more accurate when higher FC bacteria coefficients are applied. This assertion is substantiated by actual runoff sampling data provided by the Cornell Cooperative Extension. Repeated stormwater sampling results from Huntington, New York (another area of Long Island) indicate that the mean set of FC bacteria concentrations may best represent local conditions.

Supplemental to the model, Horsley & Witten developed a management decision-making template to assist the Peconic Estuary Program and other stakeholders in developing strategies to remediate and/or prevent contamination through stormwater runoff to embayments within the Peconic region. To develop a management template Horsley & Witten identified the steps that are necessary to identify the appropriate management strategies to attain water quality standards. This template can be applied throughout the watershed to assist managers and stakeholders in identifying the costs, benefits and priorities in any given management strategy.

The following document details the research, methodology, and analyses performed by Horsley & Witten through October 2001 and is submitted to PEP as a final report.

2.0 INTRODUCTION

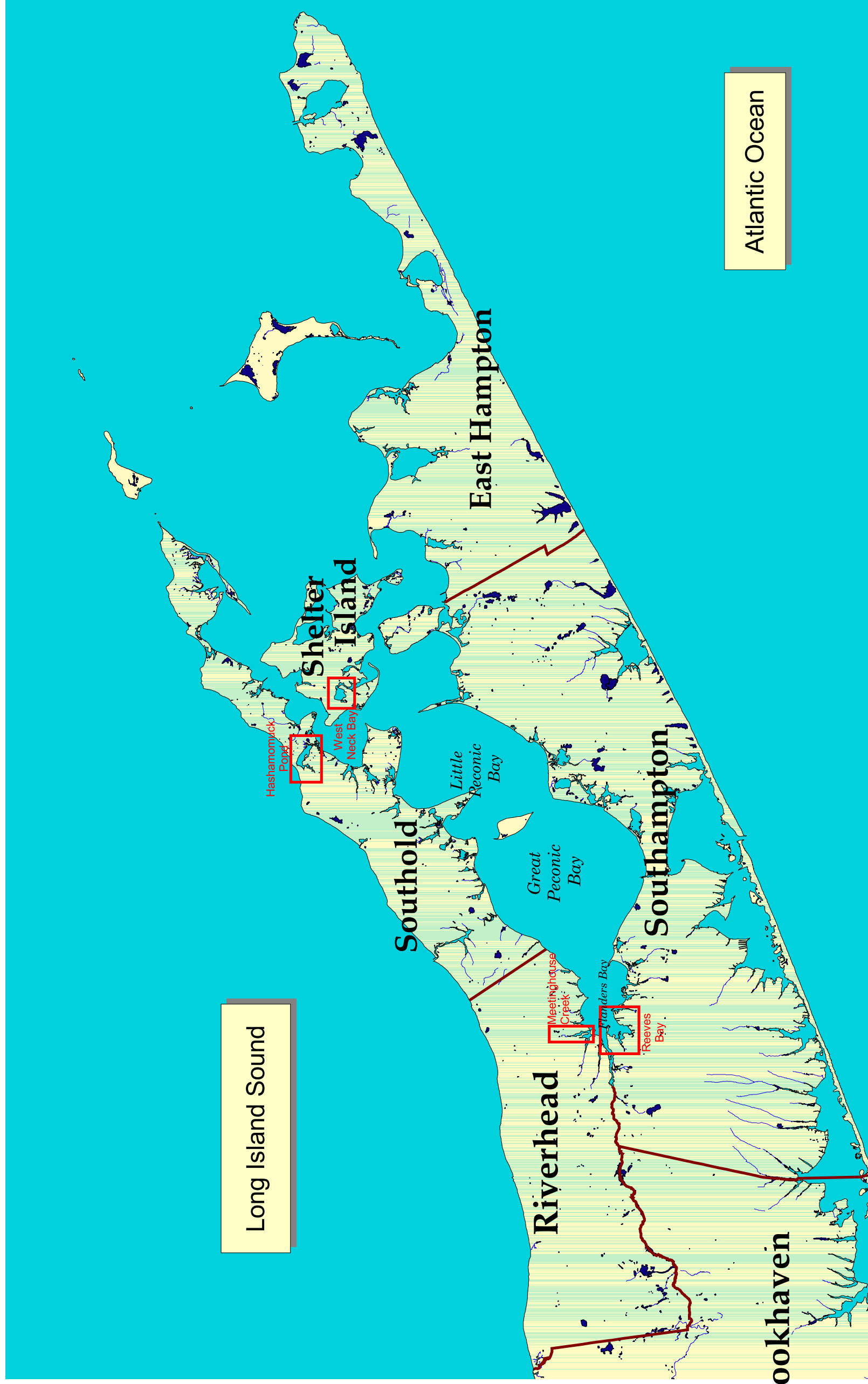
2.1 The Peconic Estuary

The Peconic Estuary is located on the eastern end of Long Island, New York between the North and South Forks. Its waters cover approximately 158,000 acres with 340 miles of shoreline and support a wide array of wildlife. There are several smaller bays recognized throughout the greater Peconics including Flanders Bay, Great Peconic Bay, Shelter Island Sound, Gardiners Bay, and Little Peconic Bay. Bordering this estuary are the towns of East Hampton, Southampton, Brookhaven, Riverhead, Southold, and Shelter Island (Figure 1). The region is very popular in the New York State area for vacationing and supports a wide variety of both recreational and natural resources. Boating, swimming and sunbathing are a few of the many recreational activities that draw thousands of people to this region each year on a seasonal basis. With regard to local industry, fishing and shellfishing are two of the predominant exploits directly dependent upon the water quality of the estuary. Economic studies of the overall Peconic Bay region have estimated that those businesses and industries directly tied to the estuary produce upwards of \$450 million of annual income within the region (PEP CCMP, 2001).

The shellfishing industry in the Peconic Estuary region has relied on significant fisheries to continuously harvest several mollusk species including hard clams (littlenecks, cherrystones, and chowders), oysters and scallops. Although all of the 121,000 acres of bay floor are recognized by state agencies as shellfishing areas, the majority of yield comes from the shallow embayments that line the estuary. Estimates have varied as to how much of the bay is highly productive with figures ranging from 8,000 acres (Lewis et al., 1997) to 20,880 (PEP CCMP, 2001). The harvesting in these areas is highly concentrated due to the fact that these beds comprise only six to eighteen percent of the entire shellfishing area (Lewis et al., 1997). The clustering of these shellfish in the smaller embayments demonstrates that estuarine environments with secluded shallower areas are highly biologically productive.

The shellfishing beds in the Peconic Estuary have been monitored for several decades by the New York State Department of Environmental Conservation (NYSDEC) in order to assess the safety of these shellfish for consumption. High levels of coliform bacteria have resulted in the closure, either periodic or year-round, of much of the more productive beds in the estuary. Coliform bacteria, specifically fecal coliform, are produced in the intestinal tracts of warm-blooded animals and are present in high concentrations in their fecal matter. FC bacteria are not necessarily harmful pathogens when isolated. However, measured levels of FC bacteria are used as an indicator for the presence of other, potentially harmful pathogens.

Figure 2 shows digitally mapped closure areas for the year 2000 and the clustering pattern of these restrictions along the coastline in the more productive embayment areas. These restrictions represent a 14% closure rate. Although this percentage of closures within the Peconic Estuary ranks favorably next to other regions in New York State,

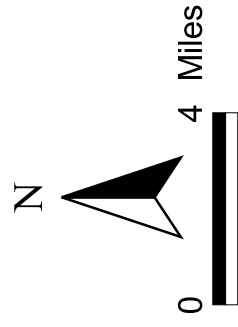


Long Island Sound

Atlantic Ocean

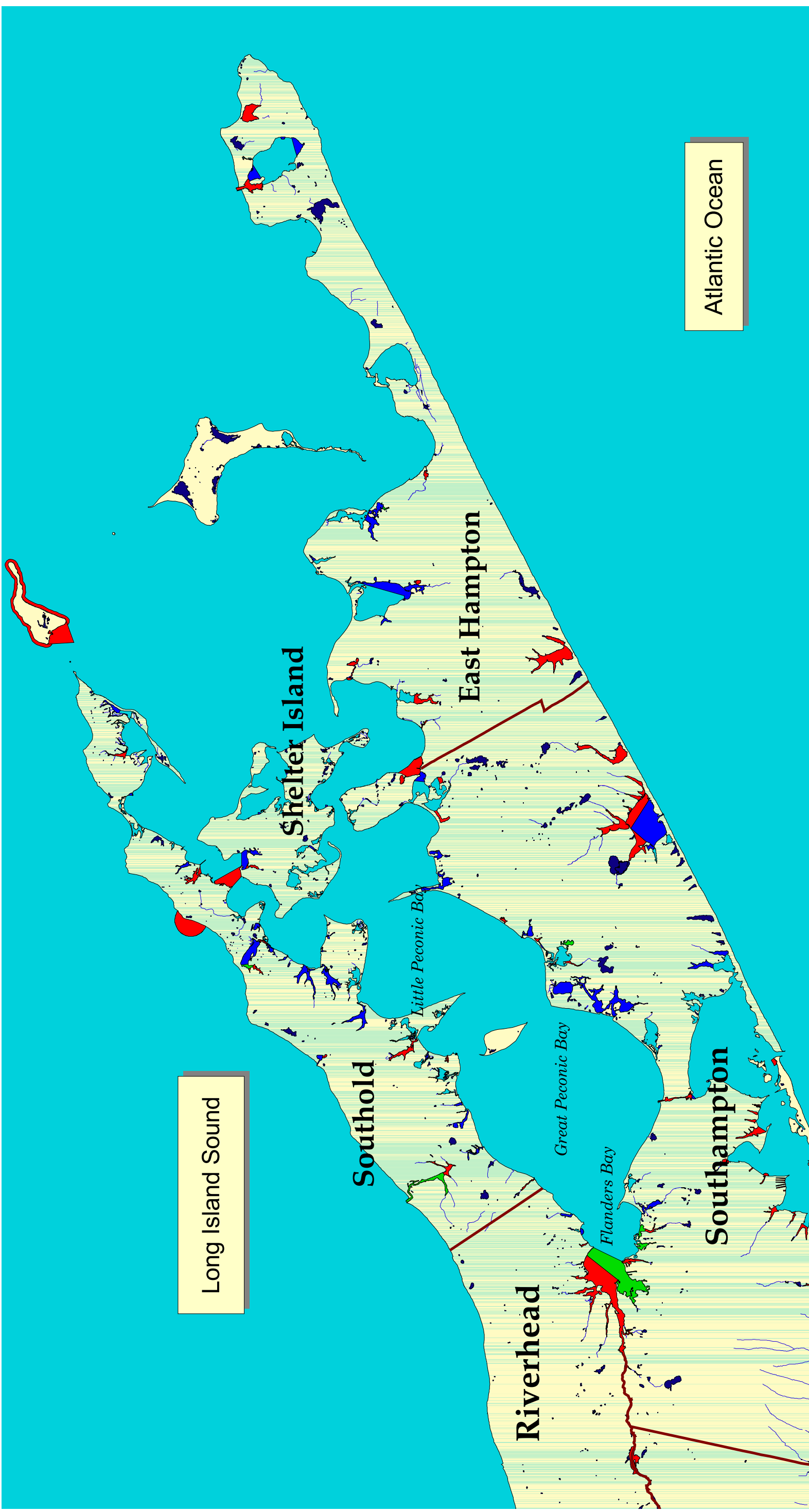
Legend

- Embayments Chosen for Assessment



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**The Peconic Bay
 Region Locus Map**



Legend

Shellfish Closure Areas

- year round
- seasonal
- conditional



0 4 Miles



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**The Peconic Bay
 Regional Shellfishing Closures**

Figure 2

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estimates of resulting income loss have gone as high as \$300 per acre when looking at shellfish yield from a single harvest (Lewis et al., 1997). From another economic perspective, surveys have shown that these resource areas could draw up to \$30,000 annually in public funding for each acre experiencing problems with bacterial loading (Opaluch et al., 1999). These estimates demonstrate the high economic potential and social value that can be associated with any management strategies designed to lower bacteria counts throughout the estuary.

Efforts to lower bacterial loading to Peconic Bay have been ongoing for many years and have developed concurrently with federal programs such as the Nationwide Urban Runoff Program (NURP) and such legislation as the Clean Water Act (CWA). In 1987, the CWA was amended to include the National Estuary Program. Under Section 320, the CWA allows individual States to nominate estuaries for funding toward the development of a Comprehensive Conservation and Management Plan (CCMP). Once an estuary receives funding from the National Estuary Program, the CCMP is designed to address the unique environmental needs of that specific region. Under the CCMP of the Peconic Estuary Program, activities related to shellfishing are a primary focus of ongoing research.

To date, those studies that have investigated the incidence of coliform bacteria in the Long Island region have concluded that the predominant source of this pollutant is stormwater runoff (NURP 1983, PEP 1992 Brown Tide). For this reason, the CCMP prepared by the Peconic Estuary Program focuses heavily upon assessing and ultimately eliminating pollutant loads that result from runoff. One section of the CCMP, the “Pathogens Management Plan”, states that a primary objective is to “maintain the current status of certified (seasonally and year-round) shellfish beds and re-open uncertified beds as long as these do not conflict with the need to protect human health nor with the need to protect and enhance natural resources” (PEP 1999).

Within the CCMP, non-point source pollution, including stormwater runoff is given the highest priority for remedial efforts beyond the scope of bacteria loading as well. Stormwater runoff will not only transport potentially high levels of bacteria to the bay, but other pollutants such as heavy metals and nutrients. Another specific priority within the Peconic Bay CCMP is the limiting of nitrogen loading to the bay as nitrogen can damage estuarine ecosystems and cause potentially harmful algal blooms such as those associated with “Brown Tide”. In areas where lawns and agricultural areas are regularly fertilized, stormwater runoff can load significant amounts of nitrogen to a receiving embayment. A well-designed stormwater management plan could therefore treat several potential water quality problems simultaneously. Carefully planned strategies could successfully limit loadings of both FC bacteria and nitrogen. These strategies would therefore work to accomplish several of the goals outlined within the Peconic Bay CCMP including reopening shellfishing areas, reducing overall nitrogen loading, and decreasing the occurrence of Brown Tide.

2.2 Applicable Regulations for Shellfishing Areas

The National Shellfish Sanitation Program (NSSP) is the federal program that outlines all procedures relevant to the permitting of shellfish growth, bed classification, storage, transport and sale within the United States. The Program is used as a guide for the appropriate state authority responsible for the implementation and oversight of the program. In New York State, the NYSDEC is the operating authority for the classification of shellfish beds on a statewide basis. The guidelines used by the authority to certify shellfishing areas are taken directly from the guidance outlined within the federal program. Documentation for both the NYSDEC certification procedure (6 NYCRR Part 47) as well as the NSSP ordinance is most readily available via the Internet for the most current versions.

Bacteriological monitoring for shellfish bed classification is conducted by the NYSDEC in accordance with 6 NYCRR Part 47. The closures administered under these sampling methods follow the same standard as those found in the NSSP. Although classification of shellfish beds can be accomplished using data for either FC or total coliform (TC) bacteria, the NYSDEC has historically tested for both of these groups. Testing for FC bacteria was temporarily suspended in June of 1998 and resumed as of January of 2001. With regard to sampling collection and analysis, the NYSDEC has historically used both of the sampling methodologies specified in the federal guidance: Systematic Random Sampling and Adverse Pollution Condition Sampling.

Table 1. A Summary of the Bacteriological Standards Applied to Both Adverse Pollution Condition and Systematic Random Sampling

Total Coliform (TC)	Fecal Coliform (FC)
median 70 MPN/100 ml	median 14 MPN/100 ml
not more than 10 percent of samples will have a measurement over 330 MPN/100 ml when examining three test tube samples	not more than 10 percent of samples will have a measurement over 49 MPN/ 100 ml when examining three test tube samples
not more than 10 percent of samples will have measurements over 230 MPN/100 ml when examining five test tube samples	not more than 10 percent of samples will have measurements over 43 MPN/ 100 ml when examining five test tube samples

The NYSDEC classifies all shellfish closures as “year-round”, “seasonal”, or “conditional”. Year-round closures can be dependent upon water quality sampling or can be “administrative”. Administrative year-round closings are applied to areas that have regular year-round bacterial loadings from sources such as wastewater treatment facility outfalls. Seasonal closures can also be dependent upon water quality data or the presence of regular seasonal stresses such as high boat traffic and large marinas. Conditional closures are dependent solely upon the water quality sampling performed regularly by the NYSDEC.

3.0 METHODS FOR CHARACTERIZING SELECTED EMBAYMENTS

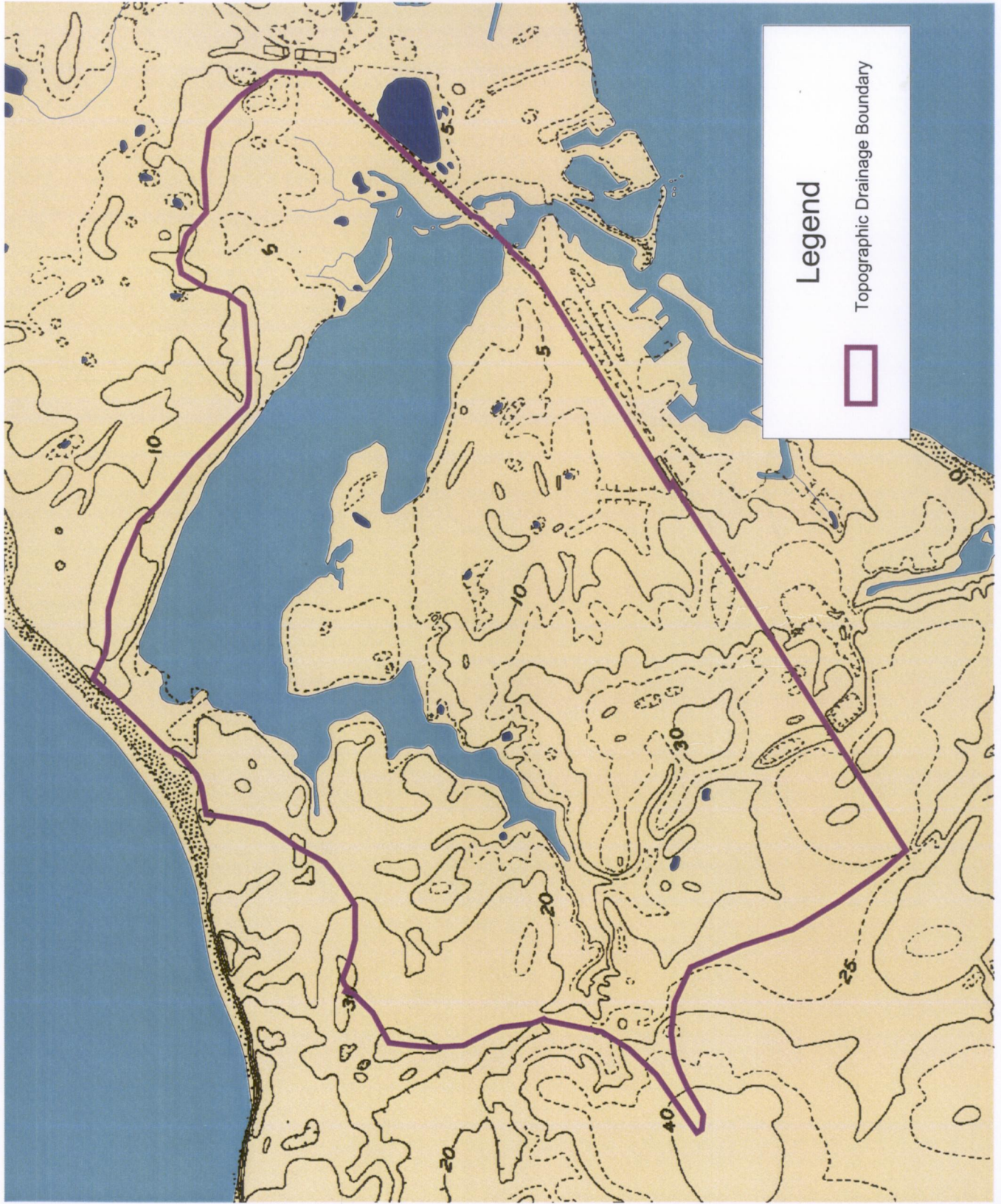
Horsley & Witten developed a standardized approach for calculating bacteria and nitrogen loading from stormwater runoff to selected embayments within the larger Peconic Estuary. This approach is watershed-based and uses the best available digital data to perform pollutant loading calculations in a GIS. For the purposes of this study, some digital data were refined through field investigation by the SCSWCD and the USDA-NRCS.

3.1 Watershed Delineation

A fundamental first step in any stormwater pollution analysis is delineating the watershed to the receiving body of water. This delineation will define the area that contributes overland flow to a receiving water body and serve as the basis for all inventories and calculations. Stormwater flow within a developed watershed occurs most frequently when rain runs from impervious surfaces like rooftops or roadways. In areas with more natural conditions, runoff occurs when surface soils reach saturation during a rain event. At the point of saturation, rainfall will begin to run across the surface in a downgradient direction towards the nearest surface water body or depression. Based on this principle of hydrology, it is possible to reasonably delineate the drainage area for an embayment using a topographic map. This method is used when a topographic map represents the best available data for a particular watershed and will give a reasonable delineation under natural conditions. An example of this type of delineation is shown in Figure 3 for the Hashamomuck Pond embayment.

The land use profile surrounding Peconic Bay is mixed with several areas of residential, open space and agricultural parcels. Mixed use will generally involve the construction of impervious surfaces, the use of stormdrain systems, and the grading of land surface to accommodate different site designs. As a result, the overall size and shape of a watershed can be altered significantly and a field survey is required for an accurate drainage delineation. In support of this study, the SCSWCD was funded to perform field survey delineations for four priority embayments within the Peconic Bay Region: Hashamomuck Pond, West Neck Bay, Meetinghouse Creek, and Reeves Bay. The USDA-NRCS provided technical support for this project. These delineations include discreet subwatersheds that are determined through a combination of natural topography and observed structural drainage. The Peconic BayKeeper completed fieldwork that inventoried all of the catch basins and stormdrain outfalls potentially affecting the final delineation.

Maps of the field-surveyed watershed delineations were submitted to Horsley & Witten by the SCSWCD on hard-copy survey maps from the Suffolk County Department of Public Works. These drawings were then digitized into ArcView GIS over the basemap data provided by PEP. The mapped inventories of stormdrain infrastructure were provided to Horsley & Witten by PEP and digitized into ArcView GIS. Maps of the preliminary digitized watershed delineations were sent to the SCSWCD for review before further analysis was performed.



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Topographic Drainage for
Hashamomuck Pond



Figure 3

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3.2 Modeled Rain Events

The modeling performed by Horsley & Witten is “event-based” modeling in that it predicts bacterial and nitrogen loading resulting from specified rain storm levels. Rainfall data from the Islip MacArthur Airport and the Cornell Cooperative Extension Riverhead Office on Sound Avenue were analyzed to choose modeled rain events. The record of precipitation data used for the Islip station covered sixteen years (1984-99) and the Riverhead data covered forty years (1960-1999). From a statistical perspective, Horsley & Witten chose the mean rainfall amount from these data sets and the 90th percentile rain event as two viable options. The mean rainfall event for both of these data sets is approximately 0.6 inches and 90% of the rainfall events fall below 1.3 inches. A third rain event chosen by Horsley & Witten was the one-quarter inch (0.25) event. This event was chosen to potentially isolate the first-flush phenomenon. Subwatersheds with directly connected lawns or impervious surfaces may produce significant amounts of runoff and FC bacteria loading even with small amounts of rainfall. Land use data from each of the four watersheds analyzed in this report indicates that small storms play a significant role in the regular pollutant loads received by these embayments. Using a small storm of this nature will help to isolate subwatersheds that contribute bacteria and nitrogen during the most common rainfall events.

3.3 Applying the NRCS Technical Release 55 Equation to Calculate Runoff Volume

The NRCS Technical Release 55 (TR-55) equation was used to calculate the volume of runoff draining from each subwatershed from specific rain events. Early in the development of this model, the calculations were generated in a more complex set of equations found in TR-20. This model is thought to be one of the most accurate for estimating overall runoff volume and is regarded as an industry standard. Unfortunately, TR-20 is generally inaccessible to most agencies because of its highly technical nature and cost. Further, there is general consensus that the TR-20 model is better suited for larger drainage areas that produce high levels of runoff discharge. In an effort to make this model more practical for state and municipal regulatory agencies, TR-20 was simplified into a set of equations that could be performed manually. This model, TR-55, was released in 1975 (subsequently revised in 1986) under the title “Urban Hydrology for Small Watersheds” (NRCS, 1986). For the purposes of the GIS-based pollutant loading model, Horsley & Witten applied the equation in three separate ways, which will be explained in the following sections.

3.3.1 The Conventional TR-55 Equation

Horsley & Witten applied the conventional TR-55 equation to the pollutant loading model under the guidance of the Suffolk County NRCS. The curve number used in the TR-55 equation represents the runoff response of a drainage area to a specified amount of rainfall over a twenty-four hour period. The number is qualitatively assigned to a discreet area of land based upon the observed land use, the surficial soils, and the

vegetative cover. The TR-55 manual contains several matrices that list a variety of land use categories for rural, urban, and suburban style developments as well as the four hydrologic soil groups (Table 2). The hydrologic group is a single letter code, A through D, which describes the permeability of the soil and its capacity to generate runoff. “A” soils represent the most permeable surface material, which will create conditions of high recharge and low runoff. The hydrologic soil categories progress toward increasingly poorly drained conditions with “D” soils creating the highest levels of runoff. Once each of the individual curve numbers are assigned to discrete parcels within a watershed, a weighted average is then calculated based on the area of each parcel. This weighted average is the curve number (CN) input for the TR-55 equation.

The TR-55 Equation:

$$Q = (P - .2S)^2 / (P + .8S)$$

where

$$S = 1000 / CN - 10$$

Q = precipitation excess (runoff height)

P = cumulative precipitation

S = potential maximum retention or abstraction

CN = curve number selected by land use and soil type

Table 2. Sample Table of Curve Numbers Taken from TR-55 Manual

Cover Description		Curve Numbers for Hydrologic Soil Group			
Cover Type	Hydrologic Condition	A	B	C	D
Pasture, grassland, or range – continuous forage for grazing	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow – continuous grass, protected from grazing and generally mowed for hay	–	30	58	71	78
Brush – brush-weed-grass mixture with brush the major element	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30	48	65	73
Woods – grass combination (orchard or tree farm)	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30	55	70	77
Farmsteads – buildings, lanes, driveways, and surrounding lots	–	59	74	82	86

In this conventional TR-55 application, curve numbers were generated for all of the subwatersheds with the help of Suffolk County NRCS. Land use maps provided by the Suffolk County Department of Planning were taken into the field by SCSWCD and USDA-NRCS agents to verify the land use designations that would be used for generating standard curve numbers.

3.3.2 Using a Curve Number Dictionary in the Model

The assistance of the SCSWCD and USDA-NRCS showed that field verification of land use within the region should be included in future applications in the model where possible. Based on the field investigations performed by these agents in this regional study, several changes were made to the land use database to more accurately reflect the actual land use activity within each watershed. However, Horsley & Witten recognized that watershed managers may want to run the model in the future for areas where field investigations of this nature have not occurred. To accomplish this, a curve number dictionary was provided in the GIS that attaches curve numbers to areas with specific land use and soil characteristics. It is important to note that, due to a lack of site-specific data, the model does make several assumptions relative to land cover when applied in this manner. The results of this method produce varied curve numbers that may be higher or lower than those that would normally be applied by NRCS. It is therefore assumed that this model scenario would only be used in instances where better data were unavailable.

3.3.3 Modified Curve Numbers Based On Rain Event

Recent research has shown that there are potential difficulties associated with applying the conventional TR-55 equations to small storm pollutant modeling exercises (Pitt, 1987). The most notable potential discrepancy results from the fact that curve numbers applied to selected land use areas will underestimate the levels of runoff generated during the smaller, more common rain events. A review of both EPA Nationwide Urban Runoff Program data and field observations performed by Dr. Robert Pitt (Pitt, 1987) showed that TR-55 tended to be most accurate when rainfall approached the two- to three-inch level. As rainfall levels move away from this range (either higher or lower), observed curve numbers show an increasing discrepancy with those that would ordinarily be used by NRCS. As rain events get smaller than two to three inches, the observed curve numbers increase. As rain events get larger, observed curve numbers decrease. Table 3 shows a more condensed version of the data appearing in Pitt's work and displays some of the potential discrepancies between NRCS curve number procedures and actual field measurements for runoff.

Table 3. Curve Numbers Determined from Field Measurements Versus Recommended NRCS Curve Numbers Taken from Pitt, 1987

Land Use and Location	Observed CN values for amount of rain in inches				Estimated CN from NRCS tables for different soil conditions (bold-faced numbers indicate the most likely number based on available site description)			
	0.2	0.5	1.0	3.0	A (sandy to sandy loam)	B (silt loam or loam)	C (sandy clay loam)	D (silty to clayey)
Low Density/ Suburban								
Austin, TX	94	84	72	53	51	68	79	84
Irondequoit Bay, NY	95	88	76	55	46	65	77	82
Med Density Residential								
Austin, TX	96	89	82	66	61	75	83	87
Broward County, FL ¹	96	89	81	65	61	75	83	87
High Density Residential								
Dade County, FL ²	99	97	94	87	77	85	90	92
Seattle, WA	94	89	80	56	77	85	90	92
Commercial Urbana³								
Champaign-Urbana ³	97	95	89	81	61	75	83	87

¹ Specified as "sandy" soils

² Specified as "Class D" soils

³ Specified as "silty, poorly drained soils"

Horsley & Witten used data from this research to extrapolate equations that adjust curve numbers based on soil type and rain level (Figure 4). These equations were then used to modify the standard NRCS curve numbers that would normally be applied to an area with discreet land use and soil type. Because the land use data taken from Pitt is not as varied as the data provided by the Suffolk County Department of Planning, the Suffolk County categories were collapsed into more general categories. Table 4 shows an example land use soils matrix applied to the adjusted runoff analysis assuming a rain event of 0.25 inches. The table shows the consolidated land use categories, the NRCS curve numbers that would ordinarily apply, and the modified curve numbers calculated from the equations in Figure 4.

Table 4. Land Use/Soils Matrix with Modified Curve Numbers for 0.25-inch Storm

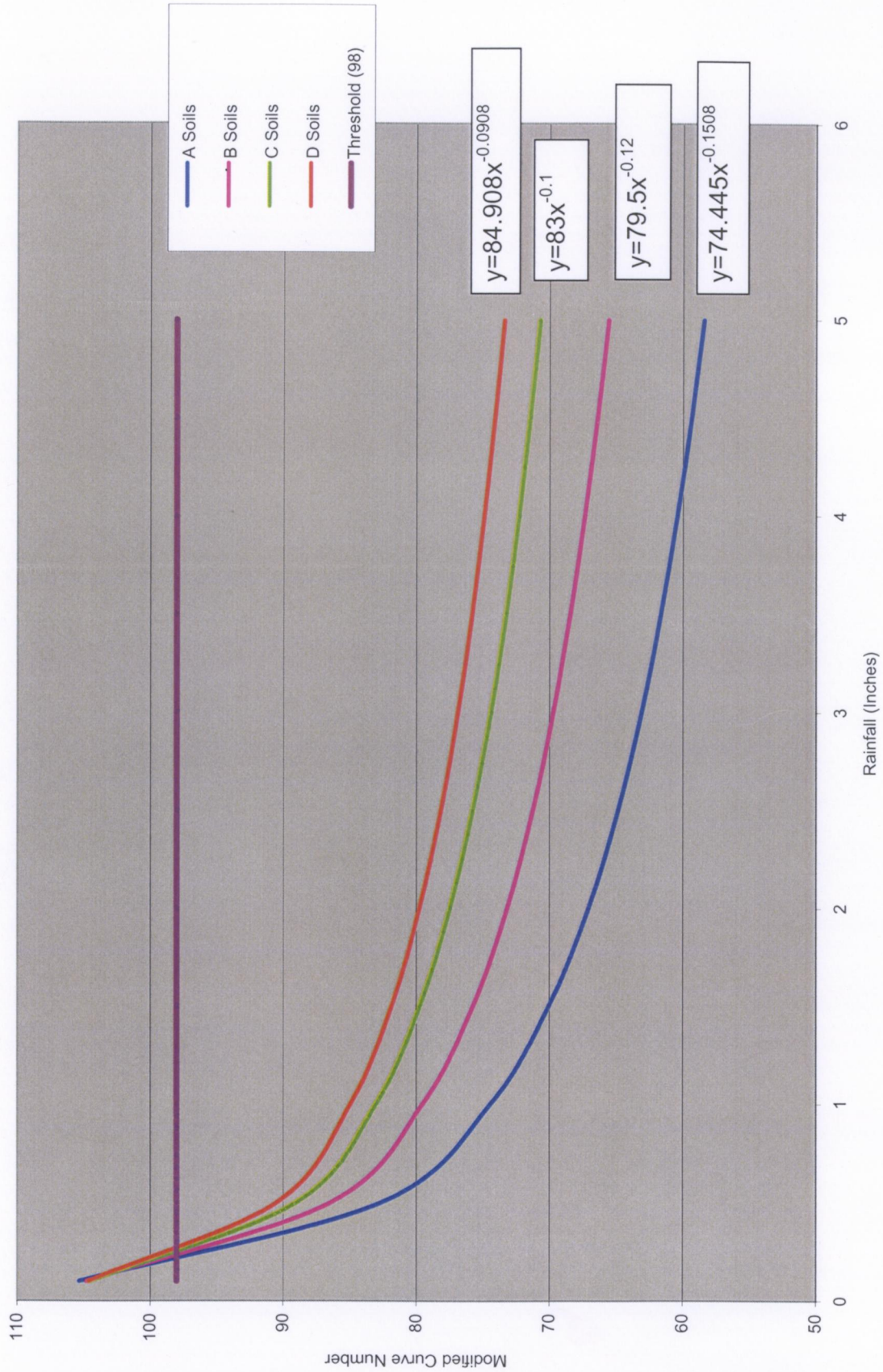
	<u>“A” Soils</u>		<u>“B” Soils</u>		<u>“C” Soils</u>		<u>“D” Soils</u>	
	SCS Curve	Modified Curve	SCS Curve	Modified Curve	SCS Curve	Modified Curve	SCS Curve	Modified Curve
Pervious Surfaces	39	92	61	94	74	95	80	96
Crops	64	98	75	98	82	98	85	98
Woods	30	71	55	85	70	90	77	93
Impervious Surfaces	98	98	98	98	98	98	98	98

Table 5 shows the progressive decrease in curve numbers for a particular soil category as the modeled rain events get closer to two inches. Note that the curve number for impervious surfaces (asphalt, roof tops) does not change since the NRCS typically assigns the highest runoff curve number to these areas.

Table 5. Example of Curve Numbers Applied to “A” Soils for Modeled Rain Levels

	NRCS	0.25 inch	0.6 inch	1.3 inch
Pervious Surfaces	39	92	80	72
Crops	64	98	98	98
Woods	30	71	62	55
Impervious Surfaces	98	98	98	98

Figure 4. Extrapolated Equations for Modifying NRCS Curve Numbers



Horsley & Witten applied the curve number adjustment methodology to each of the subwatersheds analyzed for this report. The result was a consistent increased level of runoff for most of the subwatersheds surrounding each embayment. During the smallest modeled event, 0.25-inch, certain subwatersheds generated no runoff for both the conventional and modified curve number calculations.

3.4 Sources and Pathways of Fecal Coliform Bacteria

Fecal coliform bacteria are generated primarily by warm-blooded animals and are deposited into the environment in fecal waste. With regard to bacteria that reach coastal waters, a review of scientific literature shows that research has focused on two general categories: direct deposition (Weiskel et al 1996; Alderisio et al. 1999; Benton et al., 1982), and loadings from stormwater runoff (Crane et al., 1983; Gregoire et al., 1996; Mallin et al., 2000). Although loading from groundwater has been observed in some cases, these instances are rare. This is because infiltrating runoff through unsaturated soils will result in high levels of filtration and die off of the transported bacteria. High concentrations of FC bacteria in soil and groundwater systems result from extreme high-level applications of waste to areas with a shallow depth to groundwater or in instances where waste is directly injected into groundwater (McCurry et al. 1998).

3.4.1 Direct Deposition of FC Bacteria to Coastal Embayments

Direct deposition of FC bacteria to water can come from a wide variety of sources within an estuarine environment. Most frequently discussed in current literature are deposits from waterfowl. The seasonal presence of migrating or nesting waterfowl can sometimes account for the highest loading of FC bacteria in an embayment (Weiskel et al., 1996). Studies of bacteria loading from waterfowl have shown a significant amount of variability in cases where large populations have been studied as well as with those cases that have examined individual birds. When examining entire populations, test sites will show large variations in loading related to seasonal changes. Most notably, migratory fowl often “winter over” in coastal embayments resulting in high loadings throughout the winter into spring (Valiela et al., 1991). As a result, modeling for waterfowl inputs requires seasonal data for proper calibration. Further complications with calculating loads from waterfowl are demonstrated with the varying concentrations of FC bacteria within individual fecal samples. One study of geese over the course of a year showed bacteria concentrations within the feces to range from 15,300 to over 27 million colonies per gram. Seasonal change in diet is the most probable explanation for these fluctuations. Seasons of abundant food supply, generally in the warmer months, are accompanied by higher concentrations of bacteria within the feces of these birds (Alderisio et al., 1999).

Another notable direct contribution of FC bacteria to estuarine environments comes from the wrack zone along the shoreline. These areas of grass and seaweed act as reservoirs in which enteric bacteria is both sheltered from environmental stressors and supplied with nutrients that enable proliferation. Loading from the wrack zone comes most commonly from the repeated flushing of tidal waters although major rain events can also serve to flush FC bacteria from these reserves. During tidal fluctuations, bacteria lie protected in

the wrack zone until an incoming tide suspends or rainfall washes through the vegetation releasing the bacteria in potentially large quantities (Weiskel et al., 1996). Hashamomuck Pond experiences a tidal flux of approximately four feet in each cycle. Although there are no reliable estimates as to the acreage of wrack zone around this embayment, the occurrence of tidal fluctuations suggests that resuspension of wrack vegetation could load significant levels of bacteria to the embayment.

A final source of direct deposition to be considered is that which comes from marine sediments. Several studies have attempted to measure or predict the levels of enteric bacteria in bottom sediments of fresh and salt water environments and results have shown high variability. Studies have shown FC bacteria concentrations in resuspended sediments to range from 7 to 12,000 organisms per 100 mL of water (Sherer et al., 1988 and 1992; Valiela et al., 1991; Weiskel et al., 1996; Crane et al., 1986). Similar to the wrack zone, sediments can provide an environment conducive to the extended survival or proliferation of FC bacteria. These areas of the marine environment are often rich in nutrients and will keep bacteria from being fully flushed during tidal fluctuations.

The levels of FC bacteria attached to any area of sediments are difficult to predict. However, it has been shown that the most significant measurements are found in the uppermost areas where sediments receive nutrients from the overlying waters (Sherer et al., 1988; Weiskel et al., 1996). Consequently, the addition of FC bacteria to the water column from bottom sediments is generally thought to be the result of actively disturbing these sediments. Tidal flux and wind can account for limited amounts of perturbation, however most significant disturbances come from anthropogenic activity. In an estuarine environment, bathing, boating, and shellfishing are three primary examples of the activities likely to cause FC bacteria loading from resuspending bottom sediments. The irregular occurrence of these activities can cause highly variable measurements of bacteria within short periods of time (Sherer et al., 1992). Attempting to model the change in concentrations from resuspended sediments requires data relative to bacteria counts within the topmost layer of bottom sediments.

Direct deposition of FC bacteria from the sources listed above can prove to be a significant problem for estuarine environments where shellfishing or swimming are regular activities. Several attempts have been made to quantify the relationship between the presence of waterfowl, tidal fluctuation, and concentrations of FC bacteria in embayment waters. Table 6 lists several of the FC bacteria coefficients that have been associated with waterfowl, the flushing of wrack and the resuspension of sediments.

Table 6. Sample Loading Coefficients for FC Bacteria from Direct Deposition

Source	Loading Coefficient	Citation
Swans	10^7 FC/day-bird	Valiela et al., 1991
Ducks	10^9 FC/day-bird	Weiskel et al., 1996
Geese	10^7 FC/day-bird	Weiskel et al., 1996
Concentration in Gull Feces	3.68×10^8 FC/gram	Alderisio et al., 1999
Yield from Wrack Zone	1.25×10^6 FC/kg wrack	Weiskel et al., 1996
Resuspended Sediments	7-18 FC/100 mL seawater	Valiela et al, 1991

Although some data exist for bird counts within the Peconic Bay region, these data are sporadic and vary in quality from one embayment to the next. In order to estimate populations of waterfowl within the selected embayments, Horsley & Witten averaged the densities of birds from several aerial photographs of small embayments within the region taken by the U.S. Fish and Wildlife Service. The resulting density of waterfowl is 0.3 birds per acre of surface water. This density was multiplied by the surface area of each embayment to estimate the population of waterfowl. The resulting population was then multiplied by the average daily loading coefficient for ducks and geese: 10^8 FC/day-bird (Weiskel et al., 1996). This coefficient was chosen because the counts from the aerial photos show a mixture of ducks and geese.

3.4.2 Sources of Bacteria via Stormwater Runoff

Stormwater runoff from urban and suburban areas typically enters receiving surface water bodies by roadway drainage. Drainage from impervious surfaces can either run overland to areas where roadways open to the shoreline or can be channeled to the receiving water body via stormdrain systems. In an area like Peconic Bay where there is considerable shoreline development, residential lawns and commercial parking areas can also produce high levels of runoff that drain directly to the embayment. Irrespective of the source, it can be assumed that stormwater runoff from every type of land use surrounding Peconic Bay will carry some level of FC bacteria. The concentration of bacteria within the runoff will depend upon how often and how intensely each area of land use is exposed to FC bacteria deposition.

With regard to human waste disposal, septic system failures and combined sewer overflow (CSO) systems can lead to extremely high loads of FC bacteria during larger storm events. However, the presence of FC bacteria in residential or commercial areas is generally associated with a combination of domesticated animals (pet waste) and wildlife. Potentially a predominant source of FC bacteria in residential areas is the presence of dog feces (Weiskel et al., 1996). Pet waste generated from dogs is potentially a major contribution to surface runoff pollution depending on a variety of factors. Most obvious of these variables is the population level within a given watershed and the way in which waste disposal from these animals is managed. Communities with tightly enforced

curbing laws or higher levels of public education stand to fair much better with regard to overall bacteria loadings to nearby surface water bodies. Daily droppings from dogs within a localized area can produce significant stores of bacteria that build up between rain events. Reported estimates for the “average” dog show that each will produce 450 grams of fecal waste each day and that each gram will contain one million FC bacteria. Because feces rarely wash away completely during the more common storm events, FC bacteria can accumulate and remain viable over extended periods of time (Weiskel et al., 1996).

Whether from domestic animals or wildlife, FC bacteria are often bound to sediments throughout residential areas that collect on impervious surface (Gobos, 1999). Comprehensive loading concentrations have been sampled using two different methods. First, concentrations in runoff have been sampled downgradient of different residential densities to compare the different cumulative concentrations. Certain studies suggest that FC bacteria concentrations regularly increase as residential areas become more dense (Weiskel et al., 1996; Gobos, 1999). More detailed approaches have reported sampled runoff from roofs, driveways, lawns, and roads to compare the relative loading contributions of different surfaces within residential areas (Schueler, 2000; Gregoire et al. 1996). Almost all studies show that increases in development density and impervious surfaces yield runoff with higher concentrations of FC bacteria.

Within many areas surrounding the Peconic Estuary, there are several large parcels of land zoned for agriculture. A great deal of research has been applied to loading of FC bacteria from agricultural sources and, as with residential loading figures, methodologies for agricultural sources have varied considerably in approach. One approach has been to measure the concentration in the waste of individual animals to establish a baseline availability for FC bacteria loading (Crane et al., 1983). If data are available for the number of animals found in a feedlot or pasture, along with daily fecal production rates, a fairly specific number can be calculated for available load. However, for models that will be applied over broader ranges of land with varying levels of data specificity, this approach is not always practical. If too many assumptions are made regarding animal traffic and density, significant errors can be carried throughout the model. Furthermore, calculating the available levels of bacteria stored in manure still leaves the question as to how much of that bacteria will be transported during a specific rain event.

Other agriculturally-based studies have used measured concentrations of FC bacteria in runoff from different associated land uses in an effort to assign typical loading figures to certain agricultural practices (Moore et al., 1983). To use these coefficients in a model involves a certain level of assumption as data from one area are being applied to another with potentially different environmental variables (soils, vegetative cover, etc.). However, one advantage is that this approach does not require the level of detail needed to perform an assessment on a “per animal” basis. This approach is therefore more easily applied to studies of multiple watersheds where the level of data detail is often highly variable.

Another important approach to modeling agricultural areas is that which closely examines the storage and application of livestock waste. As potential sources of FC bacteria, storage areas will supply highly variable ranges of bacteria depending on the type of storage facility. For example, outdoor storage open to rainfall will supply much higher quantities than indoor or otherwise covered storage areas. Further, with regard to the use of waste as fertilizer, different application techniques will produce variable loading rates. For example, studies have shown that applications of manure slurry, as opposed to manure solids, can produce slightly higher concentrations of FC bacteria in runoff (Crane et al., 1983).

It is important to note that the majority of scientific study relative to bacteria in agricultural runoff focuses upon areas where manure is present. Whether applied as fertilizer, stored in bins, or deposited by grazing livestock, the introduction of manure is the most significant factor contributing to the resulting loads of FC bacteria. Data regarding those agricultural lands that do not house livestock or apply manure as fertilizer are limited. It is reasonable to assume that, relative to concentrations of FC bacteria, these lands would derive most of their bacteria stores from wildlife. As a result, coefficients for natural areas with low lying vegetation would best estimate the loadings from these farms.

Open space and forested areas surrounding the embayments in this region were assumed to have relatively low concentrations of FC bacteria in runoff. Natural areas have shown to deliver low quantities of FC bacteria in runoff probably due to high attenuation in soils. Because the soils in the Long Island area are highly conducive to recharge, very little runoff will leave these areas during the most common rain events. The resulting increased residence time of bacteria within these vegetated areas will likely cause the majority to die off before larger storms can wash them to the embayment.

Overall, research regarding bacteria concentrations in runoff from all of the land use categories found within the Hashamomuck Pond watershed is highly variable. Because of this variability and the lack of site-specific data, a range of concentrations was modeled for this analysis. The lowest reasonable concentrations found in the literature, the highest, and the mean were all used to produce three potential results for each subwatershed. The coefficients used are shown in Table 4. Several coefficients may appear differently in Table 4 from where they were cited. Any change in values is due to the fact that all values were normalized to a concentration within 100 mL of runoff. Also, where literature values were not present for specific land uses surrounding Peconic Bay, assumptions were made based on available data. For example, measured values for “Commercial” runoff were used for what is referred to as “Institutional” property within the selected watersheds.

3.5 Nitrogen Loading in the Peconic Bay Region

PEP has incorporated nutrient loading, specifically nitrogen loading, into its highest priorities within the CCMP. Based on their review of existing study relative to nitrogen loading and water quality data (PEP, 1999), PEP has determined dissolved oxygen (DO)

levels to be the primary indicator of nutrient loading problems to the estuary. Although the overall water quality data relative to DO indicates that the regional waters are healthy, there are isolated areas where DO measurements have dropped to levels considered deleterious to habitat maintenance.

As is often the case with nitrogen loading, groundwater recharge is considered the highest, locally controllable external contributor to the estuary. Sediment nutrient flux within the estuary is also considered to be a significant source (PEP, 1999). Although stormwater is not considered to be a major contributor of nitrogen region-wide, in more densely developed areas with a higher percentage of impervious surface, event-based loading could prove to be significant. Horsley & Witten was asked to examine the contribution of nitrogen from stormwater runoff.

3.5.1 Nitrogen in Stormwater Runoff

Modeling of nitrogen loads to marine environments is often performed as a mass-balance calculation where specific land use categories are given loading coefficients. These coefficients are then multiplied by the area of that land use or the population to determine the mass loading to the receiving water body. An example of these coefficients appears below in Table 7. These values were taken from the *Nitrogen Loading Budget and Trends* report written by the Suffolk County Department of Health Services for PEP (SCDHS, 1999). The values used in this study are given in “pounds per day” and represent the presence of nitrogen in groundwater recharge.

Table 7. Sample Loading Coefficients Taken from Suffolk County Study (SCDHS, 1999)

Source	Loading Coefficient
Human Sanitary Waste	(lbs/day/person)
Year-Round Residential	0.0137
Seasonal	0.0046
Residential Fertilizer	(lbs/day/acre)
Low Density	0.0342
Med Density	NA
High Density	NA
Residential Animal Waste/Natural Precipitation	(lbs/day/acre)
Low Density	0.0079
Med Density	NA
High Density	NA
Farmland	0.1836 lbs/day/acre
Commercial	0.1142 lbs/day/acre
Industrial	0.1142 lbs/day/acre

Although stormwater is generally not considered as much of a threat with regard to nitrogen loading, it can carry significant loads depending on the land use present within a watershed. Nitrogen loading from runoff is most commonly the result of rainfall washing fertilizer from residential and agricultural areas. Failed septic systems are another

potential source of nitrogen. Horsley & Witten researched nitrogen concentrations in stormwater and organized the data in a way that will be compatible with the basic structure of the GIS-based pollutant loading model. Nitrogen loading coefficients were assigned to each land use category provided by the Suffolk County Office of Real Property and Taxation. The values used in the calculations are found in Table 8.

Table 8. Nitrogen Concentrations Applied in Runoff from Land Use Categories Used by Suffolk County (NURP, 1983; Novotny, 1985)

Land Use Category	Concentration (mg/L)
Low Density Residential	2.0
Medium Density Residential	2.0
High Density Residential	2.0
Commercial	2.17
Industrial	2.53
Institutional	2.6
Recreational Open Space	1.6
Agriculture	4.3
Vacant	0.2
Transportation	4.2
Utilities	2.53
Waste Handling & Transport	2.53

3.6 The Mass-Balance Loading Equation

The basic structure of each loading equation follows a mass-balance approach. For both bacteria and nitrogen, the runoff volume was multiplied by a concentration of the

<p>Sample Mass Balance Equation:</p> <p>Total Bacteria Load =</p> <p>Volume of Runoff X Bacteria Concentration</p>

pollutant in runoff. A single concentration was calculated for each subwatershed as a weighted average of the individual coefficients associated with each land use. The concentration of bacteria was expressed as

organisms per 100 milliliters (orgs/100 mL) while the concentration of nitrogen was expressed in milligrams per liter (mg/L). Because the range of bacteria coefficients was very broad (varying by up to two orders of magnitude for a single land use), a weighted average was calculated for the minimum, maximum and mean coefficients. The overall runoff volume for each subwatershed is multiplied by the weighted pollutant concentration to calculate a final load.

3.7 Modeling the Quantity and Quality of Stormwater Runoff in ArcView GIS

Horsley & Witten received digital information from a variety of sources in order to create the interactive FC bacteria and nitrogen loading model in ArcView GIS. The Peconic

Estuary Program provided digitized data that would serve as the basis for all mapping and analysis. These coverages were originally assembled by the U.S. Fish and Wildlife Service in 1996. Digital orthophoto imagery was also used for land use analysis and was downloaded from the New York State GIS Clearinghouse. For the information necessary to performing the TR-55 analysis, the USDA/NRCS provided preliminary digital soils layers for the entirety of Suffolk County. These data have not yet received the final level of review by USDA. Land use layers were provided by the Suffolk County Office of Real Property Tax Service Agency under signed user agreement. Digital layers created by Horsley & Witten include the digitizing of watersheds provided by NRCS, the digitizing of water quality sampling stations taken from NYSDEC triennial reports, and the digitizing of drainage infrastructure provided by the Peconic BayKeeper.

Horsley & Witten combined the essential elements of the different data sources into a single spatial database and created an interactive pollutant loading model to run from that new database. The model was written as an Avenue Script and attached to the graphical user interface for easy user access. When executed, the model follows the basic steps for characterizing each watershed as described in the above sections. For the basic loading calculations, the model works by requesting specific user inputs for rain event, pollutant (FC bacteria or nitrogen), method of calculating runoff volume (see sections 3.3.1 through 3.3.3), and specifications for the FC bacteria coefficients (minimum, average, or maximum). If the user wishes to calculate the resulting average concentration within the embayment, the model will prompt the user for further inputs including mean low-tide depth, tidal range, and number of waterfowl within the embayment.

4.0 RESULTS FOR THE PILOT PROJECT: HASHAMOMUCK POND

Hashamomuck Pond was selected as a pilot embayment for the overall regional study. This body of water is a secluded embayment located in Southold along the North Fork of Eastern Long Island (Figure 5). The embayment is approximately one mile long and one-quarter mile across at its widest point. At the northwestern end of the embayment, a slender extension called Long Creek tapers off the main body of the embayment. The embayment narrows and connects with Peconic Bay at its southern most point through Mill Creek. The tidal range within Hashamomuck Pond is approximately three feet with the surface water covering approximately 170 acres.

Horsley & Witten performed a tidal prism calculation to estimate the average flushing time for the entire embayment (Dyer, 1997). This calculation predicted that on average the water within Hashamomuck Pond would be fully exchanged with the water in Peconic Bay in **1.2** days. The tidal prism method used to calculate this figure generally underestimates the amount of time needed for a full flush. Tetra Tech, Inc. performed a numerical flushing calculation for Hashamomuck Pond that estimated the full exchange at three days (Tetra Tech, 1999). Personal communication with Tetra Tech suggested that this flushing calculation was an overestimate of the actual exchange time. The actual flushing time for Hashamomuck Pond is therefore assumed to be approximately **2.1** days.

Insert Figure 5



Long Island Sound

Long Creek

Mill Creek

Peconic Bay



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Aerial Photograph of
Hashamomuck Pond



Figure 5

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The watershed contributing to Hashamomuck Pond is mostly residential with a large area of open field under succession and vegetable cropland in the northwest quadrant of the watershed. The southern shore of the pond near the outlet to Shelter Island Sound is primarily vacant scrubland and the northern shore near the outlet is agricultural land. The shoreline of Hashamomuck Pond is bordered mostly by low and medium density residential housing. All houses within the watershed around Hashamomuck Pond have on-site septic systems and there are no sewage treatment systems discharging directly into the Pond.

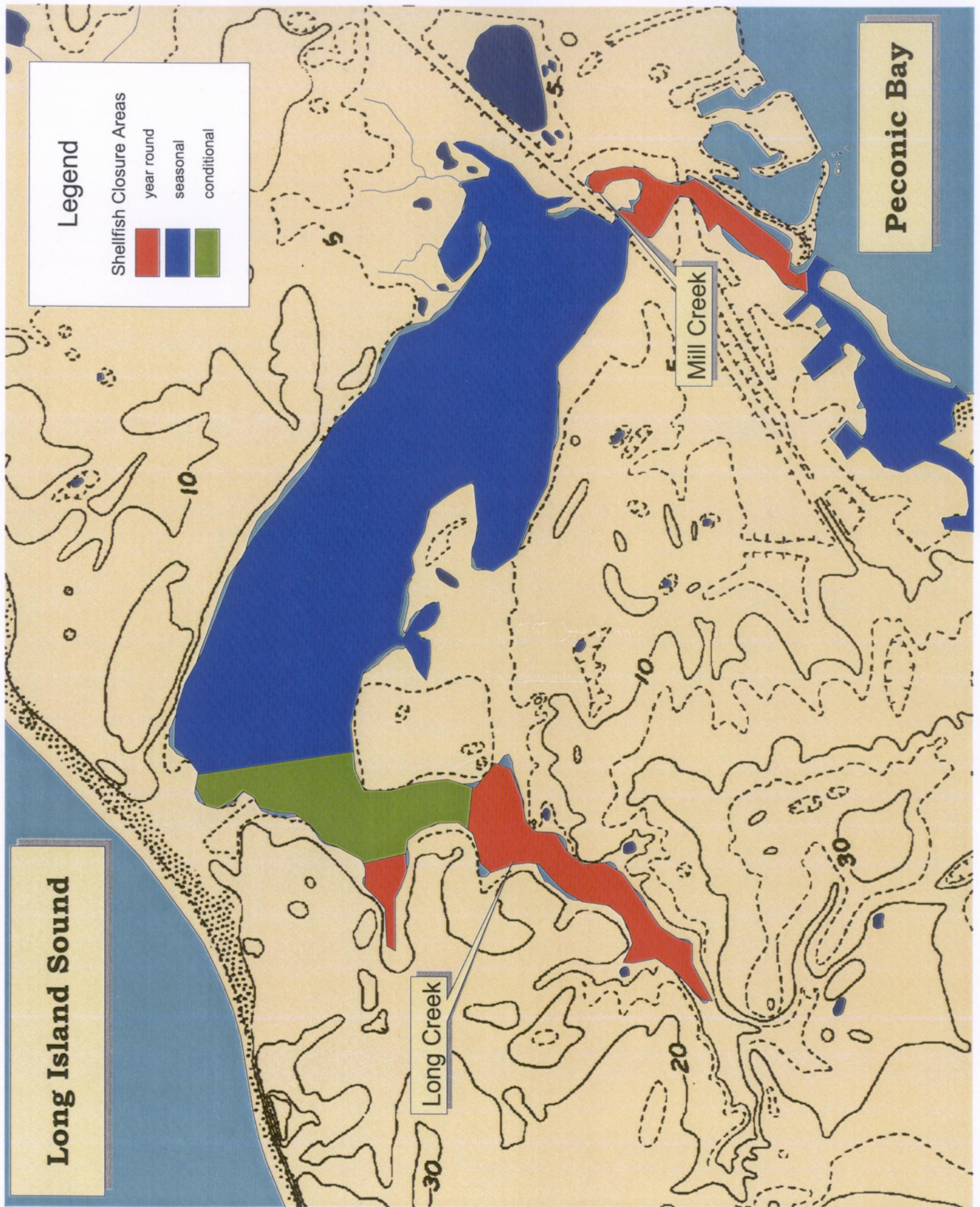
The New York State Department of Environmental Conservation (NYSDEC) has designated this embayment as growing area 23 and has monitored its water quality with varying frequency for several decades. All of the waters within Hashamomuck Pond experience some level of closure due to unacceptable levels of bacteria (Figure 6). The most secluded areas in the northeastern corner, including almost all of Long Creek, are closed year-round. Adjacent to these areas is a section of the embayment that is under a conditional program where certification is dependent upon the results of more rigorous sampling. The main body of Hashamomuck Pond experiences seasonal closure from May 1st to November 30th each year. This closing schedule is due to historic patterns of bacteria exceedance levels during these warmer months. Pursuant to federal and state regulations, bacteriological sampling and pollutant source surveys are performed annually for those areas that are seasonally and conditionally closed.

4.1 Delineation

Horsley & Witten digitized the watershed delineation for Hashamomuck Pond that was performed by an NRCS agent through field survey. This delineation is significantly different than the basin that was drawn solely by using a topographic map. Impervious surfaces, drainage culverts, and other land use characteristics create a drainage basin that follows constructed boundaries as well as those created by natural features. Field observation was also important in delineating discreet subwatershed areas that would be used as the hydrologic units for both runoff and volume calculations. These delineations serve as the foundation for both isolating areas of high pollutant loading and choosing management strategies to treat that pollution.

In order to organize the results of the analyses, the subwatershed areas were given a simple numeric system. The NRCS delineation with subwatersheds and numbering is shown in Figure 7. The delineation was also checked against aerial orthophotography to ensure the inclusion of those homes and features specified on the Tax Assessor's maps provided by NRCS.

Insert Figure 6



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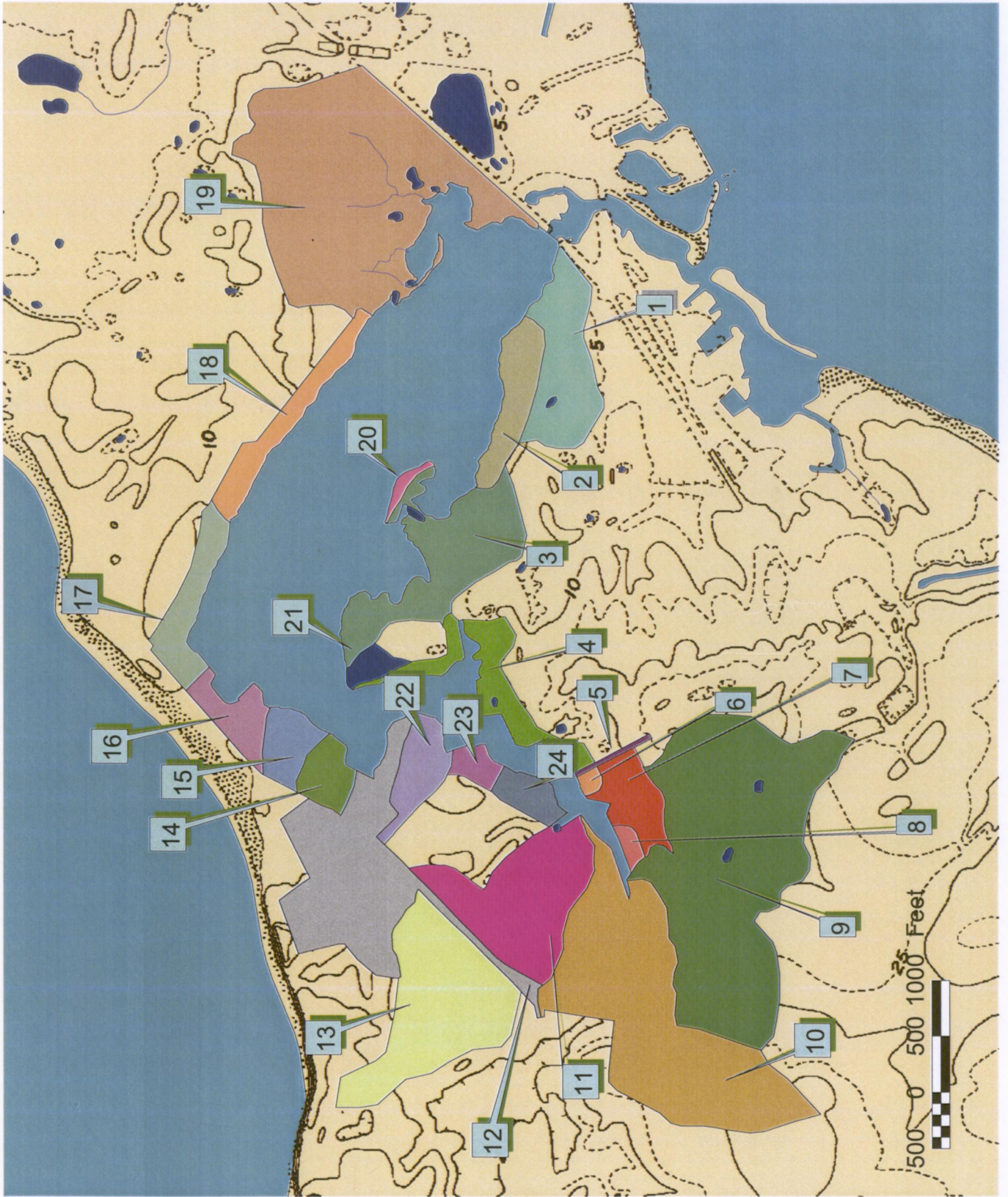
Existing Shellfish
Closures for
Hashamomuck Pond



Figure 6

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Insert Figure 7



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Subwatershed Delineations
 for Hashamomuck Pond



Figure 7

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4.2 Land Use and Soils Inventory

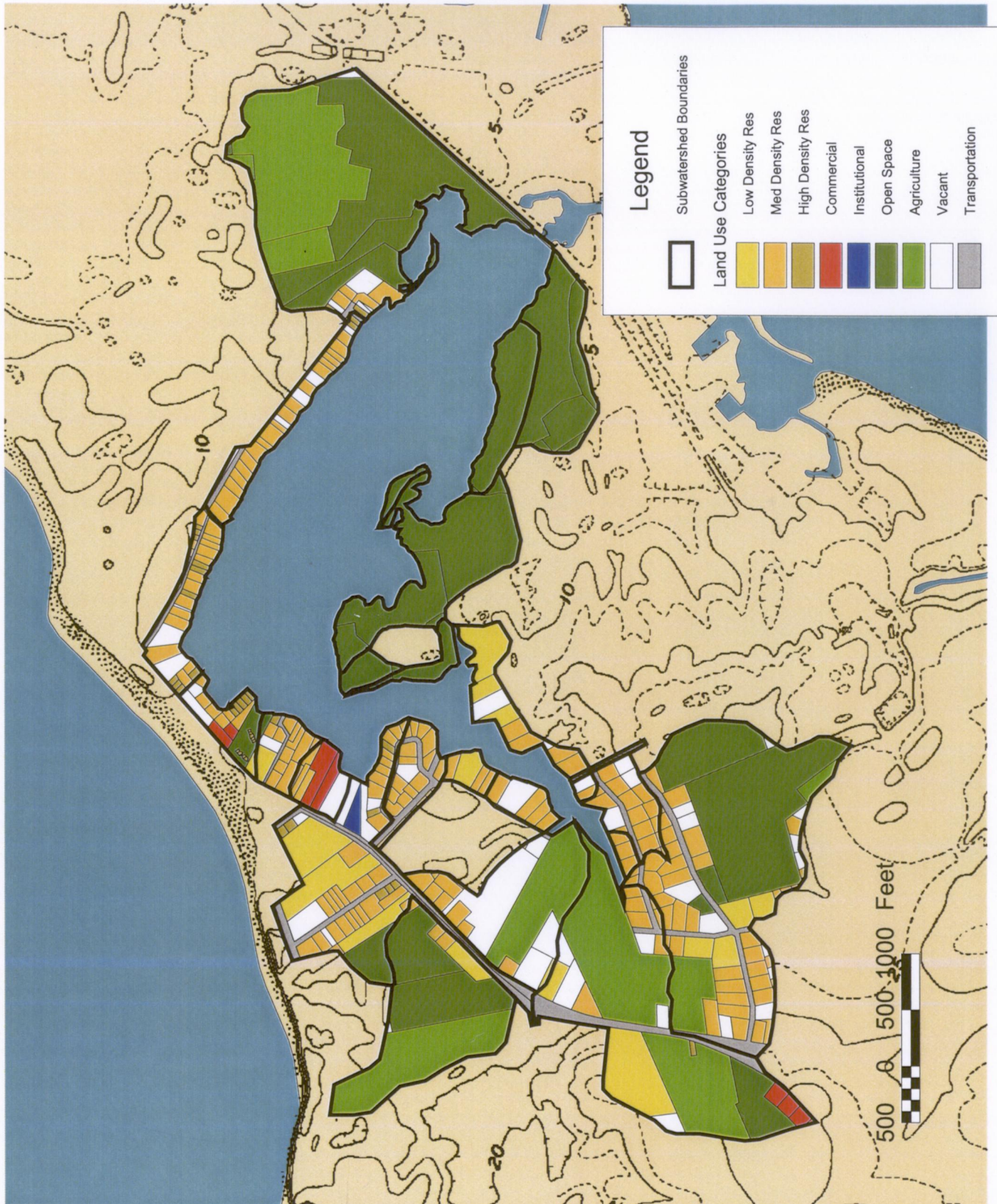
The land use profiles differ from one embayment watershed to the next in the Suffolk County area. In many cases, certain land use categories within the Suffolk County Department of Planning database will be completely absent. Table 9 shows the land use summary derived from a GIS for the Hashamomuck watershed where Industrial, Utilities, and Waste Handling & Management do not appear. The greatest single use categories, by area of coverage, are Open Space, Agriculture, and Medium Density Residential (Figure 8). These categories cover 30%, 21%, and 19% of the watershed area respectively. However, it is also important to notice that the combination of the three residential categories (High, Medium, and Low) covers a full one third of the watershed area. These areas are important since all residential area can produce stormwater runoff with significant concentrations of FC bacteria and nitrogen.

Table 9. Land Use Summary for the Hashamomuck Pond Watershed

Land Use Category	Area in Acres	Percent of Total
Low Density Residential	57.7	13%
Medium Density Residential	81.9	19%
High Density Residential	4.3	1%
Commercial	5.1	1%
Institutional	0.8	0.2%
Recreation/Open Space	35.5	8%
Agriculture	92.0	21%
Vacant	129.1	30%
Transportation	28.0	6%

Several land use categories assigned to parcels within the Suffolk County area are more general in nature and require clarification for modeling purposes. Those land use categories that required more detail were discussed with the NRCS agent responsible for the field delineation of the watershed. The Vacant land use surrounding Hashamomuck Pond was categorized as either “brush-weed-grass mixture/ good condition” or “Forested/good condition”. (The “condition” of any land use defines the extent to which the area is covered with the specified vegetation. In this case, “good condition” implies that the area is more than 75% covered.) Agricultural land use was considered to be “row crops” for all of the agricultural parcels within the watershed. The recreational parcel located in the east area of the watershed was considered to be “brush-weed-grass mixture/good condition.”

Digital surficial soils layers were provided by USDA/NRCS for the entirety of Suffolk County. The individual soil types within the Hashamomuck Pond watershed were collapsed into their general hydrologic soil category for use with TR-55. The majority of soils surrounding the pond are highly permeable type “A” and type “B” soils (Figure 9). These soils indicate conditions where a low percentage of rainfall will actually become runoff during the more common events. Type “C” soils occur mostly in areas where road construction has used artificial fill. Type “D” soils are found in isolated areas that are



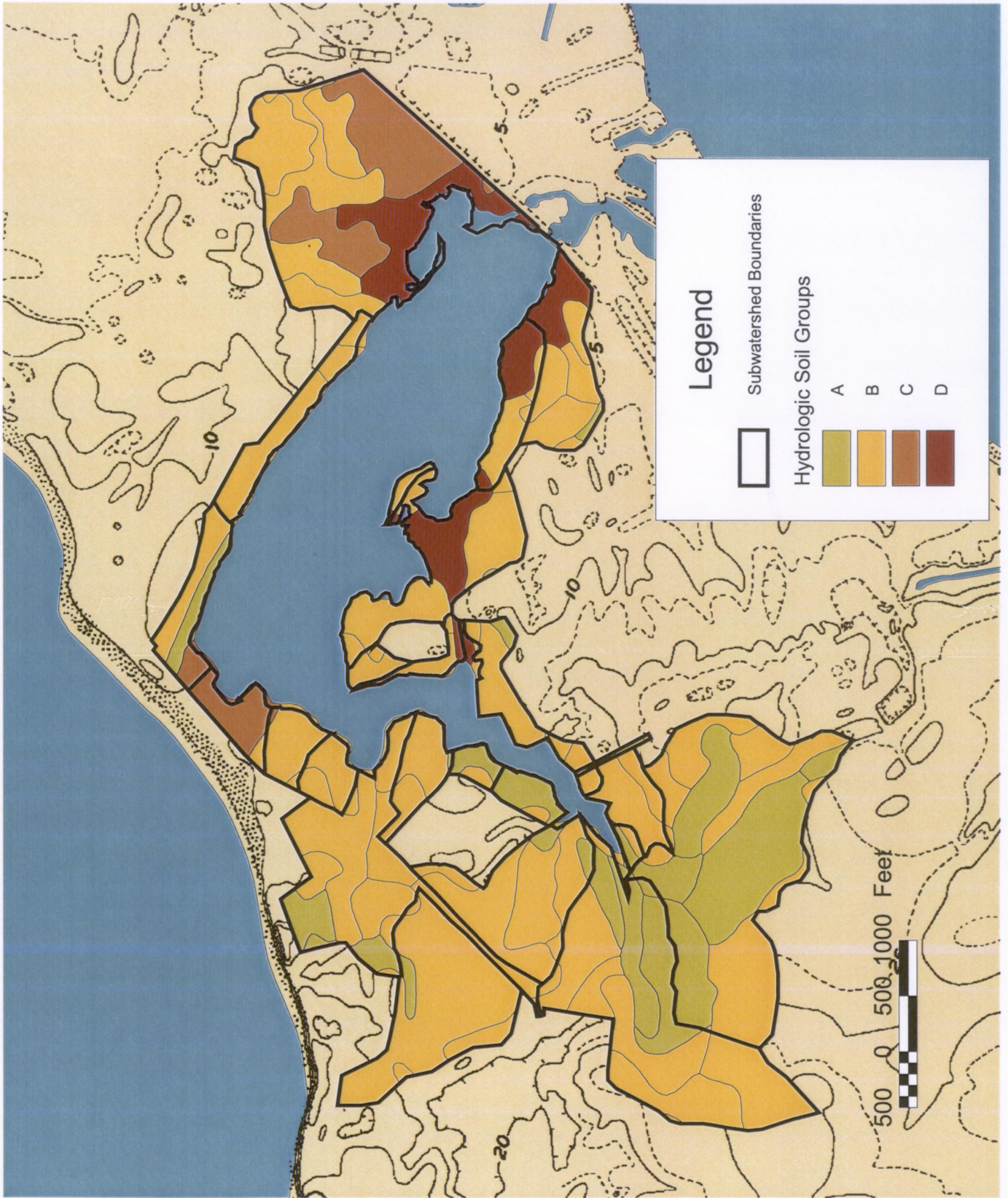
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Land Use within the Hashamomuck Pond Watershed



Figure 8

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Hydrologic Soil Groups
 within the Hashamomuck
 Pond Watershed



Figure 9

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predominately muck and tidal marsh. These small areas will provide significantly higher levels of runoff per unit of area than the wider coverages of type “A” and type “B” soils.

4.3 Generating Curve Numbers for the Conventional TR-55 Equation

Once the land use categories were renamed appropriately for TR-55 and the soils were properly grouped, the inventory of land use and surficial soils could be completed for each subwatershed. By combining the digital data layers for both soils and land use, the GIS could be queried to calculate the area of each discreet land use/soil area by subwatershed. These areas were then assigned a curve number by an agent of the NRCS. Table 10 shows an example matrix with the associated curve numbers for one of the larger subwatersheds (subwatershed 9). The land use categories that have been modified to suit the data needs of TR-55 are along the vertical axis. The general hydrologic soils categories “A” through “D” are located along the horizontal axis.

Table 10. Example Land Use/Soils Matrix Used to Assign a Curve Number to Subwatershed 9 of Hashamomuck Pond*

Land Use		Hydrologic Soils Groups			
Cover Description	Cover Assumptions	A	B	C	D
Streets		2.4 (98)	3.1 (98)	0	0
Medium Density Residential	20% impervious	9.0 (51)	13.2 (68)	0	0
Low Density Residential	12% impervious	2.0 (46)	1.1 (65)	0	0
Agriculture	row crop	4.7 (64)	0.6 (75)	0	0
Brush, Weed, Grass Mix	< 75% coverage	2.1 (30)	0	0	0
Woods	< 75% coverage	17.8 (30)	19.2 (55)	0	0
Weighted Curve Number			(54)		

* Areas are expressed in acres with corresponding curve number in parentheses

4.4 Generating Curve Numbers Using Modifications for Each Rain Event

Based on the research and methodology described in Section 3.3.3, Horsley and Witten applied modifications to the curve numbers for each subwatershed surrounding Hashamomuck Pond. The resulting sets of curve numbers were unique for each of the three modeled rain events and increased as the modeled rain event grew smaller. Table 11 shows the resulting curve numbers for each rain event and how they compare to the conventional curve numbers created using conventional NRCS methods.

Table 11. Summary of Curve Number Modifications for Hashamomuck Pond

Subwatershed	NRCS Curve (for all rain levels)	Modified Curve Numbers (curve numbers for modeled events)		
		0.25-inch	0.6-inch	1.3-inch
1	54	94	86	79
2	60	95	87	80
3	58	94	86	78
4	60	94	85	77
5	98	98	98	98
6	57	94	85	77
7	69	95	87	80
8	59	93	83	74
9	54	86	78	72
10	69	95	91	89
11	62	96	90	86
12	67	95	87	81
13	61	96	90	86
14	71	95	90	85
15	68	94	86	79
16	78	96	90	84
17	64	94	85	78
18	68	94	86	79
19	71	97	92	89
20	50	94	85	78
21	48	94	85	77
22	75	95	88	83
23	54	92	82	73
24	48	92	82	74

4.5 Stormwater Runoff Volume and Load of Bacteria

The stormwater runoff volume contributed by each subwatershed for the three modeled events was calculated using the conventional NRCS curve numbers and those modified for each rain event. Once the volume of runoff was calculated for each watershed, these volumes were multiplied by a composite FC bacteria concentration. This concentration is a weighted average based on the relative area of different land uses within each subwatershed (See Section 3.6). The results of the stormwater runoff calculations, bacteria loading, and nitrogen loading using the 0.6-inch storm event modified curve numbers are summarized in Tables 12 and 13.

Table 12. Summary of GIS-Based Bacteria and Nitrogen Loading Model for Hashamomuck Pond (0.6-inch rain event)

Subwatershed	Modified Curve Number	Runoff Volume (liters)	Bacteria Load (millions of orgs)	Nitrogen Load (pounds)
1	86	1,381	292	0.0049
2	87	6,065	1,279	0.0214
3	86	4,749	1,001	0.0167
4	85	23,149	5,095	0.0952
5	98	29,438	16,127	0.2714
6	85	714	165	0.0028
7	87	35,443	9,857	0.1712
8	83	4,692	1,169	0.0207
9	78	3,378	771	0.0146
10	91	801,534	109,822	5.9061
11	90	143,117	19,372	0.8958
12	87	125,872	36,104	0.6529
13	90	137,771	17,478	0.8618
14	90	41,865	6,016	0.1827
15	86	29,800	7,866	0.1390
16	90	33,221	7,449	0.1350
17	85	27,308	7,889	0.1284
18	86	45,921	12,481	0.2152
19	92	639,323	88,328	3.9782
20	85	0	0	0.0000
21	85	0	0	0.0000
22	88	69,660	23,402	0.4021
23	82	7,175	1,658	0.0317
24	82	92	24	0.0003
Total		2,211,667	373,645	14.15

Table 13. Comparing the Embayment Concentrations Predicted by the Model with Measured Concentrations in Hashamomuck Pond

Range of Wet Weather Measurements	Geometric Mean of Wet Weather Measurements	Modeled Concentration using Minimum Coefficients	Modeled Concentration using Average Coefficients	Modeled Concentration from Maximum Coefficients
(orgs/100 mL)	(orgs/100 mL)	(orgs/100 mL)	(orgs/100 mL)	(orgs/100 mL)
2.9 – 2,501	34	2.8	26.9	51.0

5.0 COMPARING THE RESULTS TO FIELD OBSERVATIONS AND SAMPLING DATA

Calibrating stormwater pollutant load modeling is most effective when site-specific data exist for stormwater sampling for varied land use. Well-designed sampling programs for stormwater runoff will produce a large body of data from which an Event Mean Concentration (EMC) can be calculated. The EMC would then be used as the loading coefficient in a mass-balance loading equation. However, these data do not exist for any of the four watersheds modeled in the regional study. As a result, Horsley & Witten used a combination of qualitative field observation, measured concentrations within the embayments, and stormwater runoff sampling data from other areas on Long Island to assess the accuracy of the model.

5.1 Using Qualitative Observation to Determine Small-Storm Curve Number Viability

Horsley & Witten performed a site visit to Hashamomuck Pond on July 12, 2001. During that visit, “windshield” surveys of the watershed were performed by car and by boat to compare the assumptions in the model with actual field observations. The residential areas that surround much of the embayment are characterized by manicured lawns and many sloped areas drain directly to the embayment. Based on these observations, it was clear that these areas would be creating significant levels of stormwater runoff even during smaller, more common rain events. When the conventional NRCS curve numbers were applied to several of these areas, however, many showed little to no runoff even for the 1.3-inch event. These observations support research that claims curve numbers should be adjusted for small storm events (Pitt, 1987). Based on these observations, Horsley & Witten determined that the modified curve number approach provided a better representation of stormwater hydrology throughout the watershed. Therefore, all results and calibration exercises summarized in the regional study used the modified curve number approach.

5.2 Examining the Relationship Between Sampled Data, Station Location and Time of Rainfall

To begin calibrating the bacteria loading calculations against existing data, Horsley & Witten performed sensitivity analysis with the sampling data provided by the NYSDEC for fourteen stations in Hashamomuck Pond. These analyses were designed to discern those environmental factors most influential in establishing the measured concentrations of bacteria within the embayment. Once these factors were isolated, Horsley & Witten used this analysis to calculate an average embayment concentration in the GIS-based model.

NYSDEC defines adverse pollutant conditions as those in which rainfall has occurred within the four days prior to sampling. Data for adverse pollutant condition sampling is organized into four 24-hour time periods. These time blocks record the daily precipitation level for the day the sample was taken and the three preceding days.

Horsley & Witten isolated those sampling dates where only one of these time blocks showed a rainstorm of one-tenth (0.1) inch or higher. Separating the data in this fashion ensured that analysis was focused on single rain events during a single time block with little or no cumulative impacts from prior storms. These data were then averaged at each sampling station to produce four separate average bacteria concentrations per station. The relative distance along a transect running from the tip of Long Creek to the mouth of the embayment was also determined using ArcView GIS. Horsley & Witten plotted the average measured concentrations along this transect to in order to display any patterns in the spatial distribution of bacteria within the embayment.

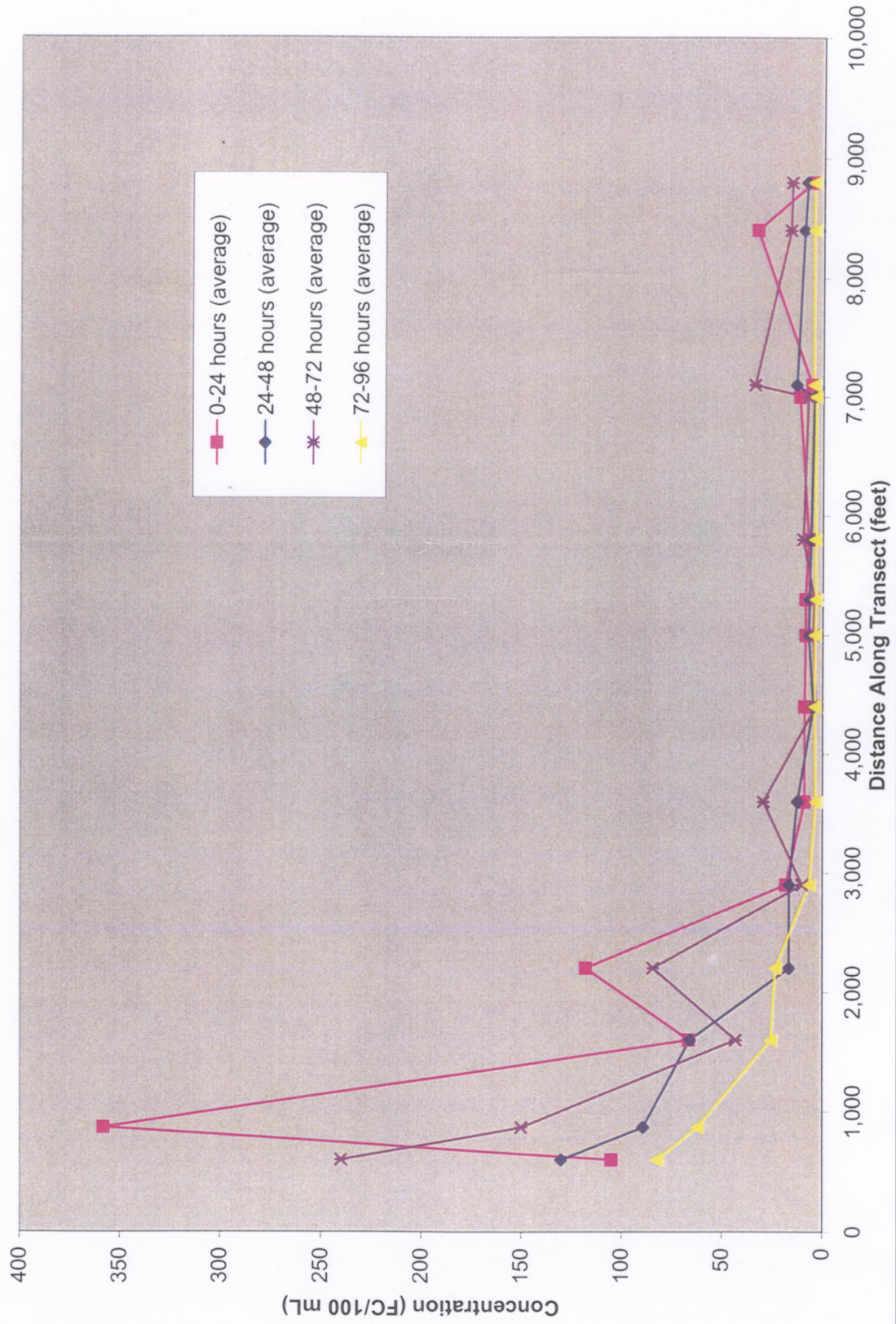
Table 14. NYSDEC Sampling Station Data Related to Distance Along Transect and Most Recent Rain Event

NYSDEC Station	Distance Along Transect (feet)	Mean Sampled Bacteria Concentration for Rain Events Occurring Within Specified Prior Timeframe (organisms/100mL)			
		0-24 hours	24-48 hours	48-72 hours	72-96 hours
1	600	105	130	240	82
1.1	870	75	89	150	62
1.2	1,600	66	66	43	25
2	2,200	118	16	84	23
2.1	2,900	18	17	10	6
3	3,600	9	12	29	3
4	4,400	9	4	3	4
5	5,000	8	7	4	3
9	5,300	8	6	4	3
6	5,800	7	6	10	4
7	7,000	11	4	7	3
7.1	7,100	5	13	34	5
8.1	8,400	33	9	16	4
8	8,800	5	8	16	5

The averaged values in Table 14 are taken from data sets that are too variable and too small to warrant complex statistical analysis. However, it is definitely reasonable to associate a decrease in bacteria concentration as samples move toward the larger volumes of water within the embayment. This confirms a trend of decreasing bacteria concentrations with increasing water volumes. The trends in sampling data are displayed graphically in Figure 10 where concentrations decrease along the X-axis, which represents the distance from the narrow end of the embayment to the outlet.

A closer look at Figure 10 reveals that some concentrations were higher when rain occurred several days before the sampling than when rain occurred the actual day of sampling. These results are counter-intuitive because those samples taken the day of a rain event would be expected to show the highest concentrations of bacteria. The farther away from the rain event in time that the sample is taken, the lower the concentration

Figure 10. NYSDEC FC Bacteria Sampling Data Plotted Along a
Transect in Hashamomuck Pond



would be expected to be. These data demonstrate that there are certain environmental factors that will affect bacteria survival on a day-to-day or season-to-season basis. Factors such as natural proliferation and die-off could cause significant fluctuations on an isolated basis depending on water chemistry, weather conditions, and tide stage. Because some sampling averages that are “closer” to the rain event are lower than those “farther away”, it is possible that proliferation is taking place at least in isolated instances. It is also reasonable to suggest that die-off may be accelerated at times causing these more recently established populations to expire more rapidly on occasion. Antecedent conditions may have caused unusually low or high bacteria loading for a single rain event. Regardless of the causes of these isolated anomalies, loadings that occurred three and four days prior to sampling still result in concentrations that exceed NSSP standards in those areas of the embayment with lower volumes. Populations of bacteria are therefore remaining viable over a four-day period within Hashamomuck Pond. As a result, it is assumed that the resulting concentrations within the embayment are driven far less by die-off than by dilution.

5.3 Comparing Mass Loads of Bacteria to Measured Concentrations Along a Transect

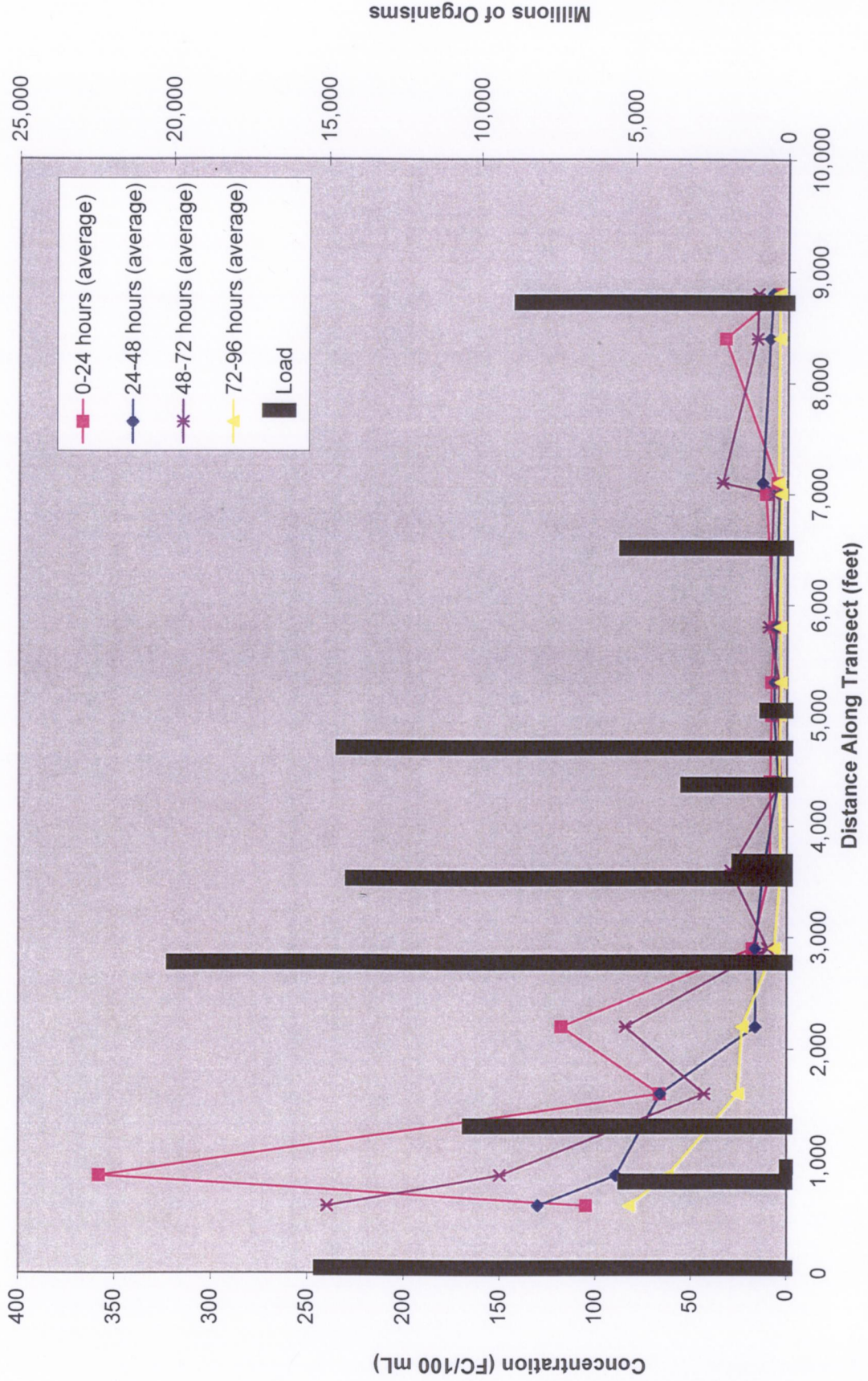
Horsley & Witten placed the loading results from the modified curve number calculations on the same graph with the water quality station data (Figure 11). The purpose of this exercise was to examine any relationship between the level of loaded bacteria and the previously observed downward trend in bacteria concentrations along the embayment. The graphs reveal that loading figures show far less of a trend moving along the transect than measured concentrations. Further along the transect, where measured concentrations are near their lowest point, modeled loads can be at their highest levels. Again, this suggests that dilution is a driving environmental factor for resulting concentrations as those areas with the larger volumes demonstrate the capacity to assimilate larger loads of bacteria.

5.4 Using Dilution to Evaluate the Range of FC Bacteria Loading Coefficients

Examining the NYSDEC sampling data suggested that dilution is the driving factor for determining resulting bacteria concentrations shortly after a rain event. Following this assumption, Horsley & Witten diluted the loads from the modified curve number analyses into the embayments in order to assess the viability of the loading calculations and to potentially calibrate for the most accurate set of loading coefficients.

The basic approach to this calibration exercise was to divide the total load of bacteria to the embayment into the total volume of water affecting the embayment over a four-day period. These concentrations were then compared to measured data. The NYSDEC data used for this analysis was the same data set used to produce Figure 10. The data in this figure represent those sampling dates where only one storm of over 0.1 inch occurred in the four days prior to sampling. The average rain event was 0.6 inch. For this exercise, the water quality sampling data within each of the 24-hour time periods was averaged to create a single point. This point represents an average concentration of bacteria within

Figure 11. Modeled Loads of Bacteria Plotted With Concentrations Along a Transect



the embayment when it rained during that 24-hour period. As the data move from the most recent time period (0-24 hours prior) to the most distant (72-96) hours prior, there is a progressive decline in average bacteria concentrations.

To calculate a modeled average concentration, Horsley & Witten used the modeled loading for the mean storm event (0.6 inch). Distribution of loading throughout the watershed from this modeled scenario is depicted in Figure 12. Horsley & Witten then divided the total bacteria load occurring over the four-day period by the total influx of water over the same span of days.

The total load was calculated by adding all of the stormwater loading from the twenty-four subwatersheds (from a 0.6-inch event) to the daily load from an assumed population of waterfowl. The volume of water used for dilution accounts for all sources of water including rainfall, low-tide volume, stormwater runoff, groundwater recharge, and tidal inflow over the four day period. These resulting average concentrations were plotted against the measured averages to display the potential accuracy of the minimum,

<p>Calculating Concentrations in the Embayment:</p> <p>Total Load = Stormwater Load + Waterfowl Load</p> <p>Total Volume = Embayment Low Tide Volume + Stormwater Runoff Volume + Rainfall Volume into Embayment + Daily Groundwater Recharge + Daily Tidal Influx</p> <p>Concentration = Total Load / Total Volume (Days 1-4)</p>

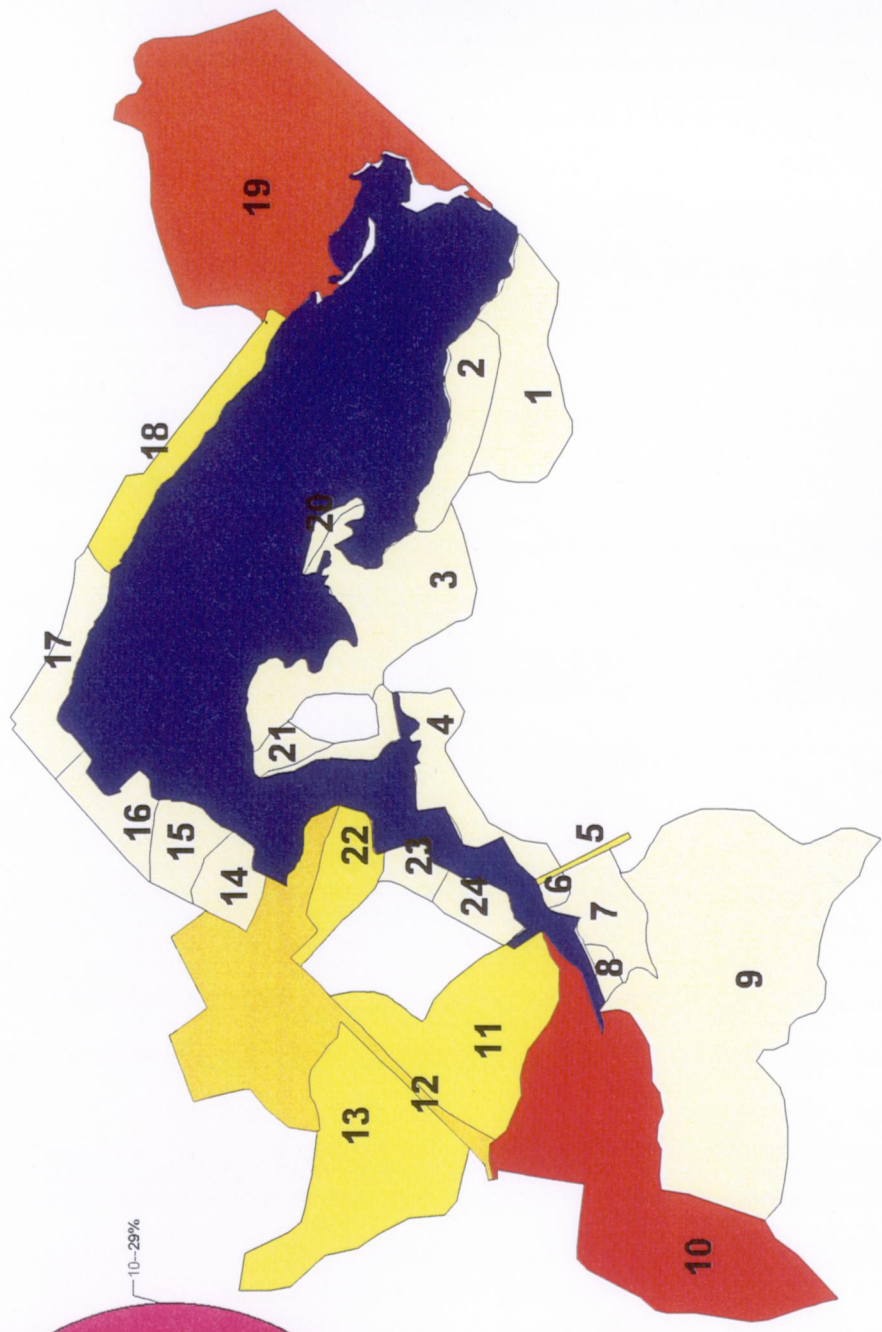
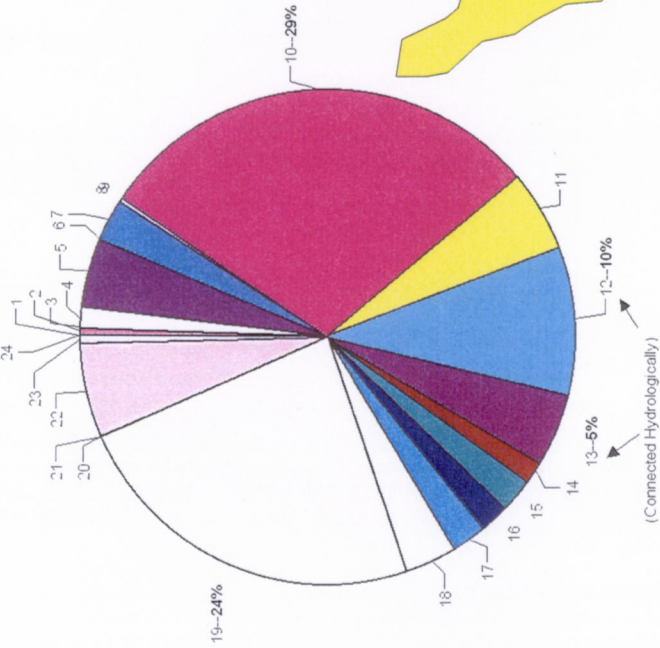
maximum, and mean coefficients (Figure 13). The comparison suggests that the loading figures are reasonable since each of the model calculations falls within an order of magnitude of the average measured concentrations. More specifically, the mean set of coefficients provides the best results for the FC bacteria modeling in conjunction with the

modified curve number runoff calculations for Hashamomuck Pond.

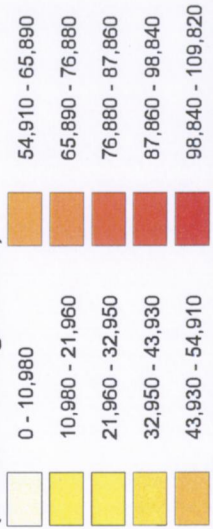
5.4.1 Reviewing Runoff Sampling Data from Long Island

The Cornell Cooperative Extension Marine Program submitted their final report entitled *Centerport Harbor Fecal Coliform Study* to the Town of Huntington in August 1995. Part of the analysis in this report entailed extensive runoff sampling on roadways, in catch basins, and in other stormwater detention basins. Horsley & Witten isolated those data specific to roadway sampling to calibrate the roadway coefficients applied in the model. The original set of data consisted of 237 data points and was refined to 226 data points when outliers were eliminated. From this dataset, a minimum value of 3 FC/100 mL and a maximum value of 110,000 FC/100 mL were applied for roadway and parking lot runoff. The resulting mean value for the model (55,000 FC/100 mL) compares favorably with the actual mean value of the Centerport Harbor dataset, which is 40,463 FC/100 mL.

Loading Percentage by Subwatershed



Graphic Distribution of Bacteria Loading (millions of organisms)



Legend



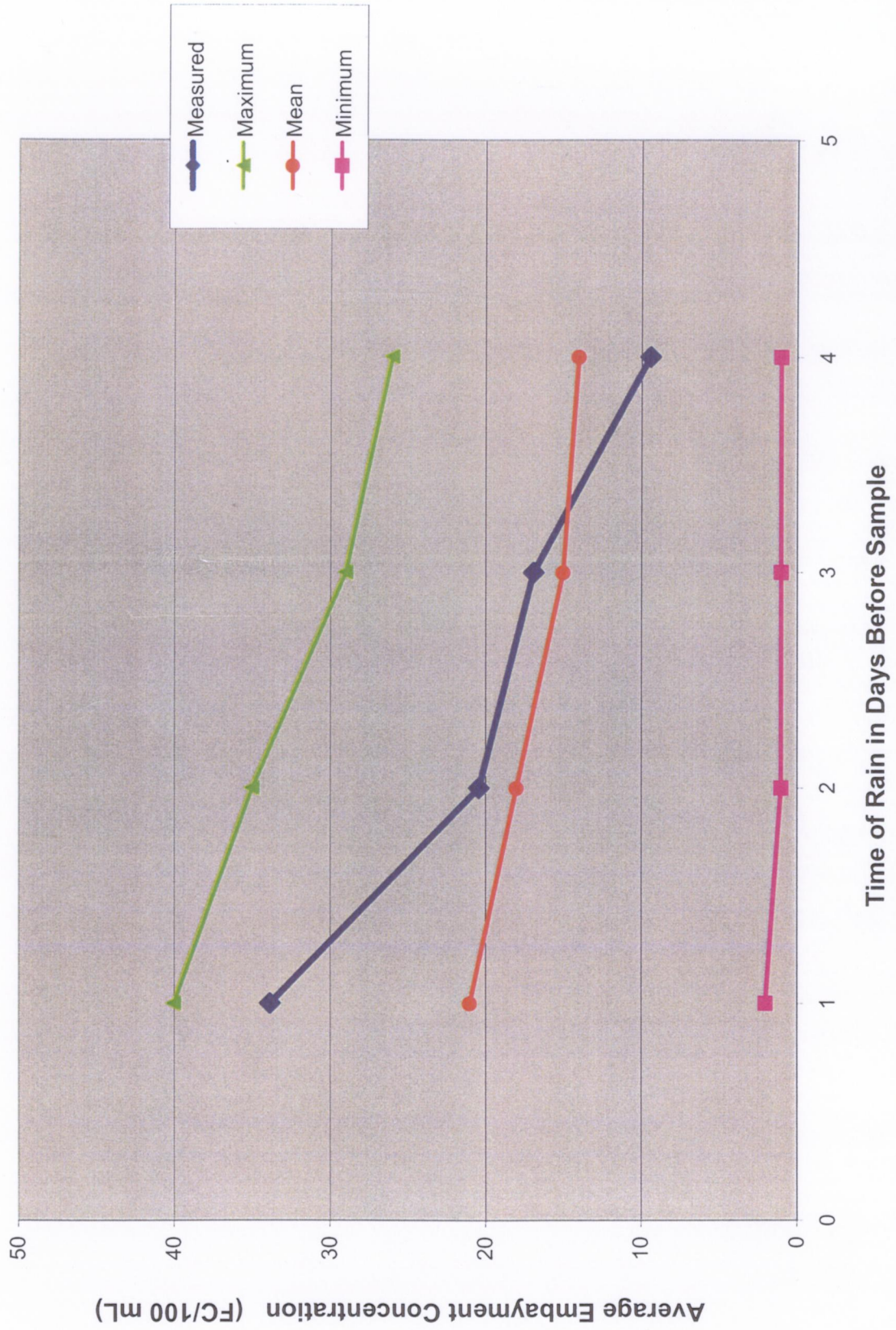
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Relative Loading of FC Bacteria from Hashamomuck Pond Subwatersheds

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Figure 12

Figure 13. Measured vs. Modeled Averages Over Four-Day Period



6.0 APPLYING THE MODEL TO THE OTHER EMBAYMENTS CHOSEN FOR THE REGIONAL STUDY

The same land use-based methodology outlined in Section 3, which was applied to Hashamomuck Pond, was applied to three other embayments in the Peconic Bay region: West Neck Bay, Meetinghouse Creek, and Reeves Bay. Based on the results of the Hashamomuck Pond calibration exercises, the remaining embayments were analyzed using the modified curve number methodology in conjunction with the mean FC bacteria coefficients. The three rain events selected for the pilot study (0.25-inch, 0.6-inch, 1.3-inch) were used to apply the model to each watershed.

Precipitation data that was recorded by NYSDEC in conjunction with their water quality sampling show that a 0.6-inch rain event represents the mean of the data set. Horsley & Witten therefore used the 0.6-inch event in the model to compare the predicted resulting concentrations with NYSDEC sampling data. This portion of the model requires the user to input the mean low tide depth, the tidal range, and the estimated number of waterfowl. The depth of the embayments and the tidal range were taken from NYSDEC sanitary surveys, while the population of waterfowl was estimated by applying a density of waterfowl per acre of surface water. Based on waterfowl counts from the region provided by the NYSDEC, a density of 0.3 waterfowl per acre of surface water was applied to each embayment. This user input can be easily refined pending the availability of site-specific data.

The quantity of water quality data for the remaining three embayments was variable and, therefore, Horsley & Witten was unable to discretize these data using the same methodology applied to the Hashamomuck Pond sampling data. Isolating the data for significant wet weather events for the day prior to sampling created data sets too small for good quality comparison. As a result, Horsley & Witten compared the results of the modeled embayment concentration with the both the full range of wet weather measurements, and the geometric mean of wet weather measurements.

6.1 West Neck Bay

West Neck Bay is located on the southwestern edge of Shelter Island. This 100-acre body of water lies at the northernmost point of West Neck Creek, a 2.5-mile long slender inlet opening into Shelter Island Sound (Figure 14). The tidal range within West Neck Bay is three feet. Land use surrounding this embayment is a mixture of residential use and open space. Approximately 30 homes line the shore of West Neck Bay, most of which are within 150 feet of the water. The actual contributing drainage area is small and covers only 96 acres. NYSDEC has designated this embayment as “growing area 20” and samples one station, Station 4, regularly according to NSSP standards. Although historic data show levels of bacteria periodically exceeding standards for shellfishing, these exceedances are rare and West Neck Bay does not experience seasonal, conditional, or year-round closures.



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Aerial Photography
West Neck Bay



Figure 14

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6.1.1 Delineation of West Neck Bay Subwatersheds

The delineation for West Neck Bay was performed by an NRCS agent in the field. The resulting watershed delineation was delivered on Assessor's maps to Horsley & Witten and digitized in ArcView GIS. The overall watershed was divided into five subwatershed areas based upon a review of topography, digital land use data, and aerial photographs. These subwatersheds were numbered for the purposes of organizing the results of the runoff and loading analyses (Figure 15). In general, the contributing area is small and does not extend far from the shoreline with the exception of one area adjacent to the northern end of the embayment (Subwatershed 1).

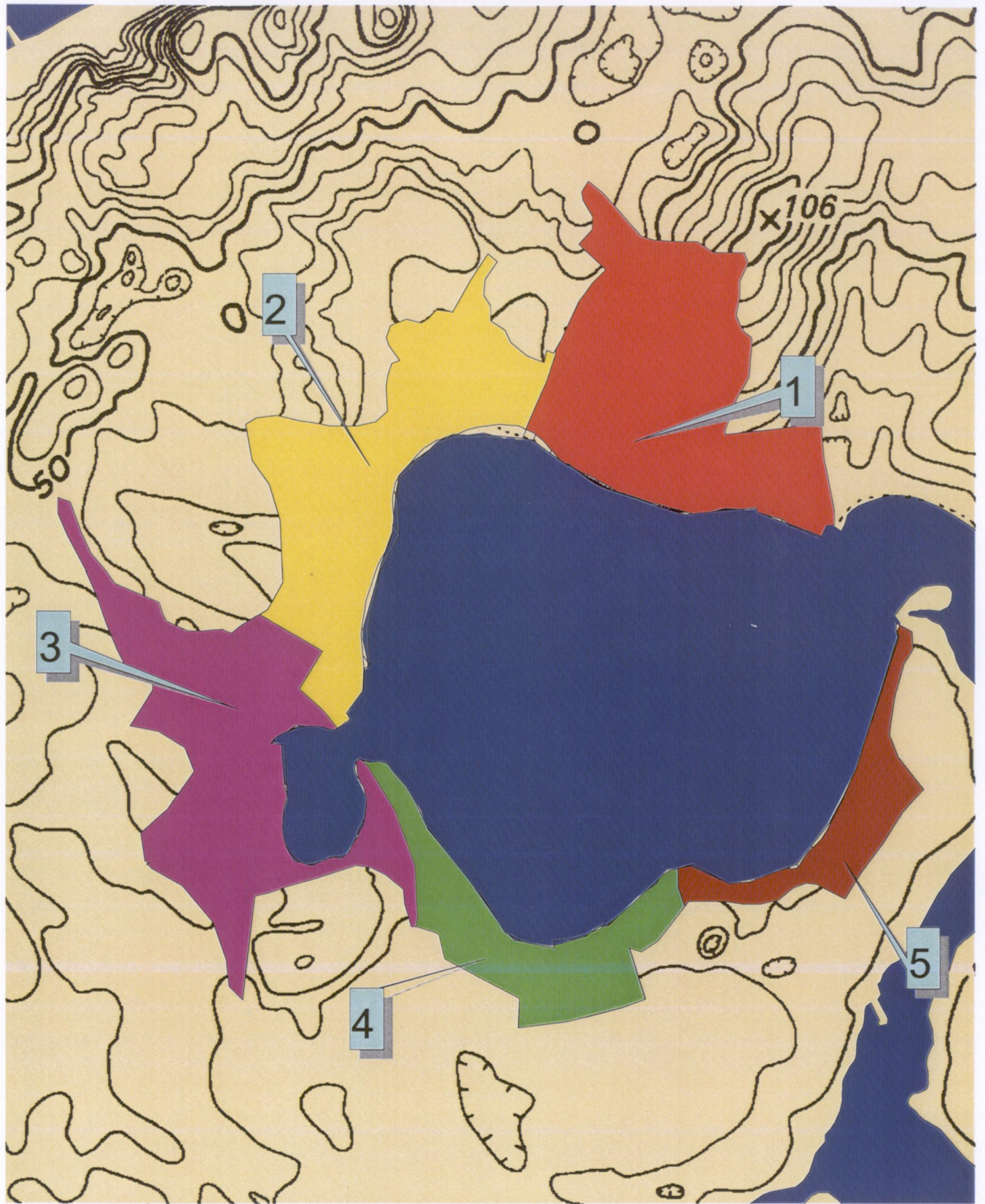
6.1.2 Land Use and Soils Inventory Within West Neck Bay Watershed

Land use within the West Neck Bay watershed is primarily a mix of residential and open space (Figure 16). Residential areas constitute the highest coverage at 40% of the overall 98 acres. A small network of roads covering eleven acres connects the residential areas and potentially discharges directly to the embayment in three locations. Several parcels were labeled as "Vacant" in the Office of Real Property taxation database. The land use or coverage associated with these parcels was clarified by NRCS or through the use of aerial photos. In almost every case, these parcels were undeveloped and were covered with wooded area, meadow, or brush. Table 15 summarizes the overall land use profile for the West Neck Bay watershed.

Table 15. Land Use Summary for West Neck Bay Watershed

Land Use	Area in Acres
Low Density Residential	26.4
Medium Density Residential	25.6
High Density Residential	13.8
Recreation/Open Space	22.5
Roads	10.6

Each of the four hydrologic soils groups ("A" through "D") is present within the West Neck Bay watershed (Figure 17). Hydrologic soil type "A" covers most of the drainage area and stretches from one end of the watershed to the other. This hydrologic soil category is highly permeable and, under natural conditions, is conducive to recharge. Small pockets of type "B" soils line the outer edge of the watershed and constitute other areas that will allow for significant amounts of recharge. Type "C" soils are found only in the northeast corner of the watershed in small amounts. A thin area of type "D" soils stretches along the western bank of the embayment where tidal marsh areas are present. Type "C" and "D" soils constitute areas where a larger percentage of rainfall will become runoff under natural conditions.



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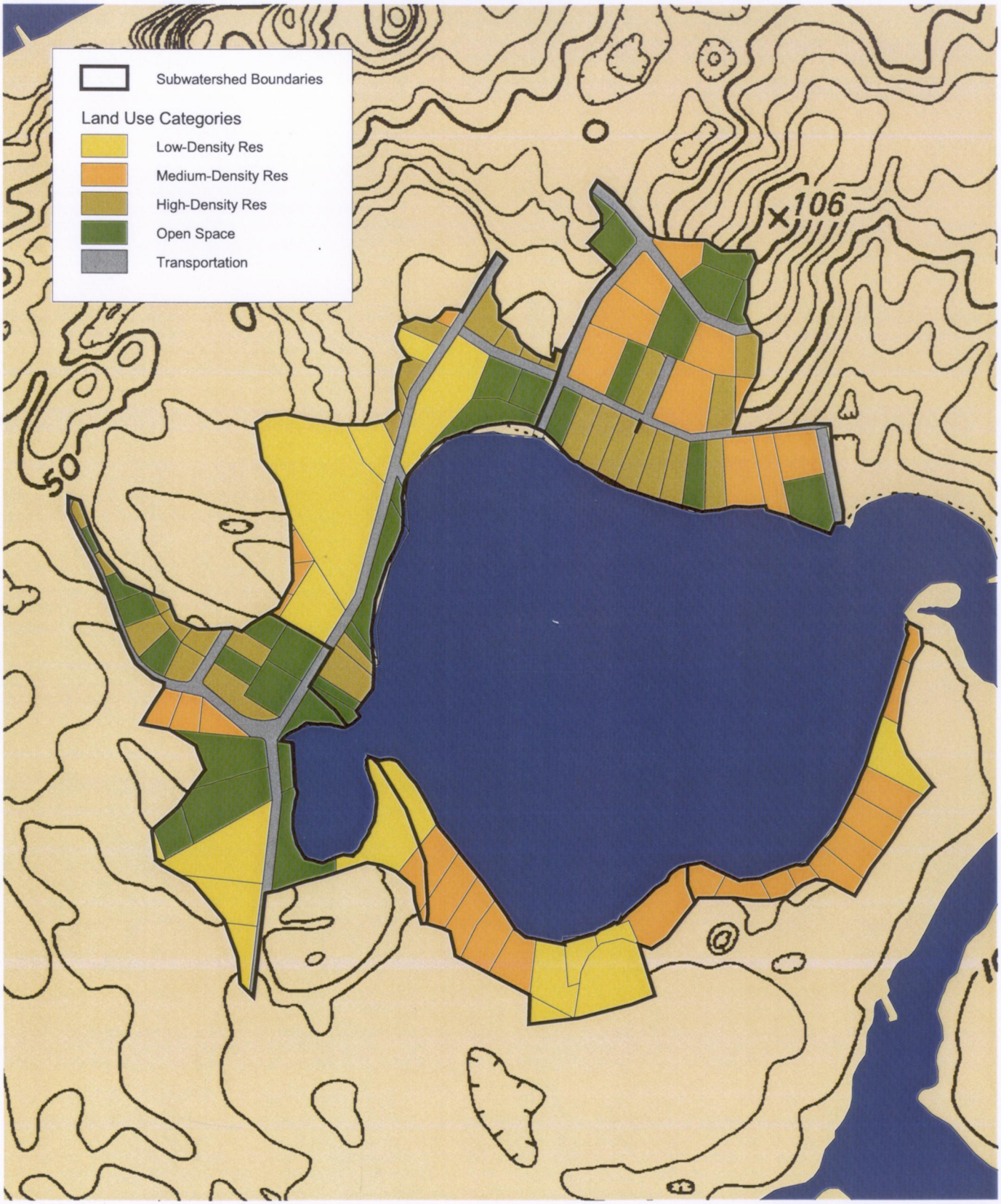








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**Subwatershed Delineations
 for West Neck Bay**

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Figure 15



 Subwatershed Boundaries
Land Use Categories
 Low-Density Res
 Medium-Density Res
 High-Density Res
 Open Space
 Transportation

N



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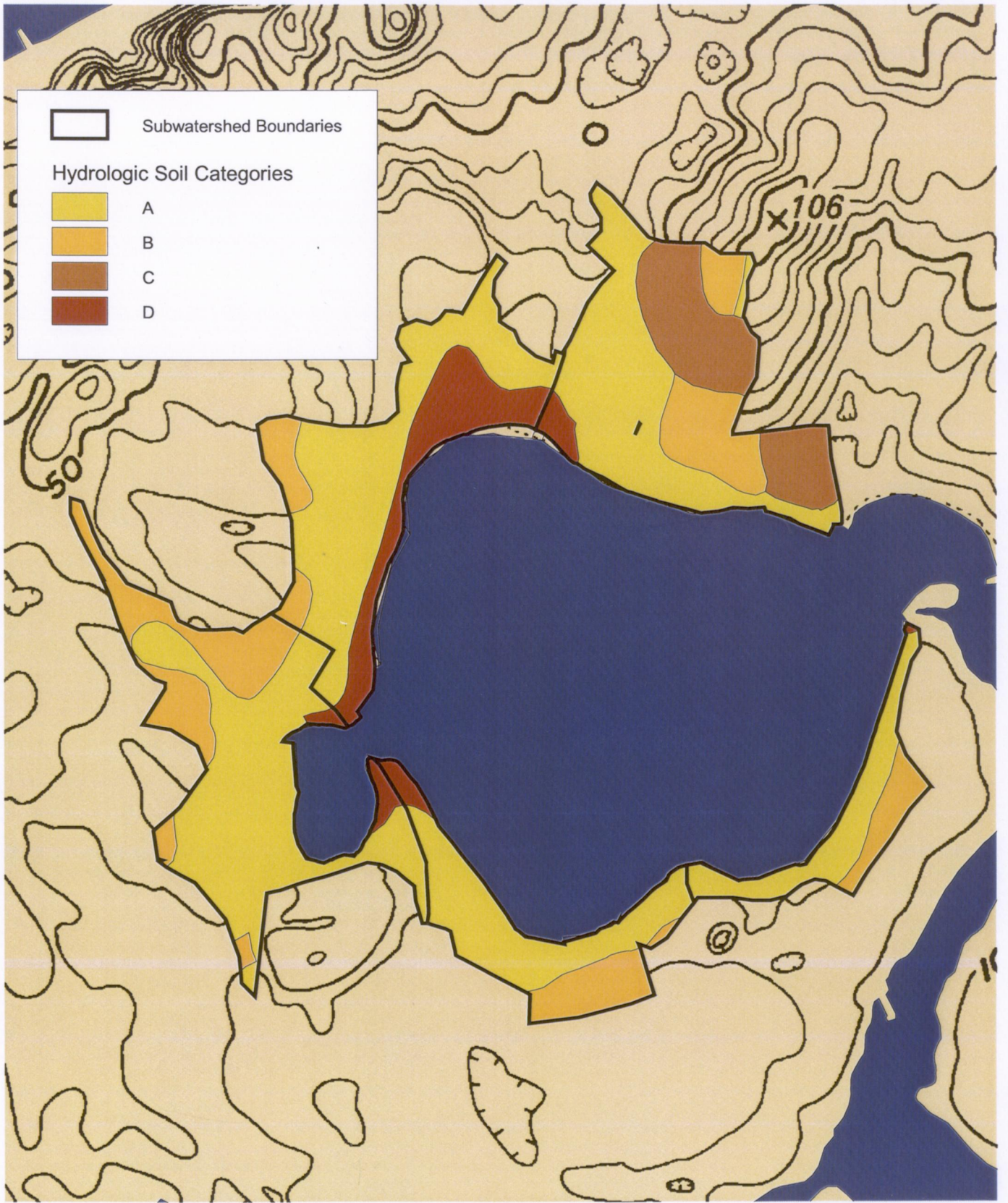



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Land Use within West Neck Bay Watershed

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Figure 16



Subwatershed Boundaries

Hydrologic Soil Categories

- A
- B
- C
- D



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Hydrologic Soil Groups within
 West Neck Bay Watershed

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Figure 17

6.1.3 Results of Pollutant Load Modeling for West Neck Bay

Loading calculations were performed for the West Neck Bay watershed using the three target storm events. The resulting average concentration in the embayment was calculated assuming a mean low tide depth of 10 feet, a tidal range of three feet, and a waterfowl population of 30. The full results of these modeled events are presented in Appendix A. A summary of the results for the 0.6-inch rain event is provided below in Tables 16 and 17 and in Figure 18.

Table 16. Summary of GIS-Based Bacteria and Nitrogen Loading Model for West Neck Bay

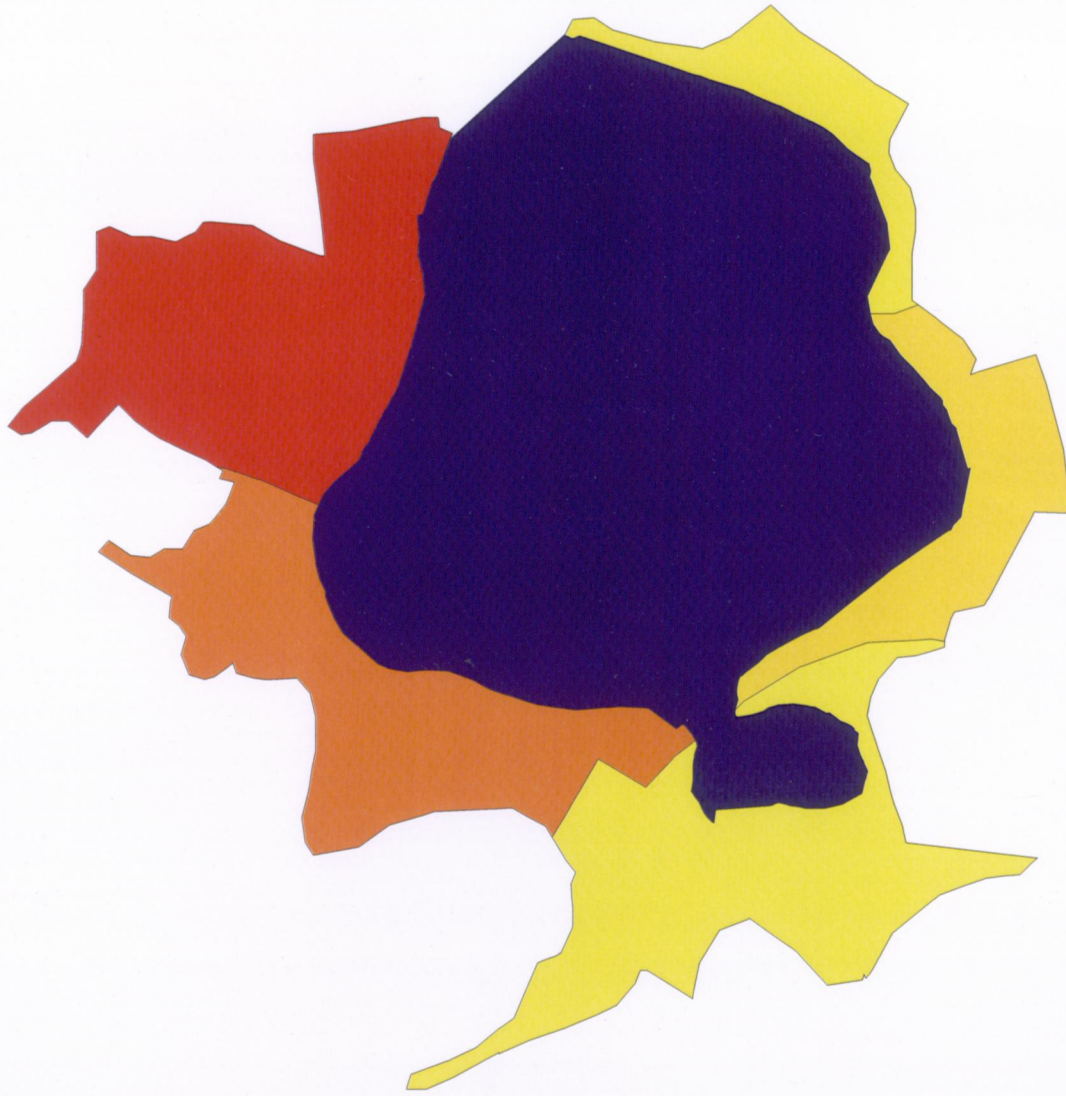
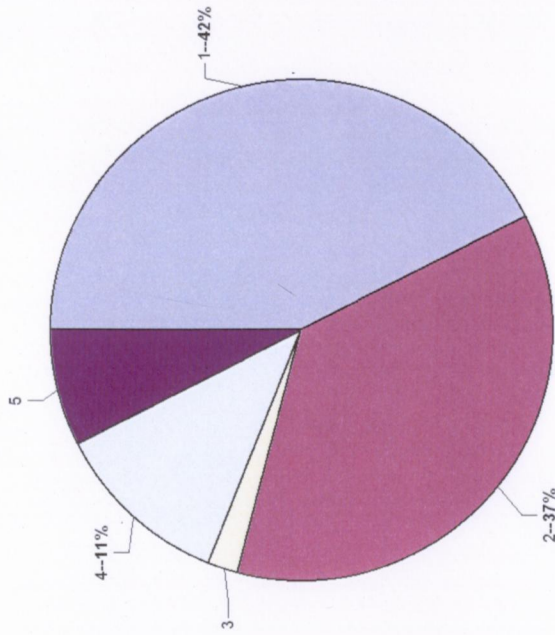
Subwatershed	Modified Curve Number	Runoff Volume (liters)	Bacteria Load (millions of orgs)	Nitrogen Load (pounds)
1	85	89,046	28,380	0.44
2	86	88,556	24,580	0.43
3	79	4,193	1,180	0.02
4	85	33,351	7,680	0.15
5	85	20,830	5,030	0.09

Table 17. Comparing the Average Embayment Concentrations Predicted by the Model with Measured Concentrations in West Neck Bay

Range of Wet Weather Measurements (orgs/100 mL)	Geometric Mean of Wet Weather Measurements (orgs/100 mL)	Modeled Concentration from Minimum Coefficients (orgs/100 mL)	Modeled Concentration from Average Coefficients (orgs/100 mL)	Modeled Concentration from Maximum Coefficients (orgs/100 mL)
2.9 – 240	6.9	1	4.5	8

Although there was some variability in the overall load distribution depending on the storm size (Appendix A), Subwatershed 1 consistently showed the highest loading of both FC bacteria and nitrogen. Wet weather sampling data are not extensive enough to use as a calibration tool, however, the range of measured values as well as the geometric mean suggest that the results of the model are reasonable. These preliminary results indicate that the best FC bacteria loading coefficients may fall between the mean and maximum sets. However, a much larger and more refined set of sampling data would be needed to perform calibrations based on concentrations within the embayment.

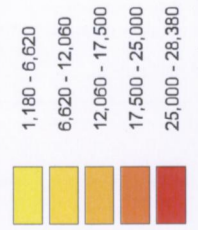
Loading Percentage
by Subwatershed



Legend



**Graphic Distribution of Bacteria Loading
(millions of organisms)**



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**Relative Loading of FC Bacteria
from West Neck Bay Subwatersheds**

k/775-wneck-results-18.ai

Figure 18

6.2 Reeves Bay

Reeves Bay is located in the Town of Southampton adjacent to the outlet of the Peconic River (Figure 19). The surface area of this bay covers approximately 300 acres with an average depth of approximately 5 feet. There is only one small tributary feeding into Reeves Bay that enters in the southwest corner. The drainage area to this embayment covers nearly 370 acres and contains a wide range of mixed use development. Most of the shore is lined with undeveloped lots except for the area farthest east, which is lined primarily with medium and high density residential development. The banks of the brook are heavily developed with a mix of medium and high density residential development. The interface between Reeves Bay and the larger Flanders Bay is wide and allows for a completely open exchange of waters during tidal cycling.

Reeves bay is part of “growing area 29”, which encompasses all of Flanders Bay. The Flanders Bay shellfishery covers over 3,000 acres and has a varying tidal range from 2.5 to 3.6 feet. Reeves bay covers approximately 300 acres with an average depth of 5 feet. Approximately half of the growing area is uncertified and the other half is conditionally certified. The two areas are divided by a straight line drawn between Simmons Point and Gooseneck Creek. The conditional certification encompasses the full extent of Reeves Bay. The conditional program establishes a “trigger” amount of rainfall within a twenty-four hour period over which shellfishing areas will be closed. This rainfall amount, 0.2 inches, is determined by examining a full year of sampling data in relation to daily precipitation data (NYSDEC, Daniel Lewis personal communication).

6.2.1 Delineation of Reeves Bay Subwatersheds

The overall watershed to Reeves Bay was delineated by an NRCS agent in the field. The delineation, including the ten subwatershed areas, was digitized by Horsley & Witten using ArcView 3.2 (Figure 20). Overall, the watershed covers approximately 380 acres. The watershed delineation for Reeves Bay is complex and often deviates from natural topography, illustrating the effects of urbanization on natural drainage patterns. Roadways such as Flanders Road and Bay Avenue establish discreet drainage boundaries or pathways for stormwater runoff. These subwatershed delineations demonstrate the importance of field survey when performing watershed-based analyses in urbanized areas.

6.2.2 Land Use and Soils Inventory Within Reeves Bay Watershed

The Reeves bay watershed contains almost every land use category found within the Office of Real Property Taxation database (Figure 21). The one exception is agricultural land. Nearly all of the drainage area is covered by a combination of open space and residential development. Within the residential developments, densities vary from low to high and cover approximately 41% of the watershed area. Based on this level of residential development alone, it can be assumed that loadings of bacteria from runoff will be high. Those parcels that were classified as “Vacant” by the Office of Real Property Taxation were divided into forested or brush-covered areas based upon field



Flander's Bay

Reeves Bay

Peconic River



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Aerial Photograph
of Reeves Bay

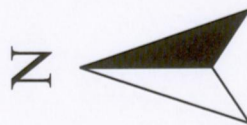


Figure 19

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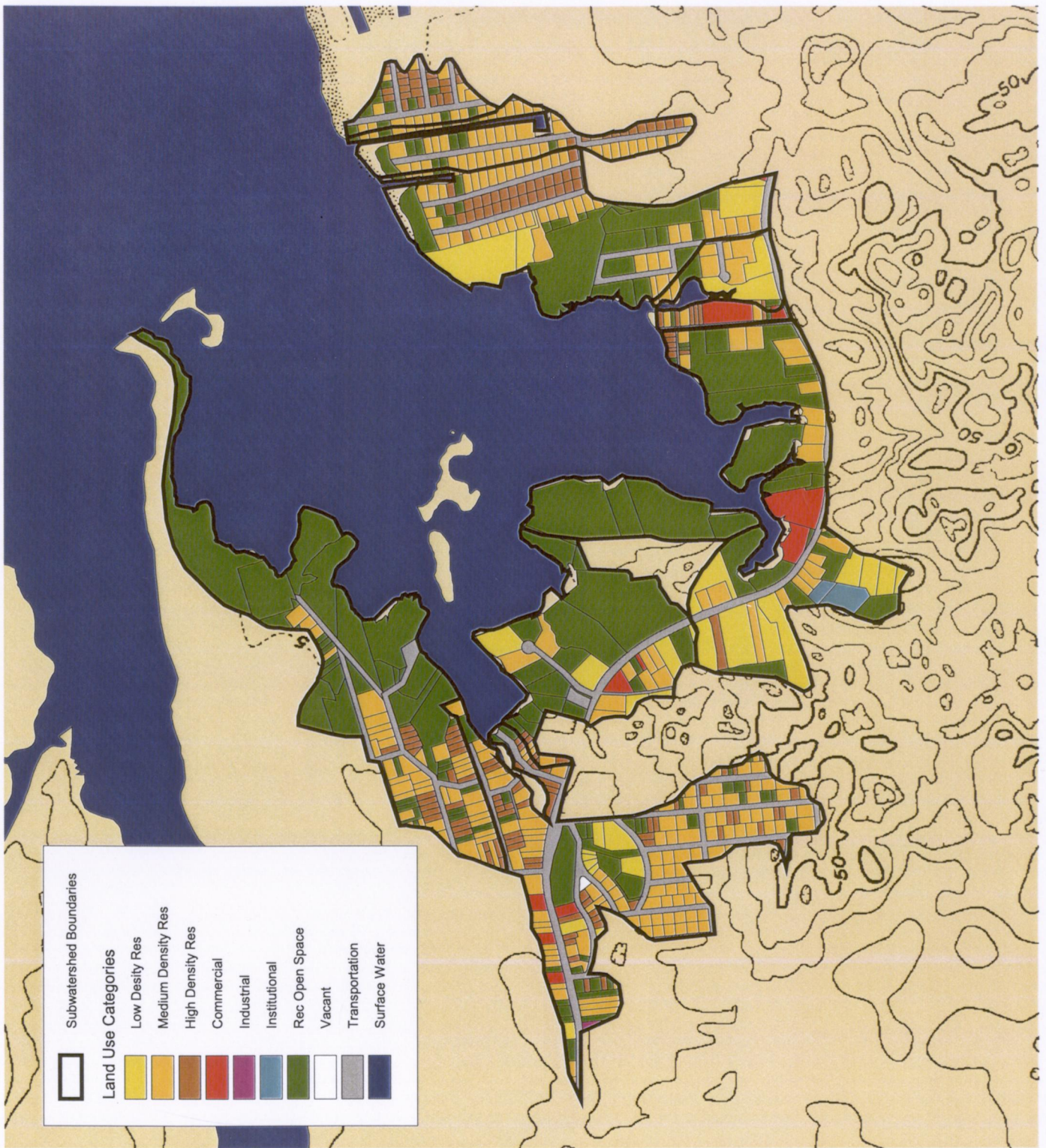
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Subwatershed Delineations for Reeves Bay



Figure 20

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Land Use within the Reeves Bay Watershed



Figure 21

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survey or review of aerial photographs. A summary of the overall land use profile is provided in Table 18.

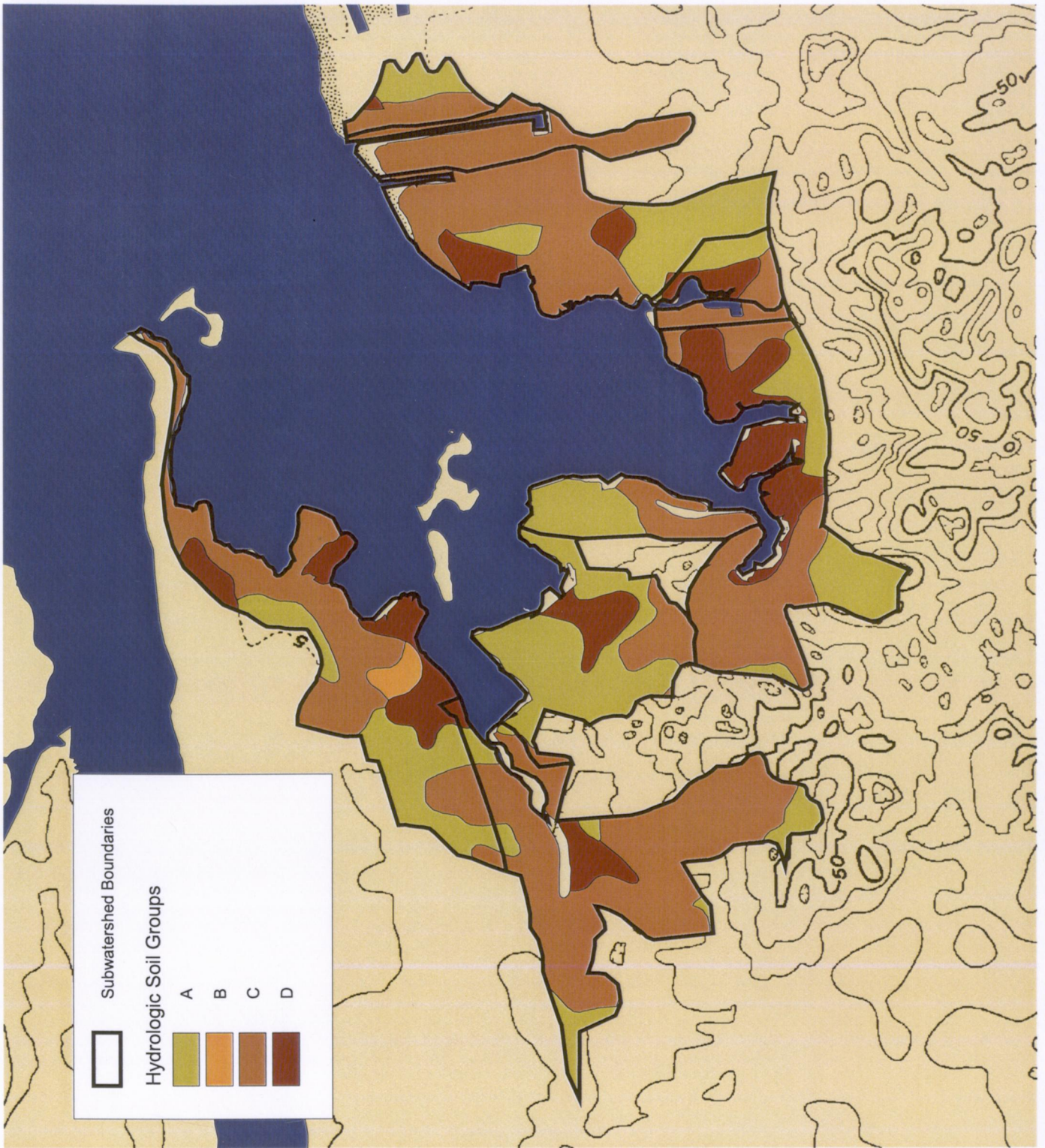
Table 18. Summary of Land Use Coverage in Reeves Bay Watershed

Land Use	Area in Acres
Low Density Residential	38.0
Medium Density Residential	91.6
High Density Residential	25.7
Commercial	10.2
Industrial	0.2
Institutional	2.2
Recreation/Open Space	153.0
Vacant	0.7
Transportation	48.0

Individual soil types were taken from digital regional coverage provided by the USDA/NRCS. Unlike the other watersheds in this study, the majority of hydrologic soil groups found within Reeves Bay watershed are characterized by low permeability (Figure 22). Almost 200 acres of the watershed (approximately 53%) are covered with type “C” soils, with an additional 60 acres of type “D” soils. The remaining areas, approximately 120 acres, are covered with high permeability type “A” and “B” soils. Because of the overall lower permeability of soils, the curve numbers generated within these subwatersheds will be higher than those from other study areas containing the same land use categories. For example a typical medium density residential parcel near Reeves Bay may have a curve number of 79 while a similar lot adjacent to West Neck Bay will have a curve number of 68. As a result, significant amounts of runoff will be generated at lower levels of rainfall within the Reeves Bay watershed.

6.2.3 Results of Pollutant Load Modeling for Reeves Bay

Loading calculations were performed for the Reeves Bay watershed using the three target storm events. The resulting average concentration in the embayment was calculated assuming a mean low tide depth of 5 feet, a tidal range of three feet, and a waterfowl population of 100. The full results of these modeled events are presented in Appendix A. A summary of the results for the 0.6-inch rain event is provided below in Tables 19 and 20 and is displayed geographically in Figure 23.



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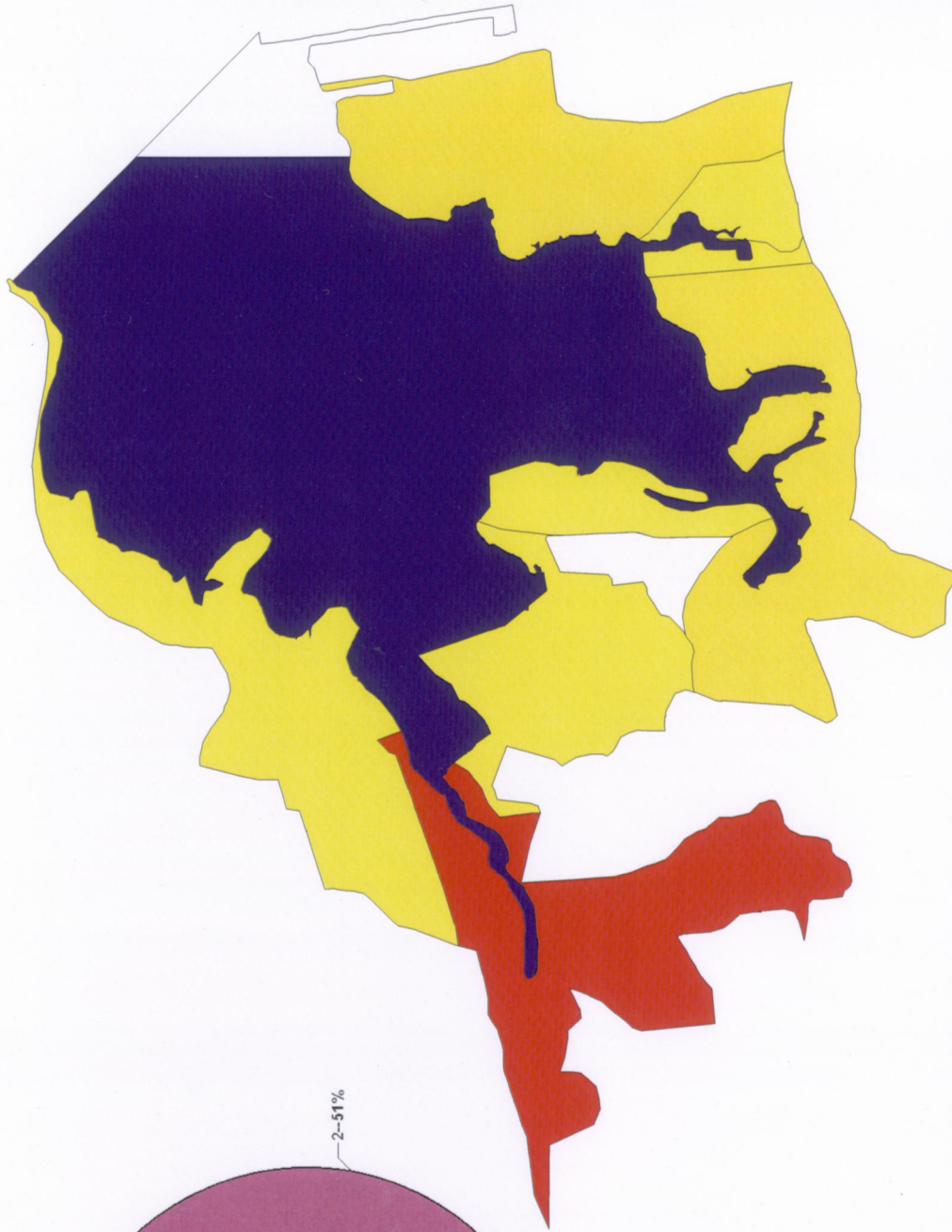
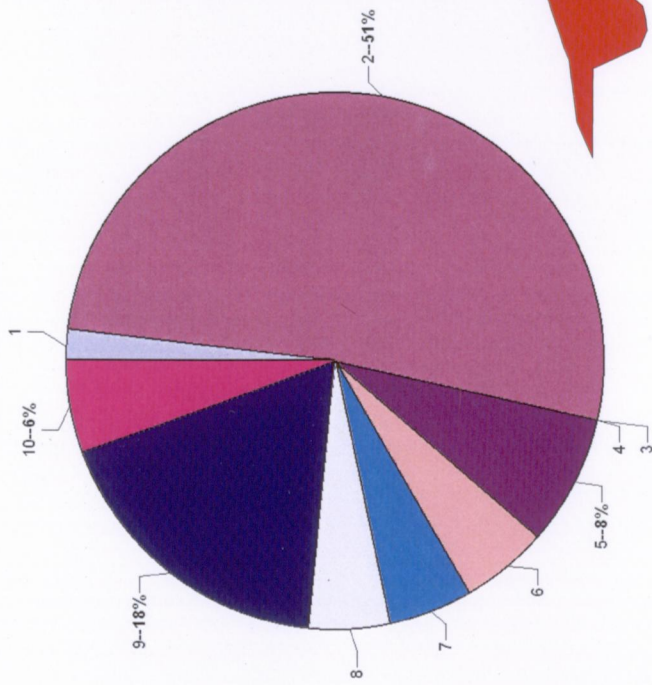
Hydrologic Soil Groups within Reeves Bay Watershed



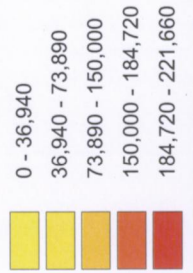
Figure 22

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Loading Percentage by Subwatershed



Graphic Distribution of Bacteria Loading (millions of organisms)



Legend



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Relative Loading of FC Bacteria from Reeves Bay Subwatersheds

k/775-reeves-results-23.ai

Figure 23

Table 19. Summary of GIS-Based Bacteria and Nitrogen Loading Model for Reeves Bay

Subwatershed	Modified Curve Number	Runoff Volume (liters)	Bacteria Load (millions of orgs)	Nitrogen Load (pounds)
1	84	132,752	34,749	0.57
2	90	684,576	221,665	3.73
3	78	2,291	549	0.01
4	71	0	0	0
5	86	238,868	53,812	1.05
6	93	75,792	20,691	0.41
7	88	65,535	18,039	0.33
8	85	174,120	48,153	0.81
9	90	193,222	59,123	0.99
10	88	77,323	27,996	0.43

Table 20. Comparing the Average Embayment Concentrations Predicted by the Model with Measured Concentrations in Reeves Bay

Range of Wet Weather Measurements (orgs/100 mL)	Geometric Mean of Wet Weather Measurements (orgs/100 mL)	Modeled Concentration from Minimum Coefficients (orgs/100 mL)	Modeled Concentration from Average Coefficients (orgs/100 mL)	Modeled Concentration from Maximum Coefficients (orgs/100 mL)
2.9 – 1,100	11.8	4	20	35

Because curve numbers are adjusted according to the size of the modeled storm, there is some variability relative to the ranking of FC bacteria loading from specific watersheds. The relative distribution of loading for different storms can be found in Appendix A. Although there was variability in relative pollutant load distribution, Subwatershed 2 consistently provided the highest levels of both nitrogen and bacteria. After this area of highest pollutant contribution, the remaining overall load is distributed almost evenly across several other areas. Subwatersheds 5, 8, 9 and 10 show significant loads at all three modeled rain events.

Wet weather sampling data for Reeves Bay are not extensive enough to use as a calibration tool, however, the range of measured values as well as the geometric mean suggest that the results of the model are reasonable. These preliminary results indicate that the best FC bacteria loading coefficients may fall between the minimum and average sets. However, a much larger and more refined set of sampling data would be needed to perform calibration based on concentrations within the embayment.

6.3 Meetinghouse Creek

Meetinghouse Creek is located in “growing area 29” on the northern coast of Flanders Bay, adjacent to the mouth of the Peconic River (Figure 24). This small embayment covers just over 30 acres and is approximately 5 feet deep on average. Meetinghouse Creek is part of the larger portion of Flanders Bay that is currently uncertified for shellfishing. The embayment that forms the mouth of Meetinghouse Creek experiences frequent boat traffic during the warmer months and provides marina facilities. At least two stormwater outfalls and two directly discharging roadways contribute stormwater flow to the embayment.

6.3.1 Delineation of Meetinghouse Creek Subwatersheds

Previous study of the Meetinghouse Creek was performed by NRCS and the Cornell Cooperative Extension Marine Program to create a management program for the Corwin Duck Farm. As part of this study, over half of the overall watershed to the embayment was delineated to estimate runoff volume. For this study, an NRCS agent delineated the remainder of the watershed and divided that area into nine subwatersheds. The resulting ten subwatersheds are depicted in Figure 25. Much like other embayments in this study, the overall watershed for Meetinghouse Creek is irregularly shaped, demonstrating the importance of watershed delineation developed in the field.

6.3.2 Land Use and Soils Inventory Within the Meetinghouse Creek Watershed

The Meetinghouse Creek watershed contains a diverse land use profile dominated by low-density residential and agricultural development (Figure 26). Agricultural land use covers approximately 29% of the watershed and is predominantly row-crop production. The combined residential land use (low, medium and high density residential) covers 44% of the overall watershed. The original Suffolk County land use database contained several “Vacant” parcels within this study area. The vast majority of these parcels were field checked by an NRCS agent, and land use code changes were made for the purposes of the modeling exercise. A summary of the overall land use profile is provided in Table 21.

Table 21. Summary of Land Use Coverage in Meetinghouse Creek Watershed

Land Use	Area in Acres
Low Density Residential	124.1
Medium Density Residential	79.0
High Density Residential	3.0
Commercial	10.5
Industrial	4.0
Institutional	1.5
Recreation/Open Space	36.3
Agriculture	136.3
Vacant	2.1
Transportation	34.7



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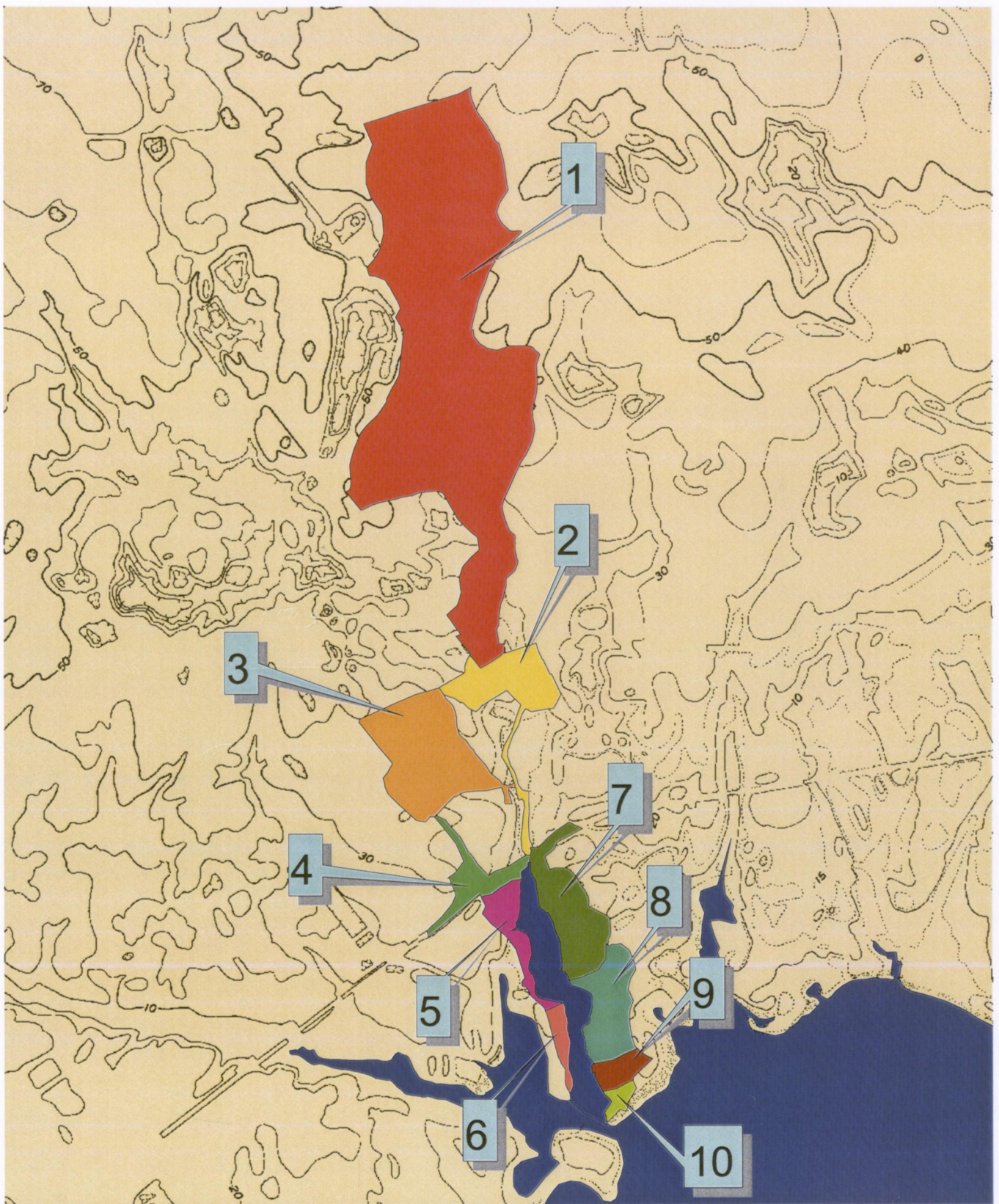
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Aerial Photograph
of Meetinghouse Creek

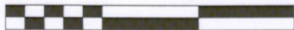


Figure 24

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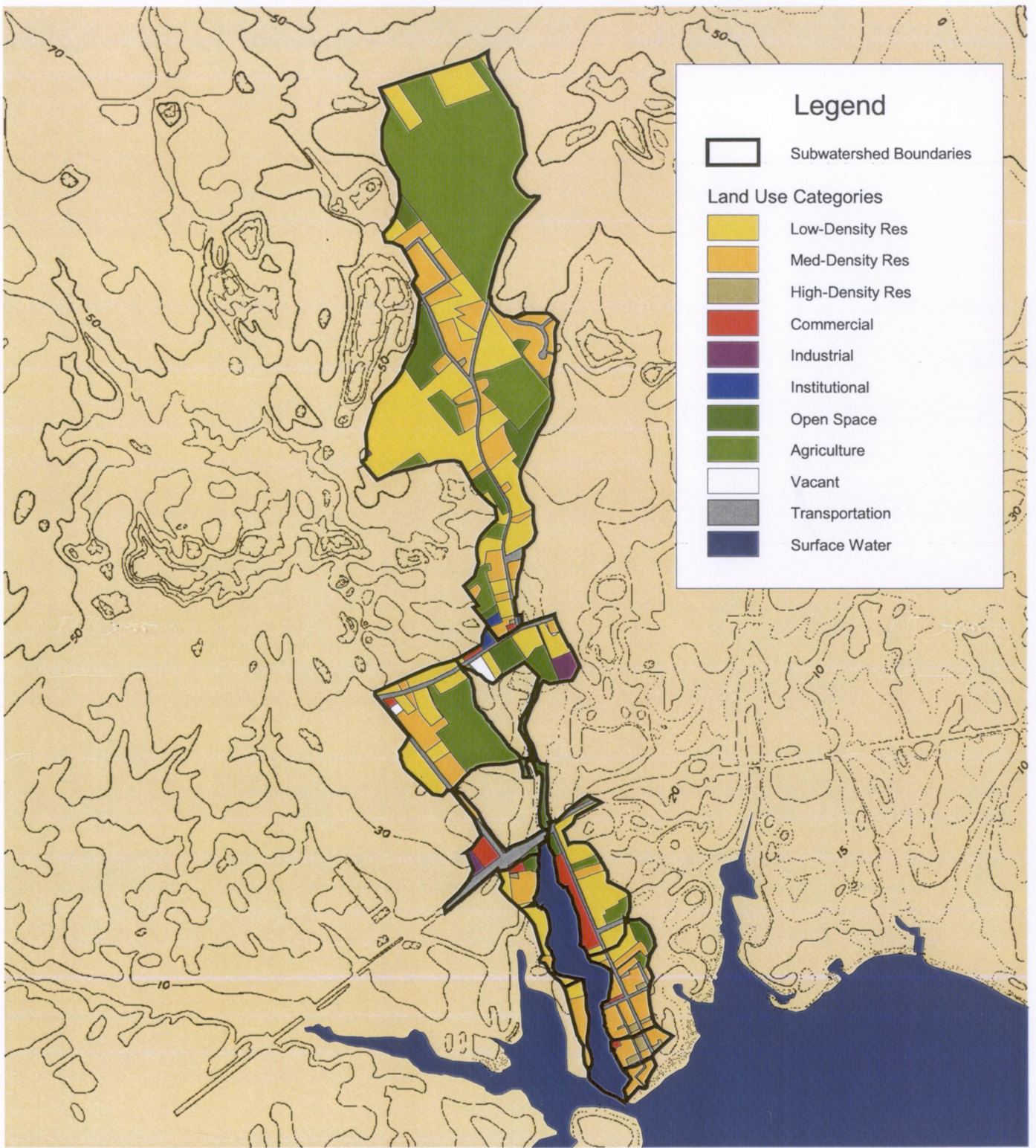


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Subwatershed Delineations for Meetinghouse Creek

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








Figure 25

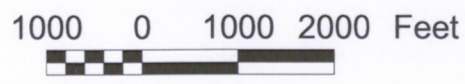


Legend

 Subwatershed Boundaries

Land Use Categories

-  Low-Density Res
-  Med-Density Res
-  High-Density Res
-  Commercial
-  Industrial
-  Institutional
-  Open Space
-  Agriculture
-  Vacant
-  Transportation
-  Surface Water



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Land Use within
 Meetinghouse Creek
 Watershed

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Figure 26

Individual soil types were taken from digital regional coverage provided by the USDA/NRCS. The hydrologic soil group distribution throughout the Meetinghouse Creek Watershed is primarily type “A” and type “B” soils (Figure 27). These two more pervious soil groups cover an almost equal area throughout the watershed (193 acres for group “A” and 218 acres for group “B”) and, combined, cover approximately 85%. The tightly packed type “D” soils are generally concentrated around the shore of the embayment and cover approximately 17 acres. The overall soil profile suggests that the watershed as a whole has a significant capacity for recharge depending on the land use overlying these soils.

6.3.3 Results of Pollutant Load Modeling for Meetinghouse Creek

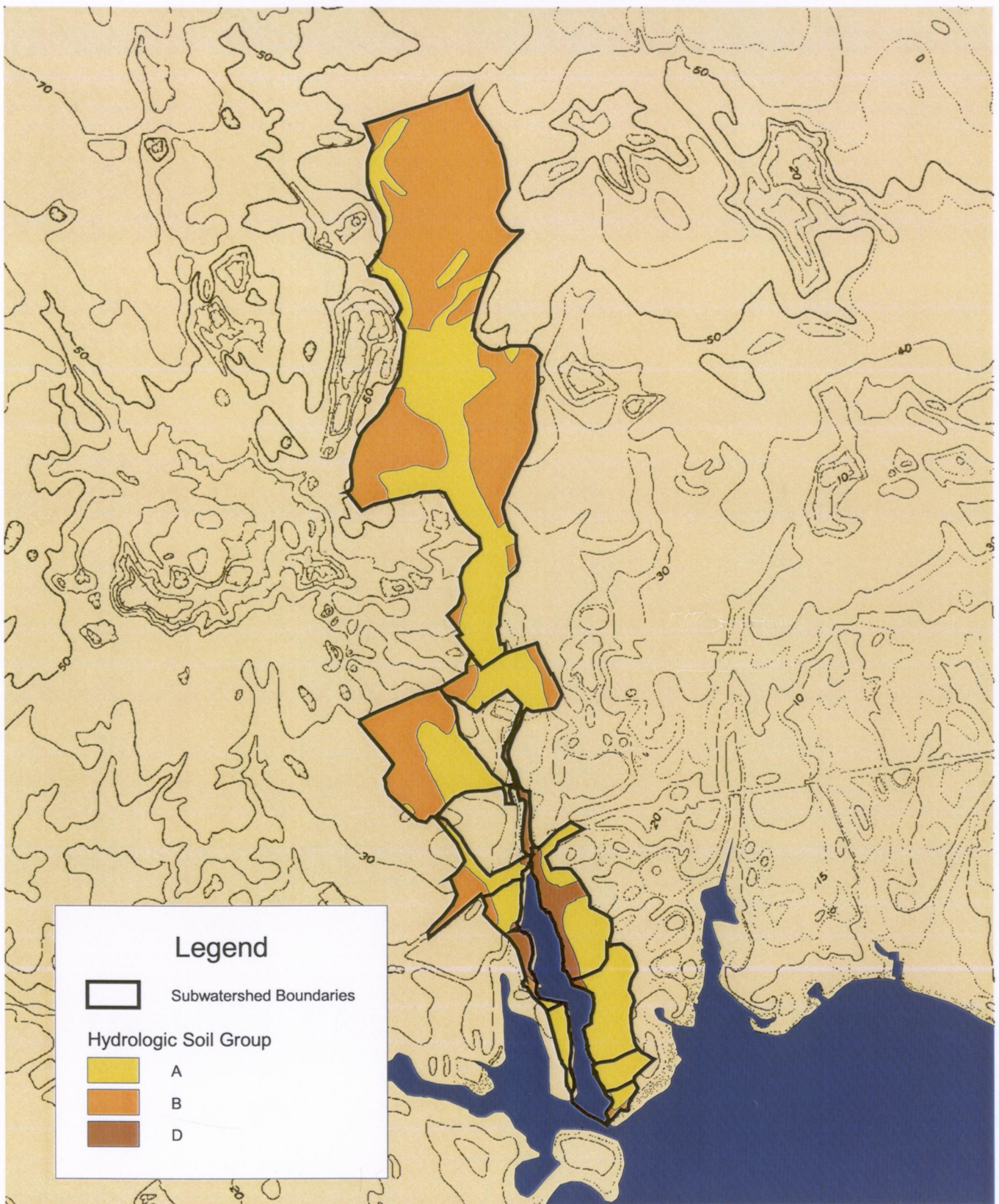
Loading calculations were performed for the Meetinghouse Creek watershed using the three target storm events. The resulting average concentration in the embayment was calculated assuming a mean low tide depth of 5 feet, a tidal range of three feet, and a waterfowl population of 10. The full results of these modeled events are presented in Appendix A. A summary of the results for the 0.6-inch rain event is provided below in Tables 22 and 23 and are presented graphically in Figure 28.

Table 22. Summary of GIS-Based Bacteria and Nitrogen Loading Model for Meetinghouse Creek


Subwatershed	Modified Curve Number	Runoff Volume (liters)	Bacteria Load (millions of orgs)	Nitrogen Load (pounds)
1	90	2,549,545	388,045	17.04
2	80	10,480	2,107	0.05
3	92	671,774	111,474	4.58
4	94	277,341	98,817	2.04
5	85	31,440	6,931	0.14
6	84	10,811	2,632	0.05
7	90	255,632	53,751	1.47
8	84	54,416	15,390	0.28
9	87	33,428	10,996	0.18
10	87	12,991	3,735	0.07




Table 23. Comparing the Average Embayment Concentrations Predicted by the Model with Measured Concentrations in Meetinghouse Creek

Range of Wet Weather Measurements (orgs/100 mL)	Geometric Mean of Wet Weather Measurements (orgs/100 mL)	Modeled Concentration from Minimum Coefficients (orgs/100 mL)	Modeled Concentration from Average Coefficients (orgs/100 mL)	Modeled Concentration from Maximum Coefficients (orgs/100 mL)
2.9 – 93	12.5	22	268	514



Legend

 Subwatershed Boundaries

Hydrologic Soil Group
 A
 B
 D

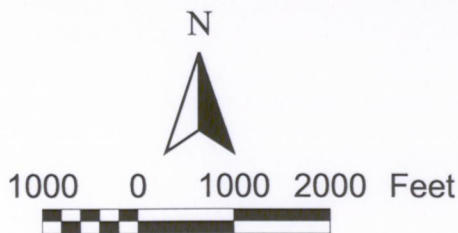


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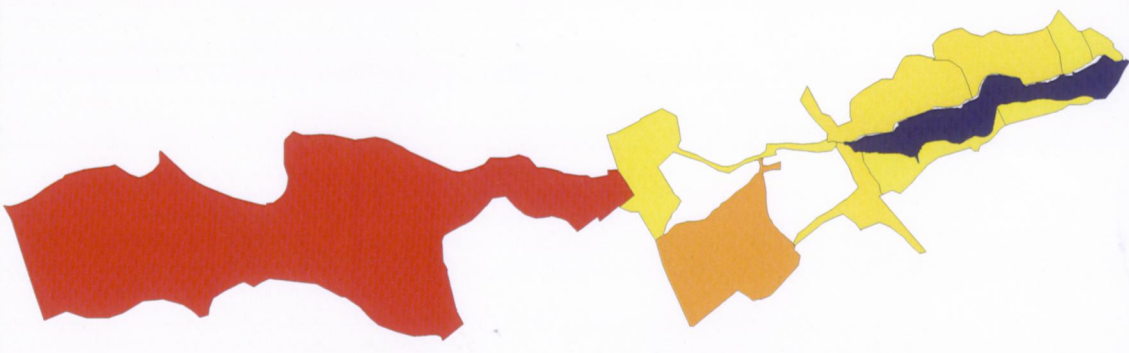
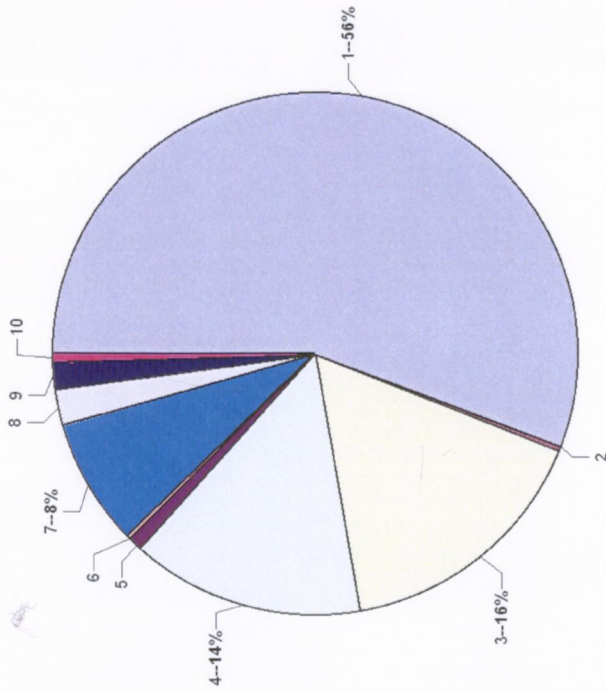
Hydrologic Soil Groups within Meetinghouse Creek Watershed

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Figure 27



Loading Percentage by Subwatershed



Legend



Graphic Distribution of Bacteria Loading (millions of organisms)



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Relative Loading of FC Bacteria from Meetinghouse Creek Subwatersheds

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The distribution of pollutant loading across the Reeves Bay subwatersheds showed limited variability at different rain levels. The relative distribution of loading for the three target storms can be found in Appendix A. The results show that Subwatershed 1 shows the highest loading for each of the storms. These high loads are driven primarily by the size of the subwatershed, which in turn generates the highest amount of runoff by a wide margin. Subwatersheds 3 and 4 consistently show the next highest loads for all three storms.

The wet weather data available for comparing embayment concentrations from the field with those from the model were limited. Of the four embayments modeled in this study, the comparison between modeled and measured embayment concentrations was the least favorable. Although all modeled values were within an order of magnitude of the measured range and geometric mean, the modeled values for the average coefficients and maximum coefficients were significantly larger than measured concentrations. In order to better assess the accuracy of the model as applied to Meetinghouse Creek, a larger set of wet weather sampling data will have to be developed.

7.0 THE REGIONAL STUDY MANAGEMENT STRATEGY

The final stage of the study performed by Horsley & Witten involved the creation of a standardized management procedure that could be applied to those embayments examined for this phase of study as well as to embayments studied in the future. The procedure is designed to provide guidance towards prioritizing areas for pollutant attenuation along with choosing and implementing management practices for specific subwatershed areas. The prioritization process for the regional study takes place on two levels. The first level involves the selection of priority embayments throughout the region. The second level involves isolating those specific areas around priority embayments that should be targeted for pollutant remediation. Existing information from local agencies was consulted along with the quantitative results from the GIS-based model to prioritize an individual embayment from the regional study as well as subwatersheds surrounding that embayment. These tools provided in this final section were compiled in a summary format that includes strategies applicable to urban areas, residential areas, agricultural operations and open space. Where structural management strategies may be applied to specific watersheds, a range of cost estimates and pollutant removal efficiencies are included based on the best available data.

7.1 Prioritizing Embayments Within the Peconic Bay Region

One of the objectives of the regional study is to provide the means by which individual embayments within the Peconic Bay region can be prioritized for pollutant remediation efforts. The embayments chosen for this regional study represent areas that have exhibited different signs of stress relative to different environmental issues. Meetinghouse Creek is listed as a high priority embayment for nitrogen mitigation (PEP, 1999) and is located in an area of administrative closing for shellfish harvesting.

Hashamomuck Pond is not specifically mentioned in the Nutrient Module of the CCMP (PEP, 1999), however the NYSDEC has placed varied restrictions on shellfishing throughout the embayment. Reeves Bay is part of “Western Flanders Bay”, which is a high priority nitrogen mitigation area. Reeves Bay also experiences conditional shellfishery closing throughout the embayment. West Neck Bay has demonstrated good overall water quality for shellfishing but is listed as a brown tide “hot spot” (PEP, 1999) and therefore may be under stress from nitrogen loading.

To prioritize from these embayments, Horsley & Witten used a series of questions designed to narrow the focus to a single area:

Which pollutants (FC bacteria or nitrogen) are priorities for the embayment?

The purpose of this regional study was to focus on impacts to selected embayments from stormwater pollutant loading. The model focuses on two potential pollutants within stormwater to determine impacts from subwatershed surrounding each of these embayments: FC bacteria and nitrogen. As discussed in Section 3 of this report, FC bacteria travels almost exclusively in stormwater runoff while nitrogen can be loaded from both stormwater runoff and groundwater recharge. Studies within the Peconic Bay region show that, with regard to nitrogen loading, groundwater recharge plays a much more significant role in the overall, locally-controllable nitrogen loading budget throughout the region (PEP, 1999). As a result, if water quality data for an individual embayment showed that nitrogen was a much higher priority than FC bacteria, it was assumed that stormwater pollution was not the main concern for that area. Those embayments that showed poor water quality data for nitrogen or DO alone were therefore given a lower ranking than those that showed problems with FC bacteria concentrations.

What is the nature of shellfishing restrictions in each embayment?

Restrictions on shellfishing areas imposed by the NYSDEC can be year-round (administrative), seasonal, or conditional. Justification for these different closure can vary depending on seasonal considerations, weather events, or the presence of point source pollution (See Section 2). With regard to ranking, those embayments currently experiencing administrative closings were given the lowest priority since these closures often reflect the existence of point source discharges that constitute a public health concern on a year-round basis. Seasonal or conditional closures are more likely to be determined based on stormwater runoff loading and were therefore given a higher ranking.

What is the quality of existing data?

The best source of data within the Peconic Bay region for determining the results of stormwater pollutant loading to selected embayments is the wet weather sampling performed by NYSDEC for the purposes of shellfish area certification. The quality of these data sets will vary from one embayment to another depending on the number of stations within each embayment and the number of data points attached to each station.

Horsley & Witten closely examined each existing data set for the four embayments chosen for this study by PEP to determine the relative quality of each set. The data were reviewed for the following conditions:

- the number of stations in each embayment;
- the number of data points for each station; and
- the number and size of wet weather events associated with water quality measurements.

How well do the modeled results represent existing data?

Horsley & Witten used the calculated concentrations from the GIS-based model to observe the degree to which the modeled concentrations represented reality. The assumptions for this exercise are that those embayments that show reasonable concentrations would be given higher ranking than those that did not show a reasonable comparison.

Are there existing or planned stormwater management practices within the watershed?

Horsley & Witten gathered information on stormwater demonstration projects, both existing and planned, within the Peconic Bay region. The purpose of this research was to isolate those areas where monitoring plans could be implemented to assess the relative success of different management practices. Those embayments with existing or planned implementations were given a higher ranking than those that did not.

The questions listed above were applied to each of the four embayments specified by PEP for the regional study. The results are summarized in Table 24. Based on these observations, West Neck Bay and Meetinghouse Creek are more quickly eliminated from the higher rankings. Existing data suggest that West Neck Bay may be more limited by nitrogen loading from groundwater. With regard to Meetinghouse Creek, the administrative closing and the primacy of nitrogen loading concerns suggest that stormwater remediation efforts would be secondary in this area. Both Reeves Bay and Hashamomuck Pond Rank high for stormwater prioritization in all categories except for existing and planned BMP implementation. Discussions with Suffolk County NRCS reveal that Subwatershed 9 in Hashamomuck Pond contains an existing stormwater detention basin. Also further communication with county agencies has revealed plans for a bio-retention pond that would receive stormwater runoff from impervious surfaces in Subwatershed 12. These existing and proposed BMPs provide an excellent opportunity for the monitoring of different systems relative to nitrogen uptake and bacteria removal. Hashamomuck Pond was therefore chosen as the highest ranking embayment within the larger regional prioritization process.

Table 24. Prioritization Rankings for the Regional Study Embayments

Embayment	Primary Limiting Condition	Shellfishing Restriction(s)	Quality of Data	Quality of Modeled Results	Existing or Planned BMPs
Hashamomuck Pond	FC Bacteria	Mixed	Good	Reasonable	Yes
West Neck Bay	(Brown Tide)	Open	(Fair)	Reasonable	(No)
Reeves Bay	FC Bacteria/ (Nutrient Loading)	Conditional	Good	Reasonable	(No)
Meetinghouse Creek	(Nutrient Loading)	(Administrative)	(Fair)	(Notable Discrepancy)	Yes

() Factors that work to decrease the ranking of an embayment appear in parentheses

7.2 Rating System for Selecting Management Techniques

The selection of appropriate management techniques should be based upon an assessment of existing and potential future water quality threats. The target pollutant or pollutants should be identified based upon which parameter(s) are expected to exceed standards. The watershed modeling conducted during the preceding tasks provides a framework for quantifying these threats. It estimates pollutant loads from each sub-watershed on the basis of soil types, land use and rainfall amount. The following approach has been developed for identifying and selecting appropriate management strategies at the watershed scale.

To provide a uniform basis for selecting stormwater management options, Horsley & Witten has developed the following rating system. It involves three steps: 1) rank and classify sub-watersheds by predicted pollutant loads and/or water quality impairment, 2) identify management options by land use type and 3) estimate pollutant reduction benefits.

Several of the recommended stormwater management measures are well-known and commonly understood by watershed managers, while others are less so. Refer to Appendix B for a description and illustrations of practices recommended in this document.

1. Based upon the pollutant loading modeling results, the subwatersheds are ranked in the order of predicted loading and/or water quality impairment. In those instances where water quality monitoring data are sufficient and/or where modeling can predict areas of impairment, critical subwatersheds can be identified and prioritized for management. Alternatively, subwatersheds can be classified into high-load and low-load areas. Impaired and/or high-load areas are targeted for “remedial” management options and non-impaired and/or low-load areas are targeted for “preservation” management measures. It should be recognized that some of the non-impaired low-load areas may also be appropriate

for a limited number of remedial measures. For example, low-density residential areas should still employ pet waste management programs and could utilize low-cost treatment methods such as swales to further reduce pollutant loads.

2. The specific types of stormwater management options for each subwatershed are then identified on the basis of land use. For example, residential areas in remedial areas would be targeted for aggressive best management practices (BMPs) known to be effective in reducing pollutant loads. These practices might include intensive pet waste management programs and/or construction of stormwater filters and/or infiltration systems to intercept and treat runoff prior to entering the receiving waters. Preservation areas which might be more intensively developed in the future are targeted for protection via land-use planning techniques including land acquisition, conservation easements, zoning and better site design. Table 25 shows a listing of the various practices that fit into each of these categories.
3. The relative benefits of each stormwater management option is then assessed by estimating the pollutant load reductions based upon published performance data for each practice. This benefit analysis can then be utilized to develop and rank specific action plans for each subwatershed.

Table 25. Matrix of Recommended Stormwater Management Practices As a Function of Land Use and Current Conditions

Current Land Use	Preservation	Remediation
Agriculture	Land acquisition/easements Erosion/sediment controls Zoning	Nutrient management Pest/pesticide management Pathogen controls
Residential	Pollution prevention management (Pet waste management, Lawn Care)	Pollution prevention Ponds Wetlands Drywells Open channels Proprietary practices
Commercial	Zoning (re-development) standards	Pollution prevention Infiltration trench Filters
Open Space	Land acquisition/easements Zoning Pet waste management	Pollution prevention Land acquisition/easement Restoration/reforestation

STEP 1: RANK SUBWATERSHEDS

The results of the water quality modeling provide for the identification of problem areas and ranking of subwatersheds. In embayments where water quality standards are exceeded, priority subwatersheds which contribute excessive pollutant loading can be identified.

In some cases water quality modeling can also provide quantification of non-compliance. In other words, the model can provide a comparison between estimated pollutant loadings, receiving water quality and the carrying capacity (allowable pollutant loading) of the receiving waters. The amount or degree of excessive loading can be calculated. Those subwatersheds which are identified to have the highest excessive loading can be ranked in order of priority.

In other instances where insufficient water quality data exists and/or modeling is not available, subwatersheds can be ranked simply by relative pollutant loads. Those subwatersheds which contribute high loads can be targeted as areas in need of “remediation.” Low pollutant load areas can be targeted as “preservation” areas.

STEP 2: SELECT BMPS

Preservation Practices:

A range of “preservation” stormwater practices are available to maintain existing low-impact land uses and to prevent future potential land uses from causing significant and unnecessary pollutant loads. Land which currently exists as open space holds the best opportunity for preservation. The greatest protection of this land is based upon ownership. If the “open space” land is held by private interests (and in some cases by government agencies) it may have significant development potential according to the zoning ordinances. In these cases acquisition by land preservation organizations such as land trusts is the most protective option, whereby a permanent deed restriction may be placed on the land, thereby preventing future development potential. Conservation easements can also be acquired at less cost to limit the development potential of a parcel without a complete fee-simple purchase.

The second best option for protecting open space land which is not deed-restricted is through zoning and other land use regulatory programs. Zoning can control the types and intensities of potential uses. It can also include requirements for the integration of state-of-the-art structural and non-structural practices in the event that the land becomes developed. The principal weakness of zoning as a water quality protection technique is the “grand-fathering” provisions which protect the land owner’s development rights on “pre-existing” lots created via the subdivision process. Future zoning changes commonly do not affect these lots.

Agricultural land typically already presents some level of stormwater impacts via fertilizer, pesticide or livestock. However, agricultural lands are vulnerable to significant

land use changes which could exacerbate these problems (most commonly, the conversion to residential use). Because agricultural land typically is not encumbered with many structures, the option of acquisition or protection through conservation easement exists. Further future development of the land can be prevented. In some cases “agricultural restrictions and/or easements” can provide the continued right to farm while limiting future development rights. Again, zoning is the second best alternative to acquisition for controlling future land use changes and subsequent stormwater impacts.

Residential land uses are typically developed close to the maximum densities afforded by the zoning in place. Undeveloped lots in otherwise residentially-developed areas represent “in-fill” and are typically protected (grand-fathered) by zoning. Therefore, the best “preservation” technique for residential areas is public (homeowner) education related to “pollution prevention” options such as pet waste management, lawn care, car washing, and stormwater management.

Similarly, commercial/industrial land uses are afforded protection (of their continued business use) by zoning. However, these areas are commonly affected by re-development as one business evolves to the next on a given property. Redevelopment of commercial/industrial property provides a unique opportunity to integrate improvements in stormwater management, as structural modifications are common. Therefore, a clear set of redevelopment standards should be provided within the zoning ordinance (and other appropriate land use controls). Public education of business owners/operators relative to pollution prevention is also recommended for stormwater management and lawn care issues. Particular attention should be paid to the proper storage of toxic and hazardous materials.

Remediation Practices:

The selection of specific stormwater remediation practices ultimately becomes a very site-specific determination and should consider the types of pollutants generated, pollutant wash-off characteristics (first-flush effect), available land area, proximity to surrounding land uses, aesthetics and the capacity for maintenance of facilities. The amount of pollutant reduction to attain water quality goals is also a criterion. However, on the watershed planning level, a short-list of appropriate practices can be developed based upon a more limited information base.

The New York Stormwater Management Design Manual (October 2001) provides an approach to screening practices based upon land use. Table 26 summarizes recommended practices for six different land uses and categorizes the practices into three groups: good option in most cases, suitable under certain conditions and seldom or never suitable. For residential areas, it recommends stormwater ponds, wetlands, dry wells and open channels as optimal in most cases. For commercial/high density areas sand filters and infiltration trenches are the most widely applicable. Other practices are identified as “suitable under certain conditions”.

The NRCS and others have identified many conservation practices for agriculture. Some include pollution prevention BMPs, which prevent contaminants from entering runoff, or prevent runoff from occurring. Others fall into the category of runoff treatment BMPs, which treat runoff after it is already occurring. Pollutant loads can be reduced and BMP reliability increased when BMPs are used in sequence, starting with reducing or optimizing the application of chemicals or fertilizers, for example, and ending with structures that capture and recycle or treat runoff. Refer to Appendix B for a description and discussion of appropriate management measures for agricultural uses.

STEP 3: ESTIMATE THE POLLUTANT REDUCTION BENEFITS

The third step in the rating system calls for estimation of the pollutant removal benefits afforded by the recommended stormwater management strategies. To provide a basis for this analysis Table 27 was compiled to provide the best available treatment potential associated with various practices. These removal rates should be considered average in that they are compiled from a national database with a considerable amount of variability. The pollutant removal data for the structural BMPs was obtained from actual water quality monitoring studies compiled by the Center for Watershed Protection (Schueler, 1997).

In residential areas pet waste is a major contributor of pathogens. The benefits of a pet waste management program are based upon the effectiveness of public education campaigns and estimated participation by volunteers. Based upon a methodology developed by the Center for Watershed Protection the benefits of a pet waste management program can be estimated as follows:

- 70% of dog owners walk their dogs
- 30% of citizens are educated by newspaper advertisements
- 50% of citizens who read advertisements will participate

Therefore, the pollutant removal benefit of a pet waste educational campaign can be calculated as $(70\%)(30\%)(50\%) = 10.5\%$

While the rating system does not specifically call for cost evaluation, Table 28 provides some general estimates of costs associated with stormwater practices. It is excerpted from a report prepared by the Center for Watershed Protection (1998). We have computed costs per acre as a basis for comparison.

Table 26. Recommended Structural Stormwater Management Measures for Remediation as a Function of Land Use Type

SMP Group	SMP Design	Rural	Residential	Roads and Highways	Commercial/ High Density	Hotspots	Ultra Urban
Pond	Micropool ED	○	○	○	◐	①	●
	Wet Pond	○	○	○	◐	①	●
	Wet ED Pond	○	○	○	◐	①	●
	Multiple Pond	○	○	◐	◐	①	●
	Pocket Pond	○	◐	○	◐	●	●
Wetland	Shallow Wetland	○	○	◐	◐	①	●
	ED Wetland	○	○	◐	◐	①	●
	Pond/Wetland	○	○	●	◐	①	●
	Pocket Wetland	○	◐	○	◐	●	●
Infiltration	Infiltration Trench	◐	◐	○	○	●	◐
	Shallow I-Basin	◐	◐	◐	◐	●	◐
	Dry Well ¹	◐	○	●	◐	●	◐
Filters	Surface Sand Filter	●	◐	○	○	②	○
	Underground SF	●	●	◐	○	○	○
	Perimeter SF	●	●	◐	○	○	○
	Organic SF	●	◐	○	○	②	○
	Bioretention	◐	◐	○	○	②	○
Open Channels	Dry Swale	○	◐	○	◐	②	◐
	Wet Swale	○	●	○	●	●	●

○: Yes. Good option in most cases.

◐: Depends. Suitable under certain conditions, or may be used to treat a portion of the site.

●: No. Seldom or never suitable.

①: Acceptable option, but may require a pond liner to reduce risk of groundwater contamination.

②: Acceptable option, if not designed as an exfilter.

¹: The dry well can only be used to treat rooftop runoff.

(Source: New York State Stormwater Management Design Manual, 2001)

Table 27. Effectiveness of Stormwater BMPs at Removing Pollutants

BMP		TSS Removal	Nitrogen Removal	Fecal Coliform	Fecal Streptococci
<i>(% removal, by mass)</i>					
Ponds	Detention Pond	7	5 ³	ND	ND
	Dry ED Pond	61	31 ³	ND	ND
	Wet Pond	77	30	65	73 ³
	Wet ED Pond	60	35 ³	65	73 ³
Wetlands	Shallow Marsh	84	24	ND	ND
	ED Wetland	63	36 ³	ND	ND
	Pond/Wetland	72	13	ND	ND
Infiltration	All Infiltration	99 ¹	60-70 ¹	98 ³	98 ³
Filters	Sand or Organic Filters	87	44	51	58
Bioretention	Bioretention	81 ²	ND	ND	ND
Vegetative BMPs	Channels	0	0	-58	ND
	Designed Swales	81	ND	-58	ND
	Filter Strips	69 ³	ND	ND	ND
Pollution Prevention	Pet Waste Management	ND	10	10	10
	Lawn Care	ND	50	ND	ND
Agricultural BMPs	Grazing Management	50-90	ND	-60	ND
	Animal Waste Management	65	ND	75	ND
	Vegetated Filter Strip	80	ND	55	ND
	Settling Basin	60	ND	67	ND
	Wetlands	70	ND	77	ND

ED = Extended Detention

1 = Not based on actual monitoring data. Source: Schueler, 1987

2 = Assumes the same removal efficiency as designed swales

3 = Based on fewer than 5 data points

ND = No or insufficient data

(Sources: Schueler, 1997; and Becker and O'Melia LLC, 2001)

Table 28. Base Costs of Typical Applications of Stormwater BMPs¹

BMP	Typical Cost	Application	Cost/Acre	Source
Pond	\$100,000	50-Acre residential site (Impervious cover = 35%)	\$2,000	Adapted from Brown and Schueler (1997)
Wetland	\$125,000	50-Acre residential site (Impervious cover = 35%)	\$2,500	Adapted from Brown and Schueler (1997)
Infiltration Trench	\$45,000	5-Acre commercial site (Impervious cover = 65%)	\$9,000	Adapted from SWRPC (1991)
Infiltration Basin	\$15,000	5-Acre commercial site (Impervious cover = 65%)	\$3,000	Adapted from SWRPC (1991)
Sand Filter	\$35,000- \$70,000 ²	5-Acre commercial site (Impervious cover = 65%)	\$10,500	Adapted from Brown and Schueler (1997)
Bioretention	\$60,000	5-Acre commercial site (Impervious cover = 65%)	\$12,000	Adapted from Brown and Schueler (1997)
Dry Swale	\$30,000	5-Acre residential site (Impervious cover = 35%)	\$6,000	Adapted from Brown and Schueler (1997)
Grass Channel/Biofilters	\$3,500	5-Acre residential site (Impervious cover = 35%)	\$700	Adapted from SWRPC (1991)
Filter Strip	\$0-\$9,000	5-Acre residential site (Impervious cover = 35%)	\$900	Adapted from SWRPC (1991)
<p>1 = Total capital costs can typically be determined by increasing these costs by approximately 30%. 2 = A range is given to account for design variations.</p>				

(Source: Cost and Benefits of Storm Water BMPs - Final Report 9/14/98)

7.3 Sample Watershed Management Program and Assessment

The Hashamomuck watershed was selected as a sample to illustrate how the rating system would be applied. Hashamomuck Pond has shellfish closures and exhibits high concentrations of fecal coliform on a regular basis. To simplify the illustration high and low pollutant loads were utilized to rank the subwatersheds.

STEP 1: RANK SUBWATERSHEDS

Based upon the modeling results, two subwatersheds (#10 and #19) were identified as high pollutant load areas. These two subwatersheds contribute 53 percent of the total fecal coliform loadings during the 0.6-inch rain event, while they comprise only 29 percent of the watershed area.

STEP 2: SELECT BMPS

The land uses in these two subwatersheds are predominantly agricultural and open space and some residential. A small amount of commercial land use also exists in subwatershed 10. Management practices were selected from Table 25. Because fecal coliform bacteria are the target, BMPs that have performance data for this parameter were selected. For the purposes of the sample illustration open space categories in the two remediation areas were assumed to be predominantly natural areas where only 10% of the land areas is utilized for pet walking.

STEP 3: ESTIMATE COST AND BENEFITS

In order to attain a water quality standard of 14 orgs per 100 mL, the modeled concentration in the Hashamomuck Pond, 27 orgs/100 mL (Table 13), was compared to the standard and the necessary reduction in loading necessary to meet the standard was calculated. In this case the necessary reduction in loading was 48 percent ($27 - 14 = 13$, then $13/27 = 48$ percent). Forty eight percent of the total load to Hashamomuck Pond equals 179,350 million orgs.

A second attempt at meeting the target reduction was made by upgrading the BMPs to more effective (higher pollutant removal rates) and more expensive options. However, this upgrade in BMPs still did not meet the target.

Using the selected BMPs, the pollutant benefits (and costs) of the management plan were initially calculated (see Table 29) using two subwatersheds (19 and 10) within Hashamomuck Pond's watershed that contribute the most fecal coliform load. An area-weighted calculation of the overall composite removal benefit was estimated to be 46 percent or a reduction of 91,149 million orgs, with an estimated cost of \$192,055. This falls short of the reduction goal of 179,350 million orgs.

Therefore it was necessary to identify additional subwatersheds for remediation in order to attain the water quality standard. Additional subwatersheds were selected based on their contributing loading (i.e., subwatersheds with higher loads were selected as priorities). The additional subwatersheds include subwatersheds 12, 22, 13 and 18. Each subwatershed was added to the cost-benefit matrix (Table 30) until the necessary reduction was attained. These six subwatersheds have a total load of 287,615 million orgs. Ultimately, a removal of 63 percent accomplishes a reduction in total load of 181,198 million orgs from the watershed. The cost estimated to implement the recommended BMPs was estimated to be \$871,770 (Table 30). The cost benefit analysis is conducted through iterative changes to Table 30. This table can be modified through either selection of different BMPs and/or treating additional subwatersheds.

Table 29. Preliminary Sample Stormwater Management Practices for Hashamomuck Pond (Fecal Coliforms)

Subwatershed	Land Use	Acres	Recommended Management Practice	Estimated Fecal Coliform Removal (%)	Estimate Cost/Acre	Total Estimated Cost	Notes
10	Residential	12.00	Ponds	65	\$2,000	\$24,000	
10	Commercial	1.58	Infiltration trench	98	\$9,000	\$14,220	
10	Open Space	8.88	Pet waste management	10	N/A	\$500	Newspaper advertising
10	Agricultural	30.72	Ponds and wetlands	72	\$2,250	\$69,120	
10	Transportation	4.90	Ponds	65	\$2,000	\$9,800	
19	Residential	2.19	Ponds	65	\$2,000	\$4,380	
19	Open Space	36.23	Pet waste management	10	N/A	\$500	Newspaper advertising
19	Agricultural	29.96	Ponds and wetlands	72	\$2,250	\$67,410	
19	Transportation	0.85	Sand filters	51	\$2,500	\$2,125	
Total		127.31		46		\$192,055	

Table 30. Final Sample Stormwater Management Practices for Hashamomuck Pond (Fecal Coliforms)

Subwatershed	Land Use	Acres	Recommended Management Practice	Estimated Fecal Coliform Removal (%)	Estimate Cost/Acre	Total Estimated Cost	Notes
10	Residential	12.00	Infiltration	98	\$9,000	\$108,000	
10	Commercial	1.58	Infiltration	98	\$9,000	\$14,220	
10	Open Space	8.88	Pet waste management	10	N/A	\$500	Newspaper advertising
10	Agricultural	30.72	Infiltration	98	\$4,500	\$138,240	
10	Transportation	4.90	Ponds	65	\$2,000	\$9,800	
19	Residential	2.19	Ponds	65	\$2,000	\$4,380	
19	Open Space	36.23	Pet waste management	10	N/A	\$500	Newspaper advertising
19	Agricultural	29.96	Infiltration	98	\$4,500	\$134,820	
19	Transportation	0.85	Sand filters	51	\$2,500	\$2,125	
12	Commercial	0.03	Infiltration	98	\$9,000	\$270	
12	Open Space	7.30	Pet waste management	10	N/A	\$500	
12	Transportation	7.05	Infiltration	98	\$9,000	\$63,450	
12	Institutional	0.84	Infiltration	98	\$9,000	\$7,560	
12	Residential	21.90	Infiltration	98	\$9,000	\$197,100	
22	Residential	4.90	Infiltration	98	\$9,000	\$44,100	
22	Open Space	0.55	Pet waste management	10	N/A	\$500	
22	Transportation	2.28	Infiltration	98	\$9,000	\$20,520	
13	Residential	2.39	Infiltration	98	\$9,000	\$21,510	
13	Open Space	15.53	Pet waste management	10	N/A	\$500	
13	Agricultural	14.54	Ponds and Wetlands	72	\$2,250	\$32,715	
13	Transportation	0.02	Ponds	65	\$2,000	\$40	
18	Residential	7.58	Infiltration	98	\$9,000	\$68,220	
18	Open Space	1.47	Pet waste management	10	N/A	\$500	
18	Transportation	0.85	Ponds	65	\$2,000	\$1,700	
Total		214.54		63		\$871,770	

8.0 CONCLUSIONS/SUMMARY

This same approach can be applied throughout the Peconic watershed to identify, prioritize and recommend appropriate actions to reduce stormwater pollutant loading of pathogens and nutrients. Once the cost benefit matrix has been refined, further management action will be necessary to implement the correct strategy. Ultimately, stormwater management is very site specific and a number of criteria will need to be evaluated to determine the feasibility of any BMP strategies. We recommend that the subwatersheds identified in the cost-benefit matrix be field-verified for the feasibility of potential structural and non-structural measures. A key consideration in stormwater management is the role and ability of individual properties and property owners in managing stormwater on-site to reduce the volume of runoff. The more that stormwater can be controlled, treated and infiltrated (as appropriate) on-site, the less runoff that will ultimately reach concentrated flow structures and discharge locations.

The management strategies chosen for a site, subwatershed, or watershed will depend on several factors including:

- The size of the drainage area and nature of contributing land uses;
- The feasibility of reducing runoff from individual properties prior to discharge to the drainage structure;
- The amount of space available for treating runoff;
- Physical limitations such as head, depth to groundwater, and slope;
- The complexity and costs associated with permitting;
- The ability of particular practices to meet specific management goals, such as recharge, pollutant load reduction, and/or reduction of flooding threats;
- The potential for harmful environmental effects from installing a particular treatment structure;
- The desired removal rate for bacteria and other pollutants;
- The cost of construction and implementation;
- The resources necessary for proper maintenance;
- The expected longevity of the structure; and/or
- Politically feasibility of land use and zoning changes.

Once these factors have been assessed the strategy may need re-evaluating either to re-prioritize or revise with alternatives. Once a strategy has been adopted we recommend implementing demonstration projects in subwatersheds that are identified and measuring their success. The success in these areas may be greater or less than estimated in the cost-benefit matrix and the plan and model should be revised accordingly. Success should be monitored through sampling water quality and biological indicators, public attitude surveys, and programmatic evaluations.

Data Gaps

Several data gaps were identified while conducting this study. The stormwater infrastructure data collected as part of this study indicates stormwater outfall locations

into the studied embayments, but does not map the network of stormwater pipes that service these more urbanized areas. We recommend that where stormwater infrastructure exists, that it be mapped. This will aid in future watershed delineations. Another data gap noted during this study was the lack of available bird population data. We estimated bird population based on aerial photography. This estimation method has obvious limitations. We would recommend that further research be conducted on the populations of birds that utilize embayments of concern. We would also recommend further sampling be conducted of pollutant concentrations in stormwater runoff from various land uses within watersheds to the Peconic Bay. While we obtained data for a nearby study conducted in Huntington New York that measured pollutants in runoff which compared well with the literature values we used in the model, we recommend some further confirmation of these values through sampling. Pet populations were also largely unknown and may have a significant contribution to loading of fecal coliform. Identifying both the size of the population and the behavior of pet owners may guide further management actions. Conducting a survey or researching the number of pets and the pet owner behaviors would aid in defining this potential source. The additional data collected through these recommendations could easily be incorporated into the modeling and management strategy provided in this report.

9.0 REFERENCES

Alderisio, K.A. and N. DeLuca. 1999. Seasonal Enumeration of Fecal Coliform Bacteria from the Feces of Ring-Billed Gulls (*Larus delawarensis*) and Canada Geese (*Branta Canadensis*). Applied and Environmental Microbiology 65(12):5628-5630.

Becker and O'Melia, LLC. 2001. AWWARF 2616; Impacts of major Point and Non-Point Sources on Raw Water Treatability.

Benton, C. et al. 1982. The Contamination of a Major Water Supply by Gulls (*Larus* sp).

Water Resources Volume 17(7):789-798.

Brown, W. and T. Schueler. 1997. The Economics of Storm Water BMPs in the Mid-Atlantic Region. Prepared for: Chesapeake Research Consortium. Edgewater, MD. Center for Watershed Protection. Ellicott City, MD.

Cape Cod Commission. 2002. Cape Cod Regional Policy Plan. Barnstable County, MA. April 29.

Center for Watershed Protection. 1998. Cost and Benefits of Storm Water BMPs Final Report 9/14/98. Ellicott City, MD.

Center for Watershed Protection (CWP). 1998. Better Site Design: A Handbook for Changing Development Rules in Your Community. Ellicott City, MD.

Center for Watershed Protection (CWP). 2000. The Practice of Watershed Protection. Edited by: Thomas Schueler and Heather Holland. Ellicott City, MD.

Center for Watershed Protection (CWP). 2001. Stormwater Managers Resource Center. Slideshows. Ellicott City, MD.

Center for Watershed Protection. October 2001. The New York Stormwater Management Design Manual. Ellicott City, MD.

Claytor, R. 2000. Personal slide collection. Sandwich, MA.

Commonwealth of Massachusetts, Executive Office of Environmental Affairs, Department of Environmental Management, Department of Food and Agriculture; On-Farm Strategies to Protect Water Quality, An Assessment and Planning Tool for Best Management Practices; October 1999.

Crane S.R., J.A. Moore, M.E. Grismer, and J.R. Miner. 1983. Bacterial Pollution from Agricultural Sources: A Review. Transactions of the ASAE 26(3):858-866.

- Droll, Robert W. Personal slide collection. Landscape Architect, Lacey, WA.
- Dyer, K. 1997. Estuaries: A Physical Introduction. 2nd Edition.
- Galli, J. 1997. Personal slide collection. Silver Spring, MD.
- Gobos, B. 1999. Malletts Bay Water Quality Inventory Report. Town of Colchester, Vermont.
- Gregoire, J., S. Horsley. 1996. Development of a Watershed-level Model for Use as a Management Tool to Assess Fecal Coliform Pollution Potential from Various Land Uses. Watershed '96.
- Lewis, Daniel. Personal correspondence. Department of Environmental Conservation 631-444-0475, dlewis@gw.dec.state.ny.us.
- Lewis, D., J. Kassner, R. Cerrato, and R. Finch. 1997. An Assessment of Shellfish Resources in the Deep Water Areas of the Peconic Estuary. Marine Sciences Research Center, State University of New York, Stonybrook, NY.
- Mallin, M.A. 2000. Effect of Human Development on Bacteriological Water Quality in Coastal Watersheds. *Ecological Applications*, 10(4):1047-56.
- Maryland Department of the Environment. 1999. Slide collection for implementation of the State Stormwater Management Program. Baltimore, MD.
- Massachusetts Executive Office of Environmental Affairs (MA EOEA), Massachusetts Department of Environmental Affairs (MA DEP), and U.S. Environmental Protection Agency (USEPA). 1997. *Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas: A Guide for Planners, Designers, and Municipal Officials*. Prepared by: Franklin, Hampden, Hampshire Conservation Districts, Northampton, MA.
- McCurry, S.W., M.S. Coyne, and E. Perfect. 1998. Fecal Coliform Transport through Intact Soil Blocks Amended with Poultry Manure. *J. Environmental Quality*. 27:86-92.
- Moore, J.A., M.E. Grismer, S.R. Crane, and J.R. Miner. 1983. Modeling Dairy Waste Management Systems' Influence on Coliform Concentration in Runoff. *Transactions of the American Society of Agricultural Engineers* 26(4):1194-1200.
- Novotny, V., et al. 1985. Estimating nonpoint pollution from small urban watersheds, *JWPCF*, 57, 339.
- Nationwide Urban Runoff Program (NURP). 1983.
- Nationwide Urban Runoff Program (NURP). 1987.

New Hampshire Department of Environmental Services. Stormwater Management and Erosion and Sediment Control Handbook for Urban and Developing Areas in New Hampshire. Exeter, NH.

Natural Resource Conservation Service (NRCS). June 1986. Urban Hydrology for Small Watersheds TR-55.

New York State Department of Environmental Conservation (NYSDEC). 6 NYCRR Part 47

Peconic Estuary Program (PEP). Comprehensive Conservation and Management Plan (CCMP). 2001.

Peconic Estuary Program (PEP). Comprehensive Conservation and Management Plan (CCMP). 1992. Brown tide module.

Peconic Estuary Program (PEP). Comprehensive Conservation and Management Plan, Pathogens Module-Draft, October 10, 1997.

Peconic Estuary Program (PEP). Comprehensive Conservation and Management Plan, Nutrient Module-Draft, May 28, 1999.

Pitt, Robert. 1987. Small Storm Urban Flow and Particulate Washoff Contributions to Outfall Discharges. A thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy. University of Wisconsin, Madison, WI.

SCDHS, Office of Ecology, Nitrogen Loading Budget and Trends: Major, External, Anthropogenic Nitrogen Sources: Groundwater and Duck Farms-DRAFT, January 15, 1999.

Sherer, B. et al. 1988. Resuspending Organisms from a Rangeland Stream Bottom. American Society of Agricultural Engineers, 31(4).

Sherer, B., J.R. Miner, J.A. Moore, and J.C. Buckhouse. 1992. Indicator Bacterial Survival in Stream Sediments. J. Environmental Quality, 21:591-595.

Schueler et al. 1992. A Current Assessment of Urban Best Management Practices. Metropolitan Washington Council of Governments.

Schueler et al. 1997. Center for Watershed Protection.

Schueler. 2000. Microbes and Urban Watersheds: Concentrations, Sources, & Pathways. Watershed Protection Techniques, 3(1):554-65.

Schueler. 2000. Microbes and Urban Watersheds: Ways to Kill 'Em. *Watershed Protection Techniques*, 3(1):566-74.

Southeastern Wisconsin Regional Planning Commission (SWRPC). 1991. *Costs of Urban Nonpoint Source Water Pollution Control Measures*. Waukesha, WI.

Suffolk County Department of Health Services (SCDHS). 1999. *Nitrogen Loading Budgets and Trends*.

Tetra Tech, Inc. *Three-Dimensional Hydrodynamic and Water Quality Model of the Peconic Estuary*, December 14, 1999.

Valiela, I., Albert, Meryll, and LaMontagne. *Fecal Coliform Loadings and Stocks in Buttermilk Bay, Massachusetts, USA, and Management Implications*. *Environmental Management*, 15(5):659-74.

Weiskel, P.K., B.L. Howes, and G.R. Heufelder. 1996. *Coliform Contamination of a Coastal Embayment: Sources and Transport Pathways*. *Environmental Science & Technology*, 30: 1872-81.

APPENDIX A

0.25" Rain Event, Average FC Concentrations, Pitt Method								
Fecal Coliform Load								
SW_ID	COUNT	SUM_AREA	AVE_FC	AVE_N	AVE_CN	AVE_Q	SUM_V	SUM_LOAD
1	18	17.7550	21118.5618	0.0000	86.3852	0.0000	0	0
2	5	9.5980	21088.0000	0.0000	88.5587	0.0000	0	0
3	18	25.3240	21088.0000	0.0000	87.0832	0.0000	0	0
4	21	12.5690	22011.6647	0.0000	91.4503	0.0040	5,141	1,132
5	6	0.7110	54784.1069	0.0000	97.9627	0.1043	7,622	4,176
6	3	0.8640	23121.9005	0.0000	89.2218	0.0001	5	1
7	33	8.1120	27809.8213	0.0000	93.0285	0.0118	9,837	2,736
8	7	1.2960	24913.3981	0.0000	93.8329	0.0181	2,413	601
9	132	75.4680	22830.7883	0.0000	85.1768	0.0000	0	0
10	64	58.0820	13701.4622	0.0000	94.8511	0.0292	174,496	23,909
11	40	26.5320	13535.4476	0.0000	91.7855	0.0052	14,232	1,926
12	139	37.1150	28682.9449	0.0000	91.8268	0.0054	20,546	5,893
13	21	32.4850	12686.0771	0.0000	90.7974	0.0021	7,040	893
14	15	5.4980	14370.3630	0.0000	93.4561	0.0149	8,433	1,212
15	20	6.1510	26397.6001	0.0000	93.8210	0.0180	11,384	3,005
16	32	6.5760	22422.8209	0.0000	93.2433	0.0133	8,993	2,016
17	65	9.8630	28888.6821	0.0000	91.7046	0.0049	4,968	1,435
18	31	9.9050	27178.5819	0.0000	93.5047	0.0153	15,586	4,236
19	60	69.8500	13815.7930	0.0000	93.7657	0.0175	125,730	17,371
20	2	1.1540	21088.0000	0.0000	85.2909	0.0000	0	0
21	3	2.6200	21088.0000	0.0000	84.6502	0.0000	0	0
22	34	7.7220	33595.0668	0.0000	94.9326	0.0303	24,051	8,080
23	12	2.8190	23115.1046	0.0000	93.2982	0.0137	3,972	918
24	14	4.3320	25518.7886	0.0000	85.8529	0.0000	0	0

0.25-inch, Pitt Method								
Nitrogen Load								
SW_ID	COUNT	SUM_AREA	AVE_FC	AVE_N	AVE_CN	AVE_Q	SUM_V	SUM_LOAD
1	18	17.7550	0.0000	1.6023	86.3852	0.0000	0	0.00
2	5	9.5980	0.0000	1.6000	88.5587	0.0000	0	0.00
3	18	25.3240	0.0000	1.6000	87.0832	0.0000	0	0.00
4	21	12.5690	0.0000	1.8676	91.4503	0.0040	5,141	0.02
5	6	0.7110	0.0000	4.1840	97.9627	0.1043	7,622	0.07
6	3	0.8640	0.0000	1.8081	89.2218	0.0001	5	0.00
7	33	8.1120	0.0000	2.1949	93.0285	0.0118	9,837	0.05
8	7	1.2960	0.0000	2.0119	93.8329	0.0181	2,413	0.01
9	132	75.4680	0.0000	2.1392	85.1768	0.0000	0	0.00
10	64	58.0820	0.0000	3.3454	94.8511	0.0292	174,496	1.29
11	40	26.5320	0.0000	2.8420	91.7855	0.0052	14,232	0.09
12	139	37.1150	0.0000	2.3532	91.8268	0.0054	20,546	0.11
13	21	32.4850	0.0000	2.8397	90.7974	0.0021	7,040	0.04
14	15	5.4980	0.0000	1.9816	93.4561	0.0149	8,433	0.04
15	20	6.1510	0.0000	2.1173	93.8210	0.0180	11,384	0.05
16	32	6.5760	0.0000	1.8465	93.2433	0.0133	8,993	0.04
17	65	9.8630	0.0000	2.1334	91.7046	0.0049	4,968	0.02
18	31	9.9050	0.0000	2.1288	93.5047	0.0153	15,586	0.07
19	60	69.8500	0.0000	2.8253	93.7657	0.0175	125,730	0.78
20	2	1.1540	0.0000	1.6000	85.2909	0.0000	0	0.00
21	3	2.6200	0.0000	1.6000	84.6502	0.0000	0	0.00
22	34	7.7220	0.0000	2.6205	94.9326	0.0303	24,051	0.14
23	12	2.8190	0.0000	2.0117	93.2982	0.0137	3,972	0.02
24	14	4.3320	0.0000	2.0103	85.8529	0.0000	0	0.00

0.6-inch Rain Event, Average FC Concentration, Pitt Method								
Fecal Coliform Load								
SW_ID	COUNT	SUM_AREA	AVE_FC	AVE_N	AVE_CN	AVE_Q	SUM_V	SUM_LOAD
1	18	17.7550	21118.5618	0.0000	78.3137	0.0008	1,381	292
2	5	9.5980	21088.0000	0.0000	80.7779	0.0061	6,065	1,279
3	18	25.3240	21088.0000	0.0000	79.0648	0.0018	4,749	1,001
4	21	12.5690	22011.6647	0.0000	83.2909	0.0179	23,149	5,095
5	6	0.7110	54784.1069	0.0000	97.9087	0.4029	29,438	16,127
6	3	0.8640	23121.9005	0.0000	81.3037	0.0080	714	165
7	33	8.1120	27809.8213	0.0000	86.2844	0.0425	35,443	9,857
8	7	1.2960	24913.3981	0.0000	85.5497	0.0352	4,692	1,169
9	132	75.4680	22830.7883	0.0000	77.9814	0.0004	3,378	771
10	64	58.0820	13701.4622	0.0000	91.7690	0.1343	801,534	109,822
11	40	26.5320	13535.4476	0.0000	87.1645	0.0525	143,117	19,372
12	139	37.1150	28682.9449	0.0000	85.3056	0.0330	125,872	36,104
13	21	32.4850	12686.0771	0.0000	86.1649	0.0413	137,771	17,478
14	15	5.4980	14370.3630	0.0000	88.7318	0.0741	41,865	6,016
15	20	6.1510	26397.6001	0.0000	86.7084	0.0471	29,800	7,866
16	32	6.5760	22422.8209	0.0000	86.8843	0.0492	33,221	7,449
17	65	9.8630	28888.6821	0.0000	84.5834	0.0269	27,308	7,889
18	31	9.9050	27178.5819	0.0000	86.5260	0.0451	45,921	12,481
19	60	69.8500	13815.7930	0.0000	89.6299	0.0891	639,323	88,328
20	2	1.1540	21088.0000	0.0000	76.9574	0.0000	0	0
21	3	2.6200	21088.0000	0.0000	76.2084	0.0000	0	0
22	34	7.7220	33595.0668	0.0000	89.5576	0.0878	69,660	23,402
23	12	2.8190	23115.1046	0.0000	84.2994	0.0248	7,175	1,658
24	14	4.3320	25518.7886	0.0000	77.6553	0.0002	92	24

0.6-inch, Pitt Method								
Nitrogen Load								
SW_ID	COUNT	SUM_AREA	AVE_FC	AVE_N	AVE_CN	AVE_Q	SUM_V	SUM_LOAD
1	18	17.7550	0.0000	1.6023	78.3137	0.0008	1,381	0.00
2	5	9.5980	0.0000	1.6000	80.7779	0.0061	6,065	0.02
3	18	25.3240	0.0000	1.6000	79.0648	0.0018	4,749	0.02
4	21	12.5690	0.0000	1.8676	83.2909	0.0179	23,149	0.10
5	6	0.7110	0.0000	4.1840	97.9087	0.4029	29,438	0.27
6	3	0.8640	0.0000	1.8081	81.3037	0.0080	714	0.00
7	33	8.1120	0.0000	2.1949	86.2844	0.0425	35,443	0.17
8	7	1.2960	0.0000	2.0119	85.5497	0.0352	4,692	0.02
9	132	75.4680	0.0000	2.1392	77.9814	0.0004	3,378	0.02
10	64	58.0820	0.0000	3.3454	91.7690	0.1343	801,534	5.91
11	40	26.5320	0.0000	2.8420	87.1645	0.0525	143,117	0.90
12	139	37.1150	0.0000	2.3532	85.3056	0.0330	125,872	0.65
13	21	32.4850	0.0000	2.8397	86.1649	0.0413	137,771	0.86
14	15	5.4980	0.0000	1.9816	88.7318	0.0741	41,865	0.18
15	20	6.1510	0.0000	2.1173	86.7084	0.0471	29,800	0.14
16	32	6.5760	0.0000	1.8465	86.8843	0.0492	33,221	0.14
17	65	9.8630	0.0000	2.1334	84.5834	0.0269	27,308	0.13
18	31	9.9050	0.0000	2.1288	86.5260	0.0451	45,921	0.22
19	60	69.8500	0.0000	2.8253	89.6299	0.0891	639,323	3.98
20	2	1.1540	0.0000	1.6000	76.9574	0.0000	0	0.00
21	3	2.6200	0.0000	1.6000	76.2084	0.0000	0	0.00
22	34	7.7220	0.0000	2.6205	89.5576	0.0878	69,660	0.40
23	12	2.8190	0.0000	2.0117	84.2994	0.0248	7,175	0.03
24	14	4.3320	0.0000	2.0103	77.6553	0.0002	92	0.00

1.3-inch Rain Event, Average FC Concentration, Pitt Method								
FC Bacteria Load								
SW_ID	COUNT	SUM_AREA	AVE_FC	AVE_N	AVE_CN	AVE_Q	SUM_V	SUM_LOAD
1	18	17.7550	21118.5618	0.0000	71.8253	0.0599	109,243	23,070
2	5	9.5980	21088.0000	0.0000	74.4867	0.0936	92,330	19,471
3	18	25.3240	21088.0000	0.0000	72.6085	0.0689	179,356	37,823
4	21	12.5690	22011.6647	0.0000	76.7699	0.1297	167,601	36,892
5	6	0.7110	54784.1069	0.0000	97.8655	1.0705	78,225	42,855
6	3	0.8640	23121.9005	0.0000	74.9698	0.1007	8,939	2,067
7	33	8.1120	27809.8213	0.0000	80.8901	0.2147	178,963	49,769
8	7	1.2960	24913.3981	0.0000	79.0196	0.1727	23,002	5,731
9	132	75.4680	22830.7883	0.0000	72.3074	0.0654	506,874	115,723
10	64	58.0820	13701.4622	0.0000	89.3171	0.4986	2,976,257	407,791
11	40	26.5320	13535.4476	0.0000	83.4721	0.2834	772,629	104,579
12	139	37.1150	28682.9449	0.0000	80.1153	0.1965	749,694	215,034
13	21	32.4850	12686.0771	0.0000	82.4663	0.2550	851,308	107,998
14	15	5.4980	14370.3630	0.0000	84.9527	0.3292	186,012	26,731
15	20	6.1510	26397.6001	0.0000	81.0157	0.2177	137,622	36,329
16	32	6.5760	22422.8209	0.0000	81.7243	0.2354	159,095	35,674
17	65	9.8630	28888.6821	0.0000	78.9311	0.1709	173,192	50,033
18	31	9.9050	27178.5819	0.0000	80.9437	0.2160	219,835	59,748
19	60	69.8500	13815.7930	0.0000	86.2711	0.3746	2,688,844	371,485
20	2	1.1540	21088.0000	0.0000	70.2804	0.0441	5,226	1,102
21	3	2.6200	21088.0000	0.0000	69.4557	0.0367	9,880	2,084
22	34	7.7220	33595.0668	0.0000	85.2619	0.3394	269,378	90,498
23	12	2.8190	23115.1046	0.0000	77.2367	0.1380	39,990	9,244
24	14	4.3320	25518.7886	0.0000	71.2479	0.0536	23,885	6,095

1.3-inch Rain Event, Pitt Method								
Nitrogen Load								
SW_ID	COUNT	SUM_AREA	AVE_FC	AVE_N	AVE_CN	AVE_Q	SUM_V	SUM_LOAD
1	18	17.7550	0.0000	1.6023	71.8253	0.0599	109,243	0.39
2	5	9.5980	0.0000	1.6000	74.4867	0.0936	92,330	0.33
3	18	25.3240	0.0000	1.6000	72.6085	0.0689	179,356	0.63
4	21	12.5690	0.0000	1.8676	76.7699	0.1297	167,601	0.69
5	6	0.7110	0.0000	4.1840	97.8655	1.0705	78,225	0.72
6	3	0.8640	0.0000	1.8081	74.9698	0.1007	8,939	0.04
7	33	8.1120	0.0000	2.1949	80.8901	0.2147	178,963	0.87
8	7	1.2960	0.0000	2.0119	79.0196	0.1727	23,002	0.10
9	132	75.4680	0.0000	2.1392	72.3074	0.0654	506,874	2.39
10	64	58.0820	0.0000	3.3454	89.3171	0.4986	2,976,257	21.93
11	40	26.5320	0.0000	2.8420	83.4721	0.2834	772,629	4.84
12	139	37.1150	0.0000	2.3532	80.1153	0.1965	749,694	3.89
13	21	32.4850	0.0000	2.8397	82.4663	0.2550	851,308	5.32
14	15	5.4980	0.0000	1.9816	84.9527	0.3292	186,012	0.81
15	20	6.1510	0.0000	2.1173	81.0157	0.2177	137,622	0.64
16	32	6.5760	0.0000	1.8465	81.7243	0.2354	159,095	0.65
17	65	9.8630	0.0000	2.1334	78.9311	0.1709	173,192	0.81
18	31	9.9050	0.0000	2.1288	80.9437	0.2160	219,835	1.03
19	60	69.8500	0.0000	2.8253	86.2711	0.3746	2,688,844	16.73
20	2	1.1540	0.0000	1.6000	70.2804	0.0441	5,226	0.02
21	3	2.6200	0.0000	1.6000	69.4557	0.0367	9,880	0.03
22	34	7.7220	0.0000	2.6205	85.2619	0.3394	269,378	1.55
23	12	2.8190	0.0000	2.0117	77.2367	0.1380	39,990	0.18
24	14	4.3320	0.0000	2.0103	71.2479	0.0536	23,885	0.11

0.25" Rain Event, Average FC Concentrations, Pitt Method								
Fecal Coliform Load								
SW_ID	COUNT	SUM_AREA	AVE_FC	AVE_N	AVE_CN	AVE_Q	SUM_V	SUM_LOAD
1	394	270.9080	15220.0000	0.0000	94.0000	0.0250	683,089	103,963
2	63	26.1790	20100.0000	0.0000	87.0000	0.0000	0	0
3	107	47.3610	16594.0000	0.0000	96.0000	0.0480	233,309	38,720
4	50	12.4590	35630.0000	0.0000	96.0000	0.0490	63,129	22,493
5	47	11.2310	22040.0000	0.0000	92.0000	0.0080	9,314	2,052
6	10	4.9400	24345.0000	0.0000	93.0000	0.0110	5,773	1,404
7	45	26.8060	21028.0000	0.0000	95.0000	0.0340	94,255	19,825
8	75	21.3310	28275.0000	0.0000	92.0000	0.0050	10,136	2,865
9	25	6.1420	32886.0000	0.0000	94.0000	0.0210	13,467	4,431
10	13	2.6930	28760.0000	0.0000	94.0000	0.0210	5,806	1,671
Nitrogen Load								
SW_ID	COUNT	SUM_AREA	AVE_FC	AVE_N	AVE_CN	AVE_Q	SUM_V	SUM_LOAD
1	394	270.9080	0.0000	3.0350	94.0000	0.0250	683,089	4.57
2	63	26.1790	0.0000	2.0070	87.0000	0.0000	0	0.00
3	107	47.3610	0.0000	3.0950	96.0000	0.0480	233,309	1.59
4	50	12.4590	0.0000	3.3320	96.0000	0.0490	63,129	0.46
5	47	11.2310	0.0000	1.9770	92.0000	0.0080	9,314	0.04
6	10	4.9400	0.0000	2.0400	93.0000	0.0110	5,773	0.03
7	45	26.8060	0.0000	2.6070	95.0000	0.0340	94,255	0.54
8	75	21.3310	0.0000	2.3520	92.0000	0.0050	10,136	0.05
9	25	6.1420	0.0000	2.4180	94.0000	0.0210	13,467	0.07
10	13	2.6930	0.0000	2.2920	94.0000	0.0210	5,806	0.03

0.6" Rain Event, Average FC Concentrations, Pitt Method								
Fecal Coliform Load								
SW_ID	COUNT	SUM_AREA	AVE_FC	AVE_N	AVE_CN	AVE_Q	SUM_V	SUM_LOAD
1	394	270.9080	15220.0000	0.0000	90	0.0920	2,549,545	388,045
2	63	26.1790	20100.0000	0.0000	80	0.0040	10,480	2,107
3	107	47.3610	16594.0000	0.0000	92	0.1380	671,774	111,474
4	50	12.4590	35630.0000	0.0000	94	0.2170	277,341	98,817
5	47	11.2310	22040.0000	0.0000	85	0.0270	31,440	6,931
6	10	4.9400	24345.0000	0.0000	84	0.0210	10,811	2,632
7	45	26.8060	21028.0000	0.0000	90	0.0930	255,632	53,751
8	75	21.3310	28275.0000	0.0000	84	0.0250	54,416	15,390
9	25	6.1420	32886.0000	0.0000	87	0.0530	33,428	10,996
10	13	2.6930	28760.0000	0.0000	87	0.0470	12,991	3,735
Nitrogen Load								
SW_ID	COUNT	SUM_AREA	AVE_FC	AVE_N	AVE_CN	AVE_Q	SUM_V	SUM_LOAD
1	394	270.9080	0.0000	3.0350	90.0000	0.0920	2,549,545	17.04
2	63	26.1790	0.0000	2.0070	80.0000	0.0040	10,480	0.05
3	107	47.3610	0.0000	3.0950	92.0000	0.1380	671,774	4.58
4	50	12.4590	0.0000	3.3320	94.0000	0.2170	277,341	2.04
5	47	11.2310	0.0000	1.9770	85.0000	0.0270	31,440	0.14
6	10	4.9400	0.0000	2.0400	84.0000	0.0210	10,811	0.05
7	45	26.8060	0.0000	2.6070	90.0000	0.0930	255,632	1.47
8	75	21.3310	0.0000	2.3520	84.0000	0.0250	54,416	0.28
9	25	6.1420	0.0000	2.4180	87.0000	0.0530	33,428	0.18
10	13	2.6930	0.0000	2.2920	87.0000	0.0470	12,991	0.07

1.3" Rain Event, Average FC Concentrations, Pitt Method								
Fecal Coliform Load								
SW_ID	COUNT	SUM_AREA	AVE_FC	AVE_N	AVE_CN	AVE_Q	SUM_V	SUM_LOAD
1	394	270.9080	15220.0000	0.0000	86.0000	0.3670	10,222,454	1,555,853
2	63	26.1790	20100.0000	0.0000	74.0000	0.0940	252,222	50,699
3	107	47.3610	16594.0000	0.0000	89.0000	0.4690	2,281,526	378,599
4	50	12.4590	35630.0000	0.0000	93.0000	0.7020	898,999	320,312
5	47	11.2310	22040.0000	0.0000	78.0000	0.1610	185,936	40,983
6	10	4.9400	24345.0000	0.0000	77.0000	0.1280	65,054	15,838
7	45	26.8060	21028.0000	0.0000	86.0000	0.3510	967,758	203,504
8	75	21.3310	28275.0000	0.0000	79.0000	0.1640	359,350	101,603
9	25	6.1420	32886.0000	0.0000	82.0000	0.2370	149,383	49,132
10	13	2.6930	28760.0000	0.0000	81.0000	0.2140	59,120	17,004
1.3" Rain Event, Average FC Concentrations, Pitt Method								
Nitrogen Load								
SW_ID	COUNT	SUM_AREA	AVE_FC	AVE_N	AVE_CN	AVE_Q	SUM_V	SUM_LOAD
1	394	270.9080	0.0000	3.0350	86.0000	0.3670	10,222,454	68.33
2	63	26.1790	0.0000	2.0070	74.0000	0.0940	252,222	1.12
3	107	47.3610	0.0000	3.0950	89.0000	0.4690	2,281,526	15.55
4	50	12.4590	0.0000	3.3320	93.0000	0.7020	898,999	6.60
5	47	11.2310	0.0000	1.9770	78.0000	0.1610	185,936	0.81
6	10	4.9400	0.0000	2.0400	77.0000	0.1280	65,054	0.29
7	45	26.8060	0.0000	2.6070	86.0000	0.3510	967,758	5.56
8	75	21.3310	0.0000	2.3520	79.0000	0.1640	359,350	1.86
9	25	6.1420	0.0000	2.4180	82.0000	0.2370	149,383	0.80
10	13	2.6930	0.0000	2.2920	81.0000	0.2140	59,120	0.30

0.25-inch Rain Event, Average FC Conatants, Pitt Method								
Fecal Coliform Bacteria Loading								
SW_ID	COUNT	SUM_AREA	AVE_FC	AVE_N	AVE_CN	AVE_Q	SUM_V	SUM_LOAD
1	177	66.7860	26175.4290	0.0000	90.5230	0.0020	10,408	2,724
2	299	73.1210	32379.8710	0.0000	94.7960	0.0290	214,364	69,411
3	74	41.6830	23980.2250	0.0000	85.2500	0.0000	0	0
4	7	16.6310	20963.6770	0.0000	79.1660	0.0000	0	0
5	103	67.4920	22527.8450	0.0000	92.1460	0.0070	47,094	10,609
6	17	4.1380	27299.4130	0.0000	96.6390	0.0620	26,215	7,157
7	30	9.9110	27525.4620	0.0000	94.3550	0.0230	23,751	6,537
8	161	59.5010	27654.8970	0.0000	91.4700	0.0040	24,749	6,844
9	106	18.9560	30598.3550	0.0000	95.5920	0.0400	78,340	23,971
10	78	11.3160	36206.2500	0.0000	93.7800	0.0180	20,519	7,429
Nitrogen Loading								
SW_ID	COUNT	SUM_AREA	AVE_FC	AVE_N	AVE_CN	AVE_Q	SUM_V	SUM_LOAD
1	177	66.7860	0.0000	1.9440	90.5230	0.0020	10,408	0.04
2	299	73.1210	0.0000	2.4740	94.7960	0.0290	214,364	1.17
3	74	41.6830	0.0000	1.9760	85.2500	0.0000	0	0.00
4	7	16.6310	0.0000	1.6050	79.1660	0.0000	0	0.00
5	103	67.4920	0.0000	2.0020	92.1460	0.0070	47,094	0.21
6	17	4.1380	0.0000	2.4760	96.6390	0.0620	26,215	0.14
7	30	9.9110	0.0000	2.3020	94.3550	0.0230	23,751	0.12
8	161	59.5010	0.0000	2.1010	91.4700	0.0040	24,749	0.11
9	106	18.9560	0.0000	2.3250	95.5920	0.0400	78,340	0.40
10	78	11.3160	0.0000	2.5190	93.7800	0.0180	20,519	0.11

0.6-inch Rain Event, Average FC Coefficients, Pitt Method								
Fecal Coliform Bacteria Loading								
SW_ID	COUNT	SUM_AREA	AVE_FC	AVE_N	AVE_CN	AVE_Q	SUM_V	SUM_LOAD
1	177	66.7860	26175.4290	0.0000	83.5170	0.0190	132,752	34,749
2	299	73.1210	32379.8710	0.0000	89.7430	0.0910	684,576	221,665
3	74	41.6830	23980.2250	0.0000	78.0950	0.0010	2,291	549
4	7	16.6310	20963.6770	0.0000	70.9930	0.0000	0	0
5	103	67.4920	22527.8450	0.0000	85.4640	0.0340	238,868	53,812
6	17	4.1380	27299.4130	0.0000	93.3280	0.1780	75,792	20,691
7	30	9.9110	27525.4620	0.0000	88.0710	0.0640	65,535	18,039
8	161	59.5010	27654.8970	0.0000	84.7750	0.0280	174,120	48,153
9	106	18.9560	30598.3550	0.0000	90.1740	0.0990	193,222	59,123
10	78	11.3160	36206.2500	0.0000	88.2230	0.0660	77,323	27,996
Nitrogen Loading								
SW_ID	COUNT	SUM_AREA	AVE_FC	AVE_N	AVE_CN	AVE_Q	SUM_V	SUM_LOAD
1	177	66.7860	0.0000	1.9440	83.5170	0.0190	132,752	0.57
2	299	73.1210	0.0000	2.4740	89.7430	0.0910	684,576	3.73
3	74	41.6830	0.0000	1.9760	78.0950	0.0010	2,291	0.01
4	7	16.6310	0.0000	1.6050	70.9930	0.0000	0	0.00
5	103	67.4920	0.0000	2.0020	85.4640	0.0340	238,868	1.05
6	17	4.1380	0.0000	2.4760	93.3280	0.1780	75,792	0.41
7	30	9.9110	0.0000	2.3020	88.0710	0.0640	65,535	0.33
8	161	59.5010	0.0000	2.1010	84.7750	0.0280	174,120	0.81
9	106	18.9560	0.0000	2.3250	90.1740	0.0990	193,222	0.99
10	78	11.3160	0.0000	2.5190	88.2230	0.0660	77,323	0.43

1.3-inch Rain Event, Average FC Coefficients, Pitt Method								
Fecal Coliform Bacteria Loading								
SW_ID	COUNT	SUM_AREA	AVE_FC	AVE_N	AVE_CN	AVE_Q	SUM_V	SUM_LOAD
1	177	66.7860	26175.4290	0.0000	77.8900	0.1500	1,030,701	269,791
2	299	73.1210	32379.8710	0.0000	85.6620	0.3530	2,652,999	859,038
3	74	41.6830	23980.2250	0.0000	72.4380	0.0670	286,518	68,708
4	7	16.6310	20963.6770	0.0000	64.5120	0.0070	11,968	2,509
5	103	67.4920	22527.8450	0.0000	80.0960	0.1960	1,360,288	306,444
6	17	4.1380	27299.4130	0.0000	90.6350	0.5620	239,047	65,258
7	30	9.9110	27525.4620	0.0000	83.0410	0.2710	275,974	75,963
8	161	59.5010	27654.8970	0.0000	79.4110	0.1810	1,106,708	306,059
9	106	18.9560	30598.3550	0.0000	85.7680	0.3570	694,943	212,641
10	78	11.3160	36206.2500	0.0000	83.8010	0.2930	340,855	123,411
Nitrogen Loading								
SW_ID	COUNT	SUM_AREA	AVE_FC	AVE_N	AVE_CN	AVE_Q	SUM_V	SUM_LOAD
1	177	66.7860	0.0000	1.9440	77.8900	0.1500	1,030,701	4.41
2	299	73.1210	0.0000	2.4740	85.6620	0.3530	2,652,999	14.46
3	74	41.6830	0.0000	1.9760	72.4380	0.0670	286,518	1.25
4	7	16.6310	0.0000	1.6050	64.5120	0.0070	11,968	0.04
5	103	67.4920	0.0000	2.0020	80.0960	0.1960	1,360,288	6.00
6	17	4.1380	0.0000	2.4760	90.6350	0.5620	239,047	1.30
7	30	9.9110	0.0000	2.3020	83.0410	0.2710	275,974	1.40
8	161	59.5010	0.0000	2.1010	79.4110	0.1810	1,106,708	5.12
9	106	18.9560	0.0000	2.3250	85.7680	0.3570	694,943	3.56
10	78	11.3160	0.0000	2.5190	83.8010	0.2930	340,855	1.89

0.25-inch Rain Event, Average FC Constants, Pitt Method								
Fecal Coliform Bacteria Loading								
SW_ID	COUNT	SUM_AREA	AVE_FC	AVE_N	AVE_CN	AVE_Q	SUM_V	SUM_LOAD
1	91	28.9870	31872.5680	0.0000	91.6020	0.0050	13,450.9	4,287.1
2	55	24.4170	27760.8750	0.0000	93.0560	0.0120	30,078.0	8,349.9
3	83	26.2010	28077.7400	0.0000	86.4810	0.0000	0.0	0.0
4	24	12.1100	23013.3110	0.0000	93.4500	0.0150	18,513.8	4,260.6
5	19	7.3150	24126.7810	0.0000	93.4350	0.0150	11,092.0	2,676.2
Nitrogen Loading								
SW_ID	COUNT	SUM_AREA	AVE_FC	AVE_N	AVE_CN	AVE_Q	SUM_V	SUM_LOAD
1	91	28.9870	0.0000	2.2320	91.6020	0.0050	13,450.9	0.07
2	55	24.4170	0.0000	2.1840	93.0560	0.0120	30,078.0	0.14
3	83	26.2010	0.0000	2.1180	86.4810	0.0000	0.0	0.00
4	24	12.1100	0.0000	2.0000	93.4500	0.0150	18,513.8	0.08
5	19	7.3150	0.0000	2.0000	93.4350	0.0150	11,092.0	0.05

0.6-inch Rain Event, Average FC Coefficients, Pitt Method								
Fecal Coliform Bacteria Loading								
SW_ID	COUNT	SUM_AREA	AVE_FC	AVE_N	AVE_CN	AVE_Q	SUM_V	SUM_LOAD
1	91	28.9870	31872.5680	0.0000	84.9470	0.0300	89,045.6	28,381.1
2	55	24.4170	27760.8750	0.0000	85.5570	0.0350	88,555.8	24,583.9
3	83	26.2010	28077.7400	0.0000	78.9050	0.0020	4,193.4	1,177.4
4	24	12.1100	23013.3110	0.0000	84.5650	0.0270	33,350.5	7,675.1
5	19	7.3150	24126.7810	0.0000	84.6800	0.0280	20,830.4	5,025.7
Nitrogen Loading								
SW_ID	COUNT	SUM_AREA	AVE_FC	AVE_N	AVE_CN	AVE_Q	SUM_V	SUM_LOAD
1	91	28.9870	0.0000	2.2320	84.9470	0.0300	89,045.6	0.44
2	55	24.4170	0.0000	2.1840	85.5570	0.0350	88,555.8	0.43
3	83	26.2010	0.0000	2.1180	78.9050	0.0020	4,193.4	0.02
4	24	12.1100	0.0000	2.0000	84.5650	0.0270	33,350.5	0.15
5	19	7.3150	0.0000	2.0000	84.6800	0.0280	20,830.4	0.09

1.3-inch Rain Event, Average FC Coefficients, Pitt Method								
Fecal Coliform Bacteria Loading								
SW_ID	COUNT	SUM_AREA	AVE_FC	AVE_N	AVE_CN	AVE_Q	SUM_V	SUM_LOAD
1	91	28.9870	31872.5680	0.0000	79.6660	0.1870	555,658.7	177,102.7
2	55	24.4170	27760.8750	0.0000	79.6200	0.1860	465,533.6	129,236.2
3	83	26.2010	28077.7400	0.0000	72.9480	0.0730	196,741.5	55,240.6
4	24	12.1100	23013.3110	0.0000	77.5810	0.1440	179,658.1	41,345.3
5	19	7.3150	24126.7810	0.0000	77.8090	0.1490	111,728.3	26,956.4
Nitrogen Loading								
SW_ID	COUNT	SUM_AREA	AVE_FC	AVE_N	AVE_CN	AVE_Q	SUM_V	SUM_LOAD
1	91	28.9870	0.0000	2.2320	79.6660	0.1870	555,658.7	2.73
2	55	24.4170	0.0000	2.1840	79.6200	0.1860	465,533.6	2.24
3	83	26.2010	0.0000	2.1180	72.9480	0.0730	196,741.5	0.92
4	24	12.1100	0.0000	2.0000	77.5810	0.1440	179,658.1	0.79
5	19	7.3150	0.0000	2.0000	77.8090	0.1490	111,728.3	0.49

APPENDIX B

- *Pooper Scooper Ordinance.* Adopting and enforcing pooper scooper ordinances is another way to reduce pet waste from entering watersheds.



Example of public education regarding pet waste management
(source: King County Washington)

APPENDIX B

2.0 EVALUATION OF STORMWATER BEST MANAGEMENT PRACTICES

This section of the report provides a description of each of the stormwater management practices. It is organized into preservation (pre-development) and remedial (post-development) measures.

2.1 Land Use Planning and Preservation

2.1.1 Land Acquisition

One obvious way for a community to protect a resource is to buy the land outright. Acquisition priorities may include wetlands and streambanks within coastal watershed, often for access opportunities as well as for resource protection. Outright purchase of land can take four variations:

- 1) Purchase at fair market value: The buyer (community or conservation group) pays the seller the fair market value for the property.
- 2) Bargain purchase: The purchase of property below fair market value by a conservation organization or municipality. The difference between fair market value and the reduced price may qualify as a charitable deduction from income taxes for the seller.
- 3) Installment purchase: The property is purchased over a period of years. Installment purchases allow the town to spread the purchase costs over a number of years.
- 4) Purchase with a reserved life estate: The property is transferred to the town upon the death of the individual land owner. This option allows landowners to sell now, but to continue to use their property during their lifetime and/or the lifetimes of other members of their immediate family. Because of the continued use, the purchase price may be lower than fair market value.

An innovative technique for land acquisition is a land bank. Land banks receive a percentage of fees generated by real estate transfers, and use this money to fund land acquisition. Land banks are usually created by the state legislature and may apply to specific regions or statewide.

A more tradition, frequently controversial, form of land acquisition is through eminent domain. If a community can demonstrate the value of a given parcel for the public good, it can take ownership of that parcel. However, due compensation must be given to the previous owner, in accordance with the Fifth Amendment to the U.S. Constitution which states, "...nor shall private property be taken for public use without just compensation." Public approval is required or eminent domain action, since public money is spent to

compensate the previous owner. Eminent domain takings are frequently contested by the previous owner, who believes the land to be worth more than he/she is offered by the community.

Eminent domain takings should not be confused with a “takings” claim discussed previously, where a land owner challenges a town that a zoning bylaw or other regulation prohibits him from all uses of his land, i.e., his land has effectively been taken without compensation.

2.1.2 Land Donation

Land owners are often in the position of being able to donate a piece of land either to the community or a non-profit organization such as local land trusts. If so, they will find that giving the land for preservation costs them far less than they might think, particularly when a variety of tax savings are taken into account.

The initial benefit to the person donating the land comes in the elimination of estate or capital gains taxes. In addition, real estate taxes, insurance and maintenance costs are avoided. And, the entire value of the donation can be deducted, over time, from federal and, in many cases, state income tax obligations.

Donations of ecologically significant land within coastal watershed can be a particularly important technique for resource protection. Donations which provide access to water often help fulfill community goals of increased public access to waterways.

2.1.3 Conservation Easements

An easement is a limited right to use or restrict land owned by someone else. Easements are either positive (rights-of way) or negative (conservation, scenic) and may take a variety of forms. Easements can effectively assist a community in protecting land from development by restricting all or a portion of the property to open space or limited development uses. The granting of a conservation easement does not involve the transfer of ownership of the land; instead it means giving up certain development rights of the property. For example, a conservation easement may restrict the number of houses to be built upon a parcel; restrict the types of development allowed on the parcel; or specify that portions of the parcel remain undeveloped in perpetuity.

2.2 Zoning

Zoning regulations have been used throughout the country, in coastal and inland areas, to segregate different and possibly conflicting activities into different areas of a community. Following are several techniques that may be used to protect coastal resources.

- Overlay water resource protection districts
- Watersheet zoning
- Prohibition of various land uses

- Special permitting
- Large lot zoning
- Transfer of development rights
- Cluster/PUD design
- Growth controls/timing
- Performance standards

2.2.1 Overlay Water Resource Protection Districts

One technique designed to update zoning regulations for protection of a surface or groundwater resource is the creation and adoption of overlay water resource protection districts through an ordinance or bylaw.

These ordinances or bylaws, while varying in their approach toward resource protection (i.e., prohibition of various uses versus special permitting and/or performance criteria), are similar in their goals of defining the resource by mapping watershed boundaries and enacting specific legislation for land uses and development within these boundaries.

2.2.2 Watersheet Zoning

A new zoning technique that has been instituted in a few communities (but not yet tested extensively) is watersheet zoning. This is simply the idea of extending zoning districts onto water bodies. Under traditional zoning, specific areas of a community are set aside for various land uses. Under watersheet zoning, certain areas of the waterbody are set aside for such water-dependent uses as navigation channels, mooring areas, water-skiing, and so on.

2.2.3 Prohibition of Various Land Uses

Virtually every community that has adopted zoning prohibits certain land uses from specific sections of the community, although the rationale behind such prohibition may or may not be related to water resource protection. While not the most creative nor effective approach toward resource protection, prohibition of land uses such as gas stations, sewage treatment plants, landfills, or others involving the use, storage and disposal of toxic and/or hazardous materials is a first step toward the development of a comprehensive water resource protection strategy.

2.2.4 Special Permitting

If applied correctly, the special permitting (conditional use) process can be used effectively to regulate uses and structures that may potentially denigrate water quality. For example, many communities use the special permitting process to prohibit underground storage tanks or limit lawn area, thereby limiting potential fertilizer use, within watershed or groundwater recharge areas.

Examples of such use of the special permit process can be found on Cape Cod, Massachusetts, in the Cape Cod Regional Policy Plan as administered by the Cape Cod Commission, a regional planning and regulatory agency. New development projects that are designated as Developments of Regional Impact (DRI) must meet the Minimum Performance Standards of the Plan. One set of performance standards governs the protection of water resources, with the goal to “maintain the overall quality and quantity of Cape Cod’s groundwater to ensure a sustainable supply of untreated high-quality drinking water and to preserve and restore the ecological integrity of marine and fresh surface waters (Cape Cod Commission, 2002).” The performance standards, among other requirements, limit the amount of nitrogen loading allowed from a new development, with respect to the water resource recharge area in which it is located: wellhead protection areas, fresh water recharge area, marine recharge area, and potential water supply area. The nitrogen loading performance standards can be met through site designs that limit lawn size and landscaped area, turf management plans, and special conditions to use only specified organic or other fertilizers in landscaping. A copy of these performance standards is provided at the end of this Appendix for reference.

The Martha’s Vineyard Commission is a similar regional planning and regulatory agency within Duke’s County on Martha’s Vineyard, Massachusetts. That Commission, likewise, implements a special permit process for new development that can use its power to apply reasonable permit conditions to assure that new development meets the Commission’s Standards and Criteria for a Development of Regional Impact. It is reasonable that towns and regional regulatory agencies, if applicable, may utilize a similar special permit process to limit nutrient loading as it is directly related to water resources.

2.2.5 Large Lot Zoning

Large lot zoning, as the title implies, seeks to limit water resource degradation by reducing the number of buildings and, therefore, septic systems and other associated threats within a protection area. Large lot zoning has limited effectiveness in rapidly growing areas, since zoning and subdivision enabling legislation provides a broad protection to land owners from increases in minimum lot sizes. Nevertheless, when used as part of an overall protection strategy, large lot zoning within resource contributing areas can be an effective tool against water contamination. There is no definition of “large lot” zoning, although case law has upheld different variations on local government’s use of minimum lot size.

2.2.6 Transfer of Development Rights

The idea of “transfer of development rights” (TDR) is based on the concept that a parcel of land has a bundle of different “rights” associated with it. A TDR program allows a landowner to separate his or her right to develop the land, as permitted by zoning, from the other rights associated with the land, and sell those development rights.

To implement a TDR program, a governmental entity such as the town would prepare a plan designating the parcels or districts from which development rights could be transferred (a “sending” or “donor” parcel), and the parcels or districts which would receive those development rights and develop at a higher density than allowed by the underlying zoning district (a “receiving parcel”).

Typically, a sending parcel or district might be within a contributing areas to an estuary or other water resource. A receiving parcel is able, both from a physical standpoint and in terms of the community’s growth program, to accommodate additional development beyond that allowed as-of-right by zoning. In selling his or her development rights, a landowner would gain the cash value of whatever development rights the market associates with the land, and yet would keep the land in a less intensive use and help protect the resource in question. A perpetual easement or some other development restriction would be recorded with the deed of the sending or donor parcel. The purchaser of the development rights gains the ability to develop the receiving parcel at a higher density than allowed “as-of-right” and can recapture the cost of the purchased development rights through the more intensive use of the receiving parcel.

2.2.7 Cluster/Planned Unit Development Design

Cluster zoning, or planned unit development (PUD), is an alternative to the standard grid-style subdivision. It allows buildings to be “clustered” more densely on the portion of the site most suitable for development, in exchange for preserving the rest of the site, including any sensitive coastal areas, as contiguous open space. In a cluster development, smaller building lots are allowed, with resulting land savings set aside in contiguous areas of open space.

Clustering can be done at the same overall density that could be obtained in a grid system by using smaller individual lots, therefore preserving important natural areas. Often a greater number of lots (units) are allowed as a bonus for leaving more open space. Typically, cluster development allows shorter streets, reducing impervious surfaces and decreasing runoff, which may carry contaminants.

Cluster design and PUDs provide tremendous flexibility for both the developer and municipality, and often allow for greater creativity in the division of large land parcels.

2.2.8 Growth Controls/Timing

Growth controls are techniques that are used to slow or guide a community’s growth, ideally in concert with its ability to “support” growth. The term “support” has been broadly defined, and can include issues ranging from a city or town’s physical and financial ability to provide public facilities (roads, water, sewer, schools, and public safety) to its ability to retain its once rural, historic character. Growth controls vary in their application and have included outright moratoria to limitations on numbers of building permits issued in any twelve month period. One of the most widely referenced examples of growth control in the 1969 Ramapo, New York, ordinance that limited

growth and development in the community to a rate commensurate with the town's ability to provide services to new (and existing) residents.

Falmouth, Massachusetts, used growth controls to limit land subdivision within the rapidly developing watersheds to its coastal ponds. In 1985, the town adopted a zoning regulation designed to slow development within these sensitive resource areas. The idea was to "buy time" for the town to implement other management controls such as re-zoning, land acquisition and monitoring to protect the coastal water resources.

2.2.9 Performance Standards

Performance standards are based on the assumption that any given resource has a threshold, beyond which the resource's ability to function deteriorates to unacceptable levels. Performance controls assume that most uses are allowable within a designated area provided that the uses do not and will not overload the resources. A good example of a performance standard is one designed to protect surface water quality by setting a critical threshold for a contaminant. Those land uses which will cause the threshold to be exceeded in the waterbody are not allowed.

Approximately one year before Falmouth, Massachusetts, adopted the growth controls noted above, the town instituted a unique and precedent-setting approach to manage development in watershed to the town's coastal resources. All development within the defined, mapped areas (mapped as an overlay zoning district) was required to adhere to strict performance standards. In effect, these standards were designed to ensure that all development within watersheds to coastal ponds, when analyzed cumulatively, would not exceed the assimilative capacity of the resources.

2.3 Preservation Techniques: Site Planning

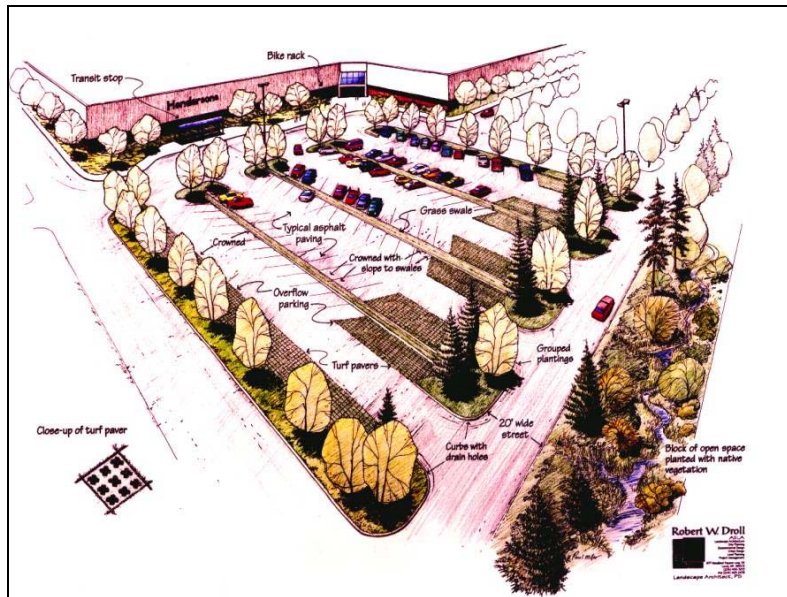
The potential impacts of construction and development within a watershed can be greatly reduced through better site design. Once a site has been chosen for development, and the type of development (i.e., commercial, residential, industrial, agricultural, etc.) has been determined, there are many techniques that can be incorporated into the design of the site that can reduce potential negative impacts on surrounding resources. Better site design can be implemented by striving for three goals at each individual site: reducing the amount of impervious cover, increasing the natural lands set aside for conservation and using pervious areas for more effective stormwater treatment. The following methods are adapted from the Center for Watershed Protection "Better Site Design: A Handbook for Changing Development Rules in Your Community" (CWP, 1998).

These goals can be reached by implementing one or a combination of appropriate techniques that fall into three broad areas:

- 1) Residential streets and parking lots
- 2) Lot development
- 3) Conservation of natural areas

Each site, with its individual location, size, use, proximity to important natural resources, climate, soil and hydrology, will dictate which techniques are appropriate. In addition, local zoning bylaws may require or possibly even prohibit the use of certain techniques. A list of these techniques is provided below.

- 1) Reduce residential street width by designing for expected traffic volumes.
- 2) Reduce residential street length by examining alternative street layouts to maximize the number of homes served per unit length of road.
- 3) Reduce residential right-of-way widths to minimum possible, while still accommodating all needs.
- 4) Minimize cul-de-sacs and use alternative layouts such as a horseshoe with landscaping where possible.
- 5) Use vegetated open channels to convey and treat stormwater in street rights-of-way when possible.
- 6) Reduce the parking ratio for residential, transit and other parking as much as possible.
- 7) Reduce parking lot imperviousness through more efficient design, using alternative pervious paving surfaces in spill-over parking areas.
- 8) Share parking areas with other users and use parking structures instead of open space.
- 9) Integrate stormwater treatment into parking lot design and landscaping.
- 10) Incorporate open space into site design.
- 11) Minimize driveway length.
- 12) Design common walkways to connect pedestrian destinations and provide sidewalks only on one side of the road where practical.
- 13) Use shared driveways and alternative pervious surfaces in developments.
- 14) Specify a legal sustainable entity to continually manage open space and recreation.
- 15) Direct rooftop runoff to pervious areas.
- 16) Maintain buffers along streams, including the 100-year flood plain, steep slopes and wetlands.
- 17) Provide off-site mitigation for on-site environmental impacts to support local watershed and environmental management plans.
- 18) Avoid allowing stormwater to discharge directly into wetlands and other sensitive resource areas.



This conceptual design of a commercial parking lot shows how impervious surfaces can be creatively reduced through site planning.
 (Source: Robert W. Droll, 1998)

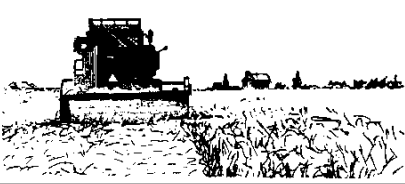

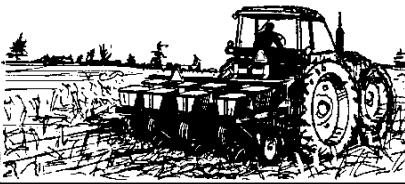

3.0 Agricultural Best Management Practices (BMPs)

3.1 Erosion and Sediment Controls

Erosion and sediment control is critical since sediment carries many pollutants to drinking water sources. Many practices are available to reduce sediment loading and erosion occurring on farms. For example, cover cropping is the practice of planting vegetation in between crops. Typically planting grasses or legumes will provide ground cover that prevents soil from eroding by reducing runoff, stabilizing soil and, for non-legumes, taking up excess nutrients that may be left in the soil, and preventing them from leaching. Following are several BMPs to improve soil stabilization:

- **Conservation Cover.** This BMP strives to establish and maintain permanent vegetative cover on land retired from production (New England Small Farm Institute, 1999). A conservation cover ensures that soils are stabilized and do not migrate off site. Plantings often include grasses, shrubs or trees with productive value.
- **Conservation Crop Rotation.** This practice involves alternating annual or perennial crops in a yearly sequence. The purpose of conservation crop rotation is to enhance the condition of the soil to both improve its production value and make it less susceptible to erosion or loss of nutrients and pesticides.
- **Conservation Tillage/Crop Residue Use.** This BMP is a crop production method that minimizes the disturbance of soil during cultivation. It usually implies that at

least 30% of the planted field is covered by plant residue. The term applies to several tillage practices, including mulch-till, ridge-till, strip-till and no-till. Conservation tillage reduces sediment runoff by stabilizing the soil in a field.

NO-TILL CROPPING SYSTEM	
	Stems, stalks and leaves (crop residue) are left on the soil surface at harvest, providing a protective blanket for the soil.
	The crop residue protects the soil from wind and rain and provides shelter and food for wildlife.
	Seeds are planted directly into the crop residue in small grooves or strips. The protective blanket remains in place.
	The crop residue provides organic matter for the soil and conserves moisture that is used by growing plants.

(▲Note: The above graphic most appropriate for corn growing - row-crop regions - of U.S.)

Steps involved in no-till conservation tillage practice (Source: CTIC, 2001)

- **Contour Farming.** This practice refers to the planting and growing of crops across the slope of a direction of crop cultivation perpendicular to the direction of runoff. The method reduces the volume and velocity of runoff and minimizes water and soil loss off site.
- **Contour Orchards.** Another useful method of stabilizing soils and reducing runoff and erosion is to grow orchards in strips along the contours of a field in annual crop production. Fields can be planted with fruit bearing trees that offer consistent soil cover and root mass while generating a harvestable crop.
- **Contour Strip-cropping.** This is a method of alternating planted strips of

protective crops across a field contour with planted areas of the primary crop, so as to reduce surface runoff and increase infiltration of water into the soil. For example, strips of meadow or small grains can be alternated with broader bands of a primary crop like corn. Planted in rotation, leguminous strip crops can add nitrogen to the soil. A similar technique, ***Contour Buffer Strips***, involves the use of strips of sod, alternated with strips of row crops. Strips of sod slow runoff, increase filtration of water into the soil, and trap sediment moving from the strip crops above.

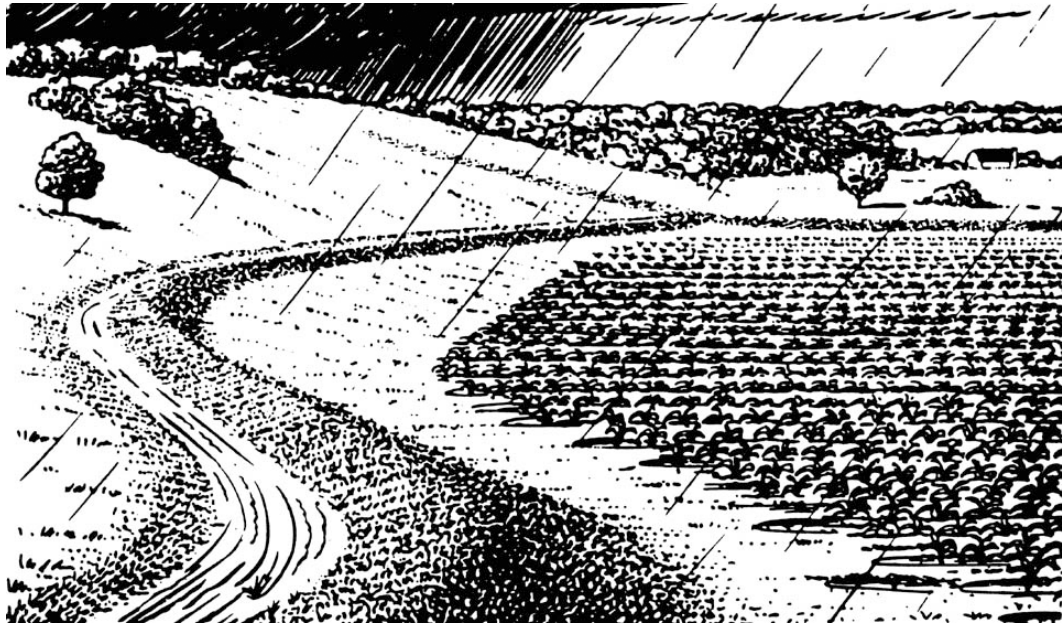


Example of contour strip cropping
(Source: CWP 2001)

- ***Cover Cropping.*** This practice refers to the planting of grasses such as rye, legumes such as beans, or small grains, to control soil erosion during the winter and through the critical high-rainfall months of spring, before regular crops are planted. Such plantings can also be used to control erosion if the primary crop, corn for example, does not provide enough cover of the soil. Plantings can also improve the soil by adding nitrogen. Cover cropping reduces the likelihood of soil movement, and thus the potential for movement of soils, nutrients, and pesticides.
- ***Critical area planting.*** It is important to identify and plant areas of land on a

farm that are highly susceptible to erosion. Perennials such as grasses, legumes, shrubs or trees are usually planted.

- **Deep Tillage.** This BMP strives to break up compacted layers in the soil, which increases the infiltration of runoff to reduce erosion. Breaking up compacted layers also improves soil conditions for plant growth.
- **Diversion of runoff.** This BMP involves constructing a clean water runoff channel or drainage path across a field slope or around a feedlot. This practice prevents pooling of excess waters and directs it to other locations where it can be used safely or infiltrated. Volume and velocity of runoff waters are thereby reduced, as is the potential for transport of contaminants and sediments off site. Diverting clean water around a feedlot prevents erosion of manure from the lot and increases the effectiveness of settling basins or other solid-liquid separation equipment. Rainwater can initially be prevented from entering a feedlot by using gutters and downspouts to handle water coming from building rooftops.



Diversion of runoff along the edge of a field
(Source: Commonwealth of Massachusetts, 1999)

- **Drainage Systems.** This management practice can improve crop production and protect surface water resources by preventing excess water on the soil surface from moving as runoff, carrying sediment and other contaminants into streams and lakes. Maintenance of drainage systems is critical to their function.
- **Filter Strips.** This BMP utilizes strips of arable land that are planted and

maintained in permanent vegetative cover, situated between cropland, grazing land, or disturbed land (Becker and O'Melia, LCC, 2001). They are used to control erosion by trapping sediments moving off site with runoff. Typically filter strips are installed along downslope field edges, on the upgradient edge of terraces or along the edge of wetlands and water courses.



Vegetated field border along a roadside serves to prevent sediments from washing onto the road and eventually reaching a water body

- **Field Borders.** This practice utilizes borders as transition areas at the edge of a field that are maintained with a perennial vegetative cover. They reduce transport of sediments by providing a physical barrier to soil movement off site.
- **Grade Stabilization.** This BMP involves the use of a physical structure, usually a cement barrier, to control the change in grade in or along the border of a cultivated field. Such water control structures reduce erosion in diversion channels and prevent the formation or increase of gullies.
- **Grassed Waterways.** This practice uses either natural or constructed stormwater collection and conveyance swales that are shaped to appropriate dimensions and seeded. They provide a predictable path for stormwater runoff, and help manage erosion by slowing the speed of runoff waters and filtering out sediments.
- **Managed Timberlands.** This measure involves excluding or managing livestock in forested areas and selective harvesting trees to promote growth. Where

livestock pasture adjoins forested lands, access is blocked with fencing or physical barriers, which protects the vegetative cover on the soil surface. Periodic harvest of trees is necessary to increase tree growth, maintaining the uptake of nutrients.

- **Mulching.** This is the practice of applying plant wastes and residues to the soil surface, thereby trapping precipitation and preventing runoff. Mulching can be used to cover bare spots, assist with growing of a crop, or to help ensure the establishment of a vegetative cover.
- **Riparian Buffers.** This BMP creates zones of vegetation along a water course or wetland that can be established as a means of preventing filtering pollutants and minimizing bank erosion. They are highly effective at protecting water quality by trapping soils and pesticides in runoff, and taking up excess nutrients.



Example of a riparian buffer (left) near a corn field (right)
(Source: CWP, 2001)

- **Sediment Basins.** These basins are constructed depressions that trap soil and debris carried overland with stormwater runoff. They both filter water discharging to surface water bodies and allow excess water to infiltrate to the subsurface environment. Sediment basins require routine maintenance.
- **Terracing.** The practice of terracing comprises an earthen embankment, channel or combination ridge and channel constructed across the slope (Becker and O'Melia, LCC, 2001). It can be thought of as a more aggressive version of cover cropping, in which hillsides are graded to create flat planting surfaces between steep drops in slope. Terracing is usually practiced in tilled areas with steep terrain.

3.2 BMPs For Nutrient Management

No single BMP can be expected to provide total control of nutrients from runoff. For example, multiple practices are necessary to fine tune timing, quantity and distribution of manure and fertilizer application to deliver nitrogen and phosphorus to meet realistic crop goals. A good nutrient management plan is vital to optimizing the use of nutrients, and involves such elements as soil surveys and testing, and estimating realistic crop yields.

Sensitive areas like wetlands, vernal pools, waterways, steep slopes and other areas susceptible to erosion, and source water protection areas for both surface and ground water drinking water sources, should be protected by limiting nutrient application in close proximity. The following BMPs are options to assist with nutrient management:

- ***Agricultural Composting.*** This BMP is a natural process involving the decomposition of organic matter like plant residues, animal beddings, and manure in an aerobic environment (i.e., with air present). Composting takes advantage of microbial activity that breaks down raw waste materials into stable soils that can be used to condition field soils and provide nutrients to crops. It decreases the risk of nitrogen pollution of ground and surface water resources by stabilizing the nitrogen component of the waste, thereby reducing its loss to leaching or runoff. Composting has the added benefit of creating an economic resource that can be sold to other farmers or to gardeners.
- ***Buffer Strips.*** See “Riparian Buffers” above in Erosion and Sediment BMP section above.
- ***Conservation Crop Rotation.*** See “Conservation Crop Rotation” in Erosion and Sediment BMP section above. This technique is also useful in lowering fertilizer requirements when legumes are planted as the rotational crop. It further serves as an alternative to continual applications of manure, which can cause high levels of phosphorus to build up in soils and create significant potential for surface water contamination if erosion occurs.
- ***Cover Cropping.*** See “Cover Cropping” in Erosion and Sediment BMP section above. Similar to crop rotation, cover cropping can supplement nutrients in the soil and reduce the need for fertilizer applications, or conversely, can take up excess nutrients in a field to reduce the potential for migration to surface or ground water resources.
- ***Drainage Systems Optimization.*** This BMP involves methods to disconnect surface runoff with important receiving waters, especially lakes, ponds, rivers, and other surface waterways. The best way to protect water resources from farm runoff is to construct drainage systems that intercept and infiltrate or store runoff waters. For example, detention ponds are highly effective at capturing and infiltrating barnyard runoff. On the other hand, subsurface drain tiles in cultivated fields can provide a direct route for nitrates to reach lakes and streams.

- ***Equipment Calibration.*** It is important to maintain the accurate and timely adjustment of equipment used to apply nutrients. Calibration is important to ensure that over application does not occur and increase the potential for contamination of water resources by nutrients moving off site.
- ***Fertilizer Storage, Handling and Containment.*** This practice involves procedures to ensure prevention of leaks and spills of fertilizer and is extremely important to minimizing risks to water resources. Storage areas must be secure and weatherproof, and located a considerable distance (at least 400 feet) from wells, surface water resources, or any porous areas in the farm terrain.
- ***Green Manure Cropping.*** This practice of planting a sacrificial crop of grass or legumes to be plowed under for its soil enrichment properties is a method used to reduce the need for commercial fertilizer applications.
- ***Nutrient Budgeting.*** This BMP is a process of evaluating all sources of nutrients contributing to the raising of a particular crop. The budget allows farmers to calculate the amount of nutrients coming from manures, composts, effluents and cover cropping/green manure cropping so that only the amount of commercial fertilizer needed to fill the nutrient gap is applied. Recommended nitrogen application rates should be adjusted to account for nitrogen supplied by a previous legume crop, manure, other organic wastes, or residual soil nitrate. By conducting soil tests of the nutrient content in a field and crediting the amount of nitrogen already in the soil, application rates that ensure optimum crop yield can be estimated. Specialized nutrient budget worksheets are available from the University of Massachusetts Extension. Successful nutrient budgeting depends on ***Nutrient Record Keeping***, a system of documenting the application of natural and commercial nutrients.
- ***Nutrient Management Plans.*** It is important to control the load of nutrients produced and exported from a farming operation. These plans should be periodically updated, and should include the following important components:
 - Farm and field maps showing acreage, crops, soils, and water bodies;
 - Realistic yield expectations for the crop(s) to be grown;
 - A summary of the nutrient resources available to the producer;
 - An evaluation of field limitations based on environmental hazards or concerns;
 - Use of the limiting nutrient concept to minimize the amount of fertilizers needed and establish the proper mix of nutrients and requirements for the crop, based on a realistic yield expectation;
 - Identifying optimal timing and application methods for nutrients in order to maximize crop growth with minimal fertilizer use;
 - Springtime applications of nutrients, as opposed to fall applications; and
 - Proper calibration and operation of nutrient application equipment.



Concrete pad under manure loading chute prevents manure from falling directly on the ground and adding nutrients to the ground water (NOTE: Farm utilizes other primary containment BMPs such as ponds and drainage systems to deal with runoff escaping the concrete pad).

- ***Optimal Timing and Application Methods.*** This practice for nutrients decreases the potential for contamination of water resources by avoiding conditions that favor runoff or excessive infiltration while maximizing plant uptake. For example application of manure or fertilizer on frozen ground is inadvisable as the potential for runoff is high.
- ***Optimal Selection of Nitrogen Fertilizers.*** This approach involves examining fertilizer characteristics such as the rate of release and the percent of soluble nitrogen. Nitrogen sources that contain a greater percentage of ammonia will be less likely to leach initially after application. Of all nitrogen fertilizers, anhydrous ammonia is the least likely to leach initially after application, followed by urea. Ammonium nitrate contains the greatest amount of nitrogen ready to leach immediately after application since half of ammonium nitrate is in the nitrate form. Soil tests before applying fertilizers are important to determine how much is needed.
- ***Proper Storage of Livestock Wastes.*** This management practice requires attending to the location and methods of waste storage. For example, waste storage structures should not be located near surface waters or wells. Also, special precautions should be taken when storing wastes in earthen structures to prevent seepage through the bottom of the basin to ground water.

- ***Reduce Wastewater and Runoff from Confined Animal Facilities.*** This BMP involves limiting surface water runoff and discharge from confined animal facilities to lakes, ponds, rivers or streams. This can be done by storing both the facility wastewater and the stormwater runoff and managing the stored runoff and pollutants through an appropriate waste utilization system.
- ***Soil Testing.*** This is a method to determine the amount of nutrients present in the soil by way of laboratory analysis. Soil testing is used to ensure the right amount of nutrients are applied to maximize crop yield and to avoid over application of fertilizers. The information in the test can be used to calibrate the amount of fertilizer being applied, thereby minimizing costs and reducing the possibility of migration of nutrients off site to ground and surface water resources.
- ***Waste Management System.*** This BMP consists of a planned system in which all necessary components are installed for managing liquid and solid waste, including runoff from concentrates waste areas, in a manner that does not degrade soil or water resources (Becker and O'Melia, LCC, 2001).
- ***Waste Storage Facility.*** This BMP consists of a waste storage impoundment made by constructing an embankment and/or excavating a pit or dugout (to create a waste treatment lagoon for example), or by fabricating a structure.
- ***Yield Data.*** This is a process of collecting information about crop yield to anticipate production accurately. Its purpose is to enable farmers to match nutrient applications to realistic levels of crop productivity and thus avoid any tendency to over fertilize in the expectation of increasing productivity.

3.3 BMPs For Pests And Pesticide Management

Pesticide management involves a minimal and discriminant use of pesticides. IPM strategies to reduce pesticide use include pest scouting, crop rotation, and species and habitat diversification to decrease vulnerability to infestation and invasion. If pesticides are necessary, careful timing of application, and efficient application methods should be used. The timing of application and subsequent rain events is the dominant factor governing the transport of pesticides exported from croplands. Application timing in concert with other runoff reduction techniques helps minimize loss of pesticides into the environment. The following BMPs can assist in minimizing the movement of pesticides into ground and surface water resources.

- ***Calibrate and Maintain Pesticide Application Equipment.*** This BMP ensures that application equipment is properly adjusted and maintained on a routine basis. It is important to recalibrate spray equipment each spray season and use anti-backflow devices on hoses used for filling tank mixtures. These steps ensure pesticides are applied at the appropriate rates, and that the potential for contamination of water supplies is minimized.

- ***Collect Data.*** This practice involves inventorying information on field characteristics, crop production and pest occurrence. Recording current and historical pest problems, cropping patterns, soil and other physical characteristics, and use of pesticides for each field enables optimal decisions to be made about pesticide use. Data on storage, mixing and loading should also be recorded and considered as part of a pesticide management plan, as should information on site characteristics such as soil drainage, nearby surface and ground water sources of public drinking water and other water resources, and land features that may affect the potential for runoff of stormwater or leaching of pesticides into the soil or ground water.
- ***Determine the Organic Matter of Soil.*** Organic matter content is one of the most important factors in controlling pesticide leaching to ground water. However, this soil property is often overlooked. Pesticides typically attach to organic matter, reducing the potential for leaching. The lower the organic matter content of soil, the more likely a pesticide will migrate downward and threaten ground water. When the organic matter level is low and adsorbing of pesticides to soil particles is minimal, there is an increased risk of applying excessive amounts of pesticides and possibly damaging the crop. Therefore, some pesticide labels will list lower application rates for soils with lower organic matter contents. By knowing the organic matter content of soil, lower application rates can be used, which means savings in dollars.
- ***Establish Physical Barriers.*** Creating barriers against insect and animal pests such as nets and crop covers to exclude various pests from areas serving as a food source or reproductive habitat, again for the purpose of minimizing the need for chemical controls.
- ***Implement Biologic Controls.*** This is a practice of fostering natural enemies of pests in order to control pest populations. Parasites, bacteria, fungi, and viruses can be used effectively to combat pests, minimizing the need for chemical applications, and thus the associated risk of water resource contamination. Such natural controls should be encouraged by maintaining conditions necessary for their growth. Maintaining populations of natural control agents should always be a factor in considering what pesticides to apply to a crop.
- ***Improve Farm Management Practices.*** This practice identifies and implements specific management techniques to reduce favorable conditions for pest reproduction. Plowing, crop rotation, staggered planting and harvesting schedules, maintaining sanitary conditions for livestock, and manure management are examples of methods to destroy breeding habitat for insect pests and minimize the need for chemical controls.
- ***Integrated Pest Management (IPM).*** This technique is a farming strategy that minimizes the amount of pesticides applied by taking advantage of natural

enemies, climate, and crop health to combat plant and insect pests. IPM is “a comprehensive approach to fine tuning on-farm management of harmful weeds and pests” (CTIC, 2001). When pesticide applications are necessary, IPM calls for careful selection of appropriate products with the lowest possible toxicity. It encourages lower pesticide application rates than those called for by the label when the pest problem can be adequately controlled using lower rates. Organic farming techniques that do not rely on the use of synthetic pesticides are meeting with increasing success across the country as public interest in organically produced foods and goods increases.

- ***Pesticide Application Plans and Records.*** These pesticide management plan components integrate all aspects of pesticide use at a farm or livestock facility. The purpose of such documents is to ensure conservative use of pesticides and to minimize improper, unnecessary or wasteful applications. Pesticides with the least potential to migrate to ground or surface water resources should always be selected for use. Application records are of great assistance in planning future pesticide applications that optimize crop production and minimize the potential for environmental damage.
- ***Safe Storage, Handling and Disposal of Pesticides.*** This BMP involves appropriate practices for the overall use and management of pesticide products. Such practices prevent accidents and the associated potential for contamination of water resources. Since quantities of pesticides are usually more concentrated at storage, mixing, loading and equipment maintenance sites than on the fields where they are applied, particular attention to this aspect of pesticide management is critical to protection of surface and ground waters in near proximity to a farm. Proper disposal of empty containers is also very important.
- ***Scout Fields.*** This is a practice which involves monitoring the presence of pests. Accurate and timely scouting may prevent unnecessary pesticide treatments or minimize the amounts that need to be applied. Since scouting techniques vary considerably depending on the insect and crop involved, a field crop scouting manual is recommended. A map of pest incidence can then be developed based on the scouting exercise. This map will help to estimate the severity of pest infestation and determine pesticide application needs.

3.4 BMPs For Pathogen Control

The movement of pathogens, primarily bacteria, and viruses, can be controlled on farms through the use of a variety of BMPs. While many of the following BMPs are also applicable to sediment and nutrient control, they are vital to management of livestock-related pathogens.

- ***Composting of Manure.*** This practice is an aerobic process of controlled biodegradation of animal wastes that reduces pathogens and stabilizes nutrients. It is a highly cost effective technique of managing wastes, producing a valuable

commodity, and reducing potential for water resource contamination. Composting requires active management in order to produce a useful soil amendment.

- ***Diversions.*** This BMP uses drainage swales or gutters cutting across a slope to capture and direct stormwater runoff. Such systems are used to divert overland flows of water away from heavy use areas like barnyards and bunker silage storage areas in order to keep runoff from transporting concentrated organic contaminants and sediments to surface water resources.
- ***Filter Strips.*** These are vegetated zones around a confined animal facility that trap sediments, organic wastes and other pollutants in stormwater runoff. They must receive regular maintenance in order to function effectively. Constructed wetlands in low-lying areas can also serve a similar purpose.
- ***Heavy Use Area Protections.*** This practice involves construction of hard surfaces in heavily used areas. Materials for construction can be concrete, asphalt, compacted gravel or compacted earth, depending on the waste management objectives. Hardening areas of heavy use prevents or slows their physical degradation and facilitates the collection and use of animal wastes, the latter being vital to protection of water resources.
- ***Keeping Livestock out of Water.*** Cutting off the access of livestock to streams and ponds with fencing reduces the potential for animals to act as a source of waterborne bacteria that can cause bovine leptospirosis, mastitis, and other ailments. Install fencing around water resources and provide a source of fresh drinking water for livestock.
- ***Manure Stacking Areas.*** These areas are temporary locations for storing animal wastes in a field prior to application. Their purpose is to supplement constructed storage facility volumes or to await favorable conditions for field application.
- ***Manure Storage Facilities.*** This BMP involves using permanent structures for storage of animal wastes on a temporary basis. They also capture polluted runoff and are therefore a useful means of preventing or minimizing transport of contaminants and sediments to surface waters.
- ***Manure and Waste Utilization Plans.*** Plans which formulate an approach to recycling animal wastes to benefit crop production while ensuring environmental quality. They can be used in conjunction with nutrient management plans to minimize the amount of commercial fertilizer applied to cropland.
- ***Reduce Wastewater and Runoff from Confined Animal Facilities.*** See Erosion and Sediment BMP Section.

- **Roof and Pavement Runoff Management.** This process controls runoff from roofs of farm buildings and surrounding paved areas. It is an essential component of coping with runoff from heavy use areas and must be considered as part of an overall effort to protect water resources.
- **Sediment Basins.** As defined in the Erosion and Sediment BMP section above, these structures are also useful in managing pathogens and other contaminants originating on barnyards by capturing and infiltrating runoff and acting as a settling basin for solids.

4.0 Erosion and Sediment Controls for Construction Site Best Management Practices

The construction phase of development is generally the most damaging to aquatic environments. Often during the construction phase, for example, more land is cleared for access than is necessary, therefore exposing excessive amounts of soil and sediment, removing wildlife habitat, and destabilizing the land surface. An erosion and sediment control (E&SC) plan can help to reduce the impacts of the construction phase on surrounding resources. Many states, including Massachusetts, Maine, Maryland, New York, and New Hampshire for example, have developed Handbooks of Erosion and Sediment Control techniques that can be used as a reference. However, many such handbooks include “cook book” references compiled from other sources that do not necessarily address the specific conditions of each individual site. Therefore, it is important to adapt the most effective and appropriate E&SC practices to the characteristics of the particular site.

4.1 Erosion and Sediment Control Practices

Effective erosion and sediment control techniques are referred to as BMPs. Descriptions of several of the more common and effective erosion and sediment control BMPs for the construction phase are provided below. This information was compiled from various sources, including the Center for Watershed Protection (CWP, 2000), the Massachusetts Erosion and Sediment Control Guidelines (MA EOEA et al., 1997), and the Stormwater Management and Erosion and Sediment Control Handbook for Urban and Developing Areas in New Hampshire (NH DES et al., 1992).

4.1.1 Erosion Control Practices

- **Seeding.** Grass that is well established on a slope is the most effective erosion control practice, and can be used for either permanent or temporary control. The success of seeding is limited by dry or cold weather and in areas of infertile soil, where it is more difficult for the seeds to establish. On most slopes, a surficial cover is also required to keep the seeds in place.
- **Mulching.** Mulching refers to the use of straw, hay, bark or a bark/compost combination spread on the land surface. It can be used as a protection for seeds or

alone as a temporary erosion control. Straw mulch should be avoided on slopes greater than 20 percent and bark/compost mulch should be avoided on slopes greater than 40 percent. Because straw and hay mulch are lightweight, this type of mulch must be secured to the soil surface.

- **Blankets.** Blankets are used to protect seeds and prevent erosion on steep slopes where mulch can be ineffective. Drawbacks of blankets are that they are more complicated and time consuming to install, and typically more expensive than mulch and seeding.
- **Plastic Sheeting.** This practice provides effective erosion control for small areas (less than 2,000 square feet), but should only be used temporarily. The plastic does not allow infiltration of runoff, and the edges must be properly weighed down to avoid runoff leaking in underneath the sheeting.
- **Sodding.** This can be a very effective erosion control mechanism because it provides immediate vegetative cover, but it is important to assure that soils are nutrient-rich and moist enough to support establishment of the vegetation. When conditions are appropriate, sodding can also be used to convey open channel stormwater flows. The major drawback to sodding is the generally high expense.

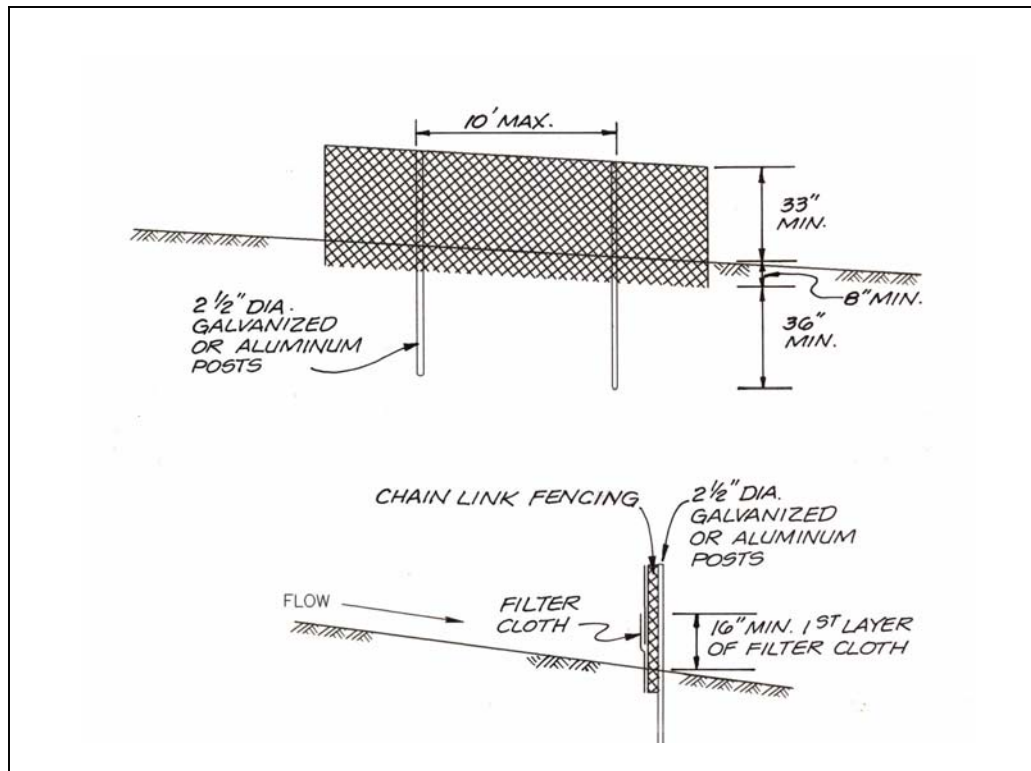
4.1.2 Sedimentation Control

- **Silt fence or super silt fence.** Silt fences are widely used for sediment control in construction areas, but are often improperly installed and/or maintained. Proper installation requires support posts driven at least 16 inches into the ground, stakes placed at most eight feet apart, embedded trenches lined with geotextile material upstream of the fence, maintenance of a ten-foot buffer between the fence and all construction activity, use of one continuous sheet of fencing material to avoid joint failure, and finally, installing the fence along topographic contour lines, not simply along the property boundaries. Anchors can be used to hold the bottom of the silt fence fabric (geotextile) in place. When properly installed and maintained, silt fences alone can be somewhat effective at controlling sedimentation from construction sites. However, they can be significantly improved by utilizing high-quality geotextiles and reinforcements, such as a chain link fence or hay bales, to establish “super silt fences.” Regular maintenance and repair of the silt fences, including after every ½-inch rain storm, and removal of sediment when it builds up behind the fence is essential for the effective function of the silt fence.



An improperly sited and poorly maintained silt fence (top) versus a super silt fence reinforced by chain link fencing (both)
(Source: CWP, 2001)





Schematic drawing of the “super silt fence”

(Source: CWP, 2000)

- Sediment traps and basins.*** These practices are used where other sediment controls are not possible or effective to prevent off-site sedimentation. Sediment traps are generally smaller than basins, used for areas smaller than 5,000 square feet, and sediment basins can be used for larger drainage areas, up to 100 acres in some cases (MA EOEa et al., 1997). Sediment traps and basins can be realistically expected to remove up to 80 or 90 percent of sediments from construction site runoff (CWP, 2001, pg. 338). They function by detaining runoff from the site and allowing enough time for the sediment to settle out of the water column before water is released from the site. Some of the water can be infiltrated into the ground as well. The size of the basin is usually determined based on a ratio of cubic feet of storage per contributing acre for a two-year storm, and a minimum length to width ratio of approximately two. An emergency spillway allows runoff from a ten-year storm to escape the basin to avoid overflow and erosion during large storms, and a trash hood on the riser prevents clogging (trash and debris should be removed regularly). Currently, the most effective sediment basins utilize floating skimmers or an increased storage volume to provide both wet and dry storage (CWP, 2001, pg. 338).



Typical example of a sediment trap used during the construction of a commercial office park
(Source: CWP, 2001)

- ***Inlet protection.*** Sediments in runoff from construction sites can quickly clog storm drains and inlets, so many states require or recommend protecting storm drain inlets from sedimentation. Inlets are protected by trapping the sediment before it reaches the inlet or by constructing a temporary barrier around the inlet that either filters the runoff before it enters the inlet or allows some settling to occur before the runoff enters the inlet. This practice should only be used in conjunction with other practices and should not be relied upon as the primary sediment control to protect storm drain systems. Generally, inlet protection practices work better under lower flow conditions, but different techniques can be used in high flow locations. Hay bales or silt fencing can be placed around inlets to filter out sediments, the area around an inlet can be excavated to allow for runoff detention and settling of sediments before the runoff reaches the inlet, or in areas where truck traffic may pass over the inlet, a wire mesh filter can be placed over the inlet and covered by gravel to provide filtration. As with the other practices, any inlet protection technique requires routine maintenance and removal of sediment build-up.



Runoff from a construction site entering a storm drain inlet illustrates the need for inlet protection
(Source: Center for Watershed Protection, 2001)



An example of inlet protection
(Source: Center for Watershed Protection, 2001)

- ***Project phasing.*** By constructing a project in phases, the amount of sediment exposed at any one time is significantly reduced, which in turn reduces the erosion and sedimentation occurring at any point in time. The success of phased construction depends on carefully developing a detailed phasing plan early on, and then following it closely. Each phase will cover a separate section of the site and will require a separate construction access way and stormwater practices to collect, convey and treat runoff as necessary. Project phasing can be especially effective at large-scale project sites.

4.1.3 Critical Elements of an E&SC Plan

Rather than specify which techniques are most appropriate for which combination of site characteristics, this handbook will provide guidance to help the developer or construction engineers shape an effective E&SC plan. There are ten critical elements to an effective E&SC plan (CWP, 2000). They are as follows:

1. Minimize needless clearing and grading
2. Protect waterways and stabilize drainage ways
3. Phase construction to limit soil exposure
4. Immediately stabilize exposed soils
5. Protect steep slopes and cuts
6. Install perimeter controls to filter sediments
7. Employ advanced sediment settling controls
8. Certify contractors on E&SC plan implementation
9. Adjust E&SC plan at construction site
10. Assess E&SC practices after storms

4.1.3.1 Keys to Success: Implementation, Maintenance, Inspection

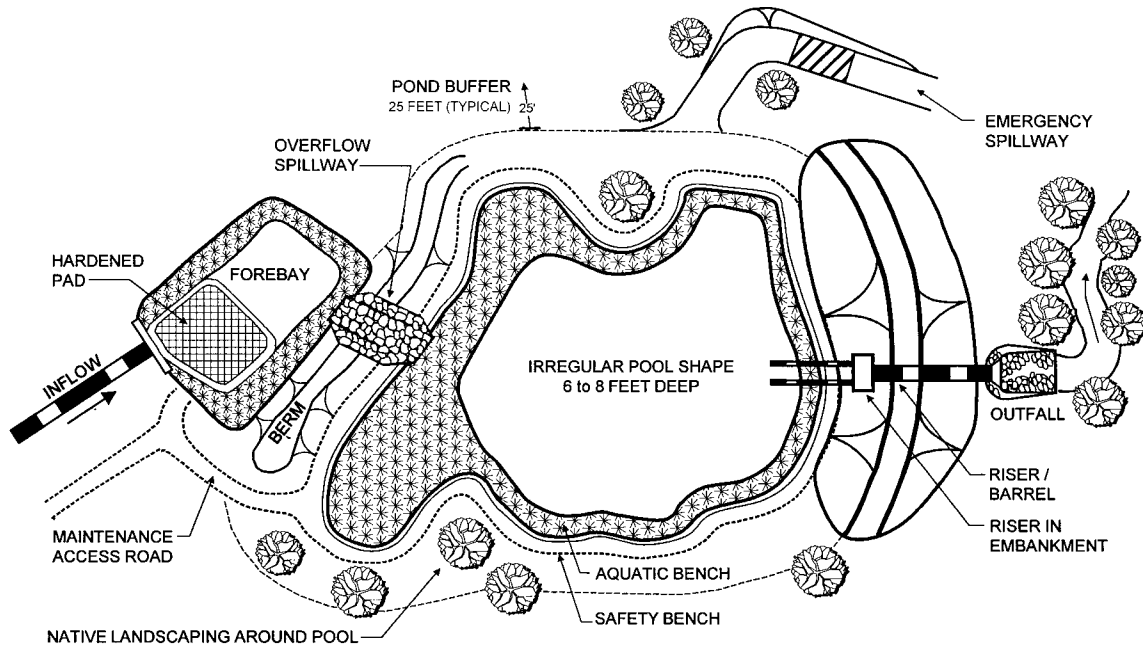
The success of an E&SC plan not only depends on developing the plan, but making sure the plan is properly implemented and routinely maintained throughout the construction phase. Several recent studies indicate that E&SC plans often fail to meet their performance goals for a variety of reasons, including: incomplete implementation of the plan, inadequate inspection of installed techniques, inadequate maintenance of techniques, inadequate training of site workers and inspectors in E&SC techniques, and inadequate review of E&SC plans prior to approval and implementation (CWP, 2000).

5.0 Urban Best Management Practices (Residential and Commercial)

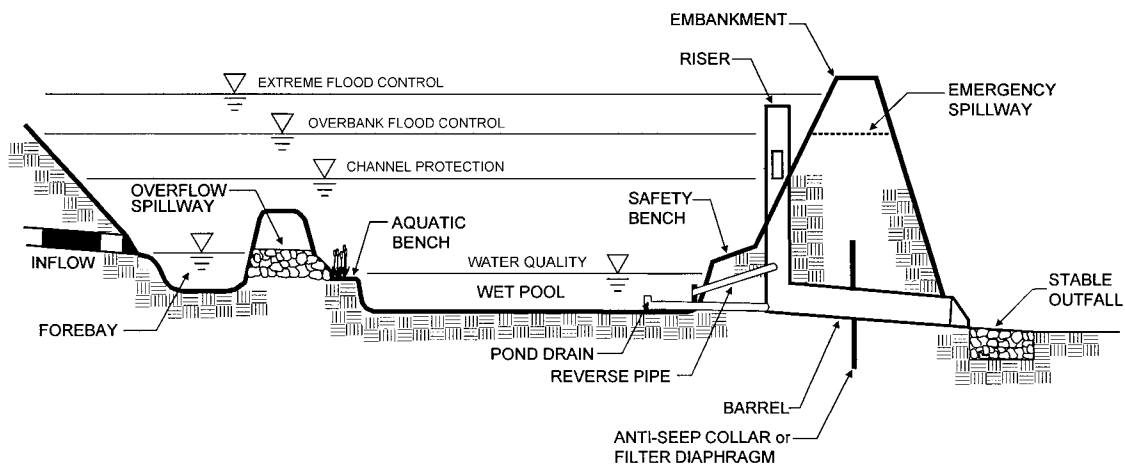
- **Ponds.** Ponds are used to detain runoff during storms and then allow pollutants to settle out. Some ponds are wet ponds, meaning they retain a certain amount of water permanently, and some detain water for the purpose of infiltrating it into the ground. Some pond designs include a micro-pool extended detention pond, a wet pond, wet extended detention pond, and a pocket pond.



Example of a wet retention pond
(Source: Maryland Department of the Environment, 1999)



PLAN VIEW



PROFILE

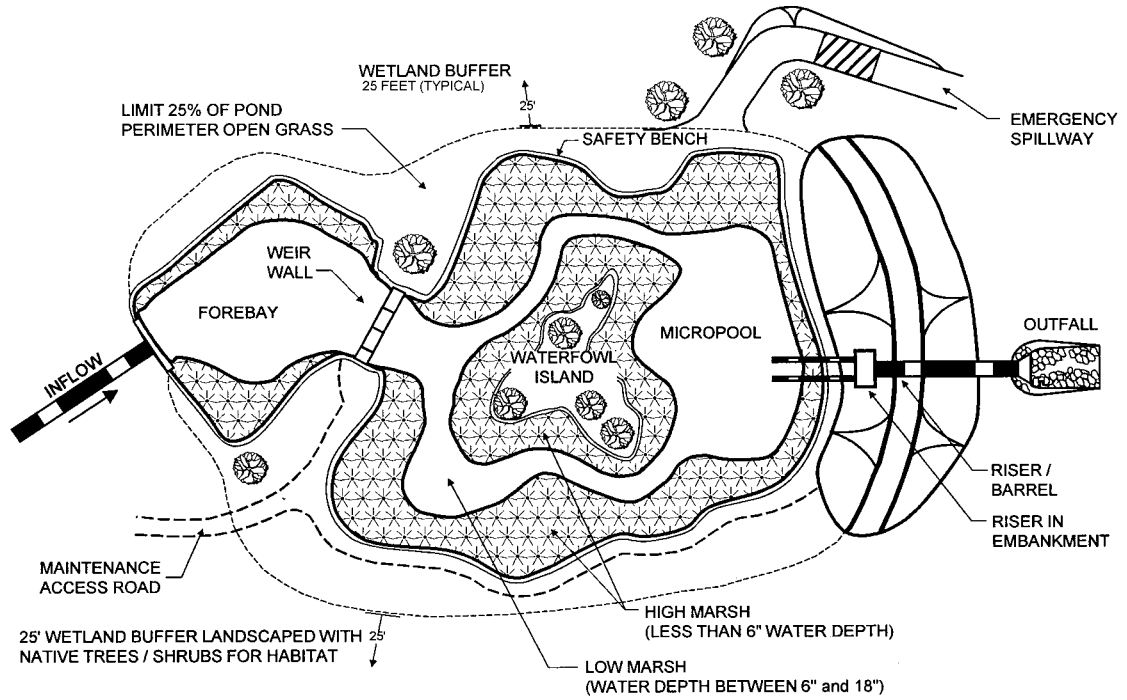
Schematic illustration of wet pond

(Source: New York State Stormwater Management Design Manual, 2001)

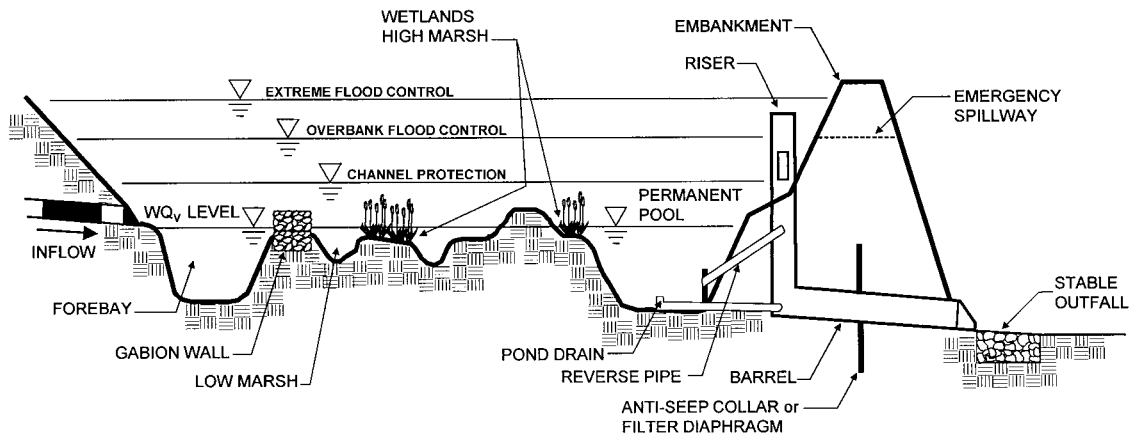
Wetlands. Wetlands are used to detain runoff, slow the velocity enough to allow settling, and provide a certain level of filtration and pollutant uptake as well, by means of the vegetation. Wetlands are more effective in residential developments than in industrial areas where the toxicity in the runoff may actually threaten the wetland vegetation. Wetland options for urban runoff include shallow marsh, extended detention wetlands, pond/marsh systems, and pocket wetlands. Two wetland designs are presented below.



Example of a constructed stormwater wetland
(Source: Galli, 1997)



PLAN VIEW



PROFILE

Shallow wetland

(Source: New York State Stormwater Management Design Manual, 2001)

- ***Infiltration.*** Infiltration mechanisms such as infiltration trenches or basins are helpful when the main concern is putting water back into the ground to recharge the ground water. This practice also provides a certain level of filtration as the runoff water passes through the soil. The photo below is an example of an infiltration trench in practice.



Example of infiltration trench with grass channel pretreatment
(Source: Claytor, 2000)

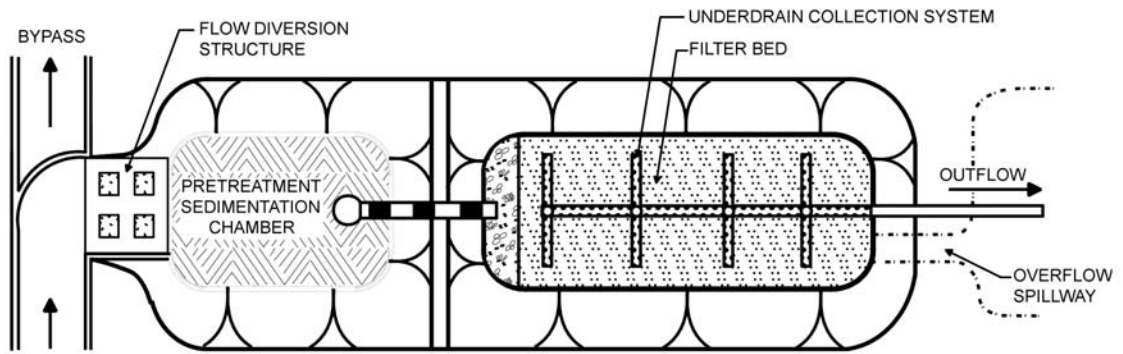
- ***Filtration.*** Stormwater filters make up a general category of runoff treatment practices that are effective in removing a wide variety of pollutants, such as bacteria, sediment, nutrients, and metals, depending on the design. The design of filters range from sand filters to organic filters to bioretention filters. Organic filters and bioretention filters rely on vegetation to take up nutrients and metals that are often dissolved in the runoff, and also slow the water to filter out particulate matter. Sand filters are more effective in removing just the particulate matter in the runoff, such as bacteria, suspended sediments, and associated adsorbed metals.



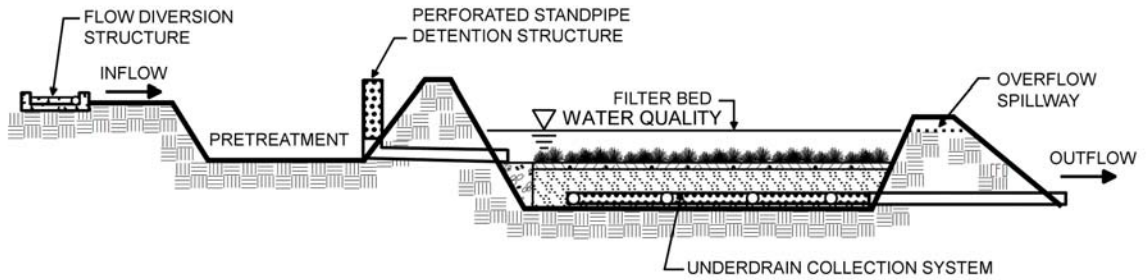
Example of surface sand filter (F-1)
(Source: CWP, 2001)



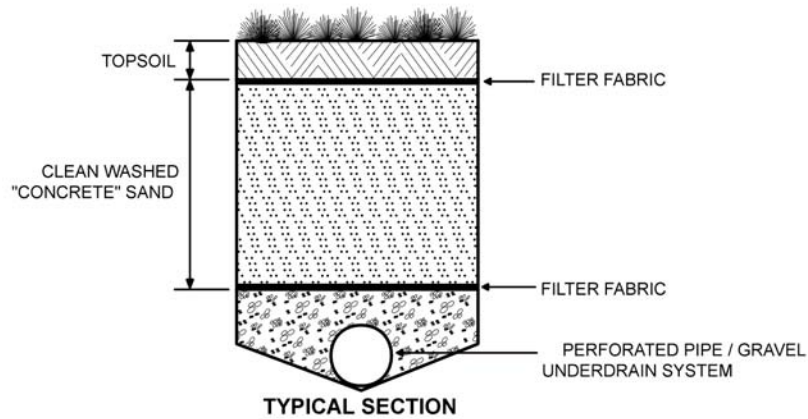
Example of perimeter sand filter
(Source: MDE, 1999)



PLAN VIEW



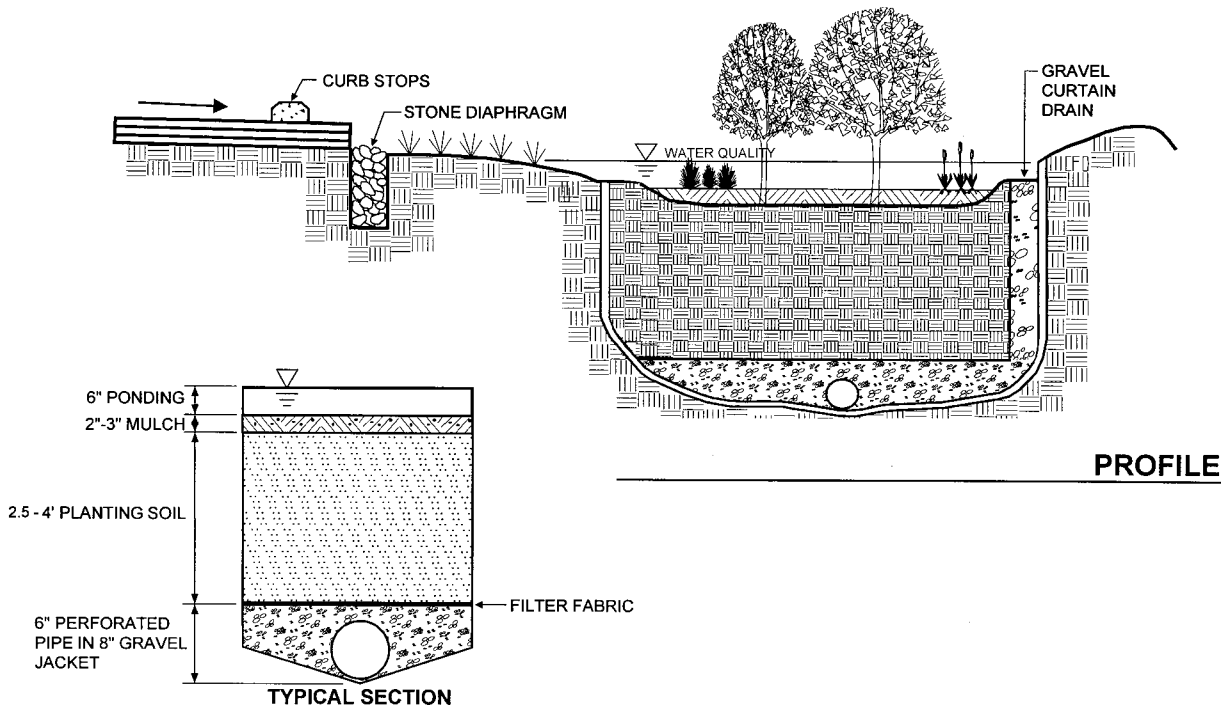
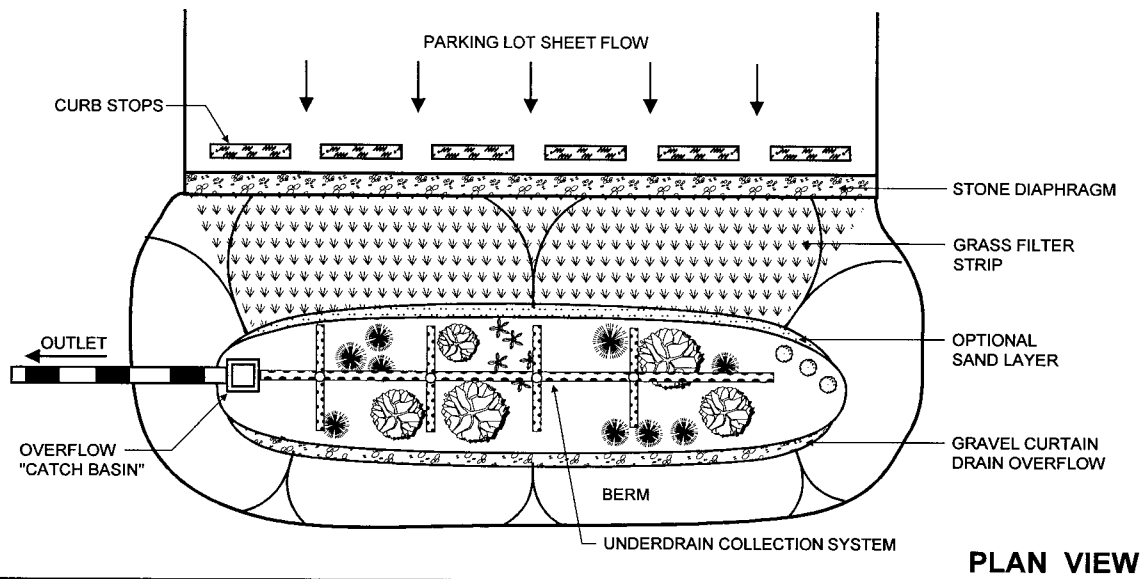
PROFILE



TYPICAL SECTION

Schematic illustration of a surface sand filter

(Source: New York State Stormwater Management Design Manual, 2001)



Example of bioretention

(Source: New York State Stormwater Management Design Manual, 2001)

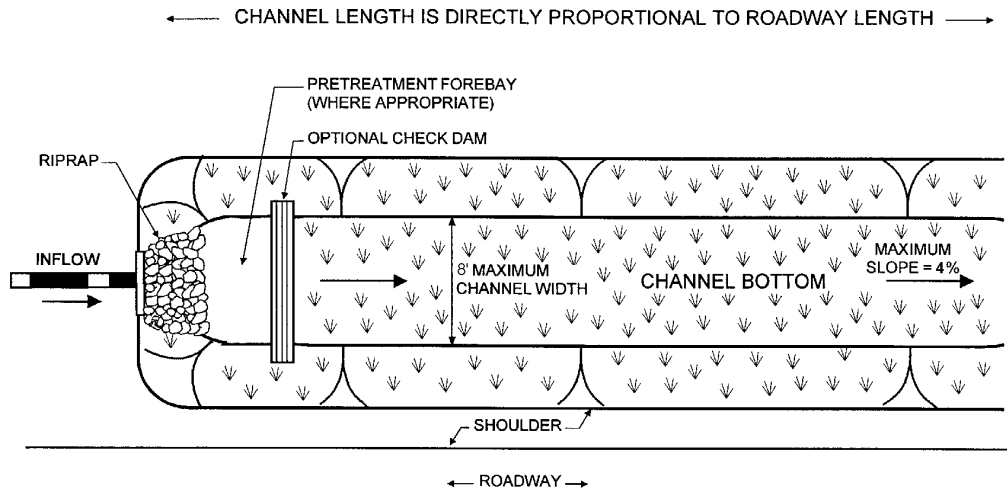
- **Open channels.** Open channels, including both wet and dry swales, provide a designated means of delivering stormwater while filtering out some level of suspended sediments at the same time. However, swales generally should be used in conjunction with other practices in order to assure effective pollutant removal from the runoff. They depend on adsorption and settling to remove pollutants so they are not effective in removing dissolved nutrients and bacteria, and only partially effective in removing metals.



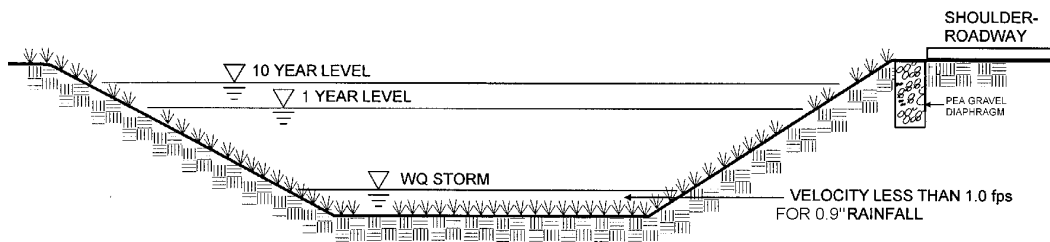
Example of dry swale
(Source: Claytor, 2000)

6.0 Pet waste management BMPs

- **Public Education.** Public education to encourage residents to clean up after their pets includes the use of outreach media such as radio announcements, signs, newsletters, and posters.
- **Provide Disposal for Pet Waste.** Encourage pet owners to dispose of pet waste properly by providing bags and/or disposal containers for pet waste at likely areas for pets to be walked and that are contributing to water quality degradation.
- **Identify Potential Pet Walking Areas.** Identifying and encouraging pet owners to utilize areas that are not hydrologically connected to waterbodies will decrease the pet waste loading to waterbodies



PLAN VIEW



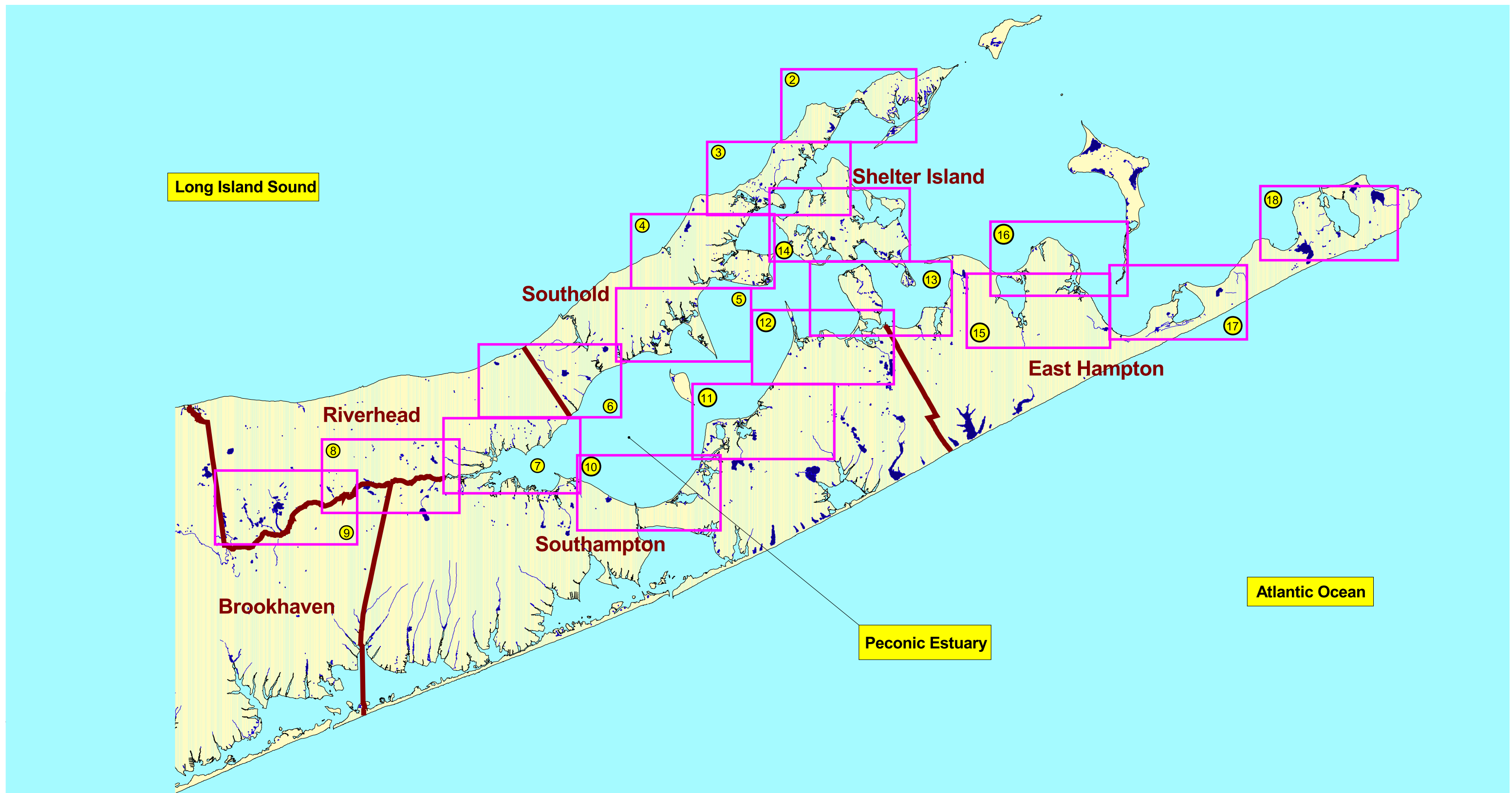
SECTION

Dry swale



(Source: New York State Stormwater Management Design Manual, 2001)

- ***Other devices.*** Several manufactured products have been produced to treat stormwater runoff from urban areas. These are collectively called “proprietary devices.” Their capabilities to remove pollutants depends on the design specifics, the type of site and pollutant load. In general, proprietary devices cannot meet all of the design criteria discussed previously. They are particularly applicable for retrofit situations or as pretreatment for other treatment practices.

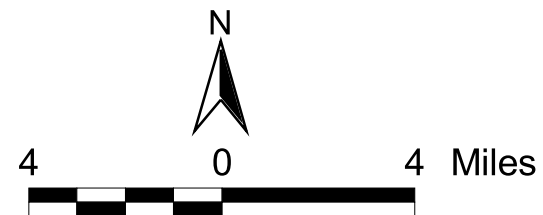
APPENDIX C




Legend

-  Figure Number
-  Town Line

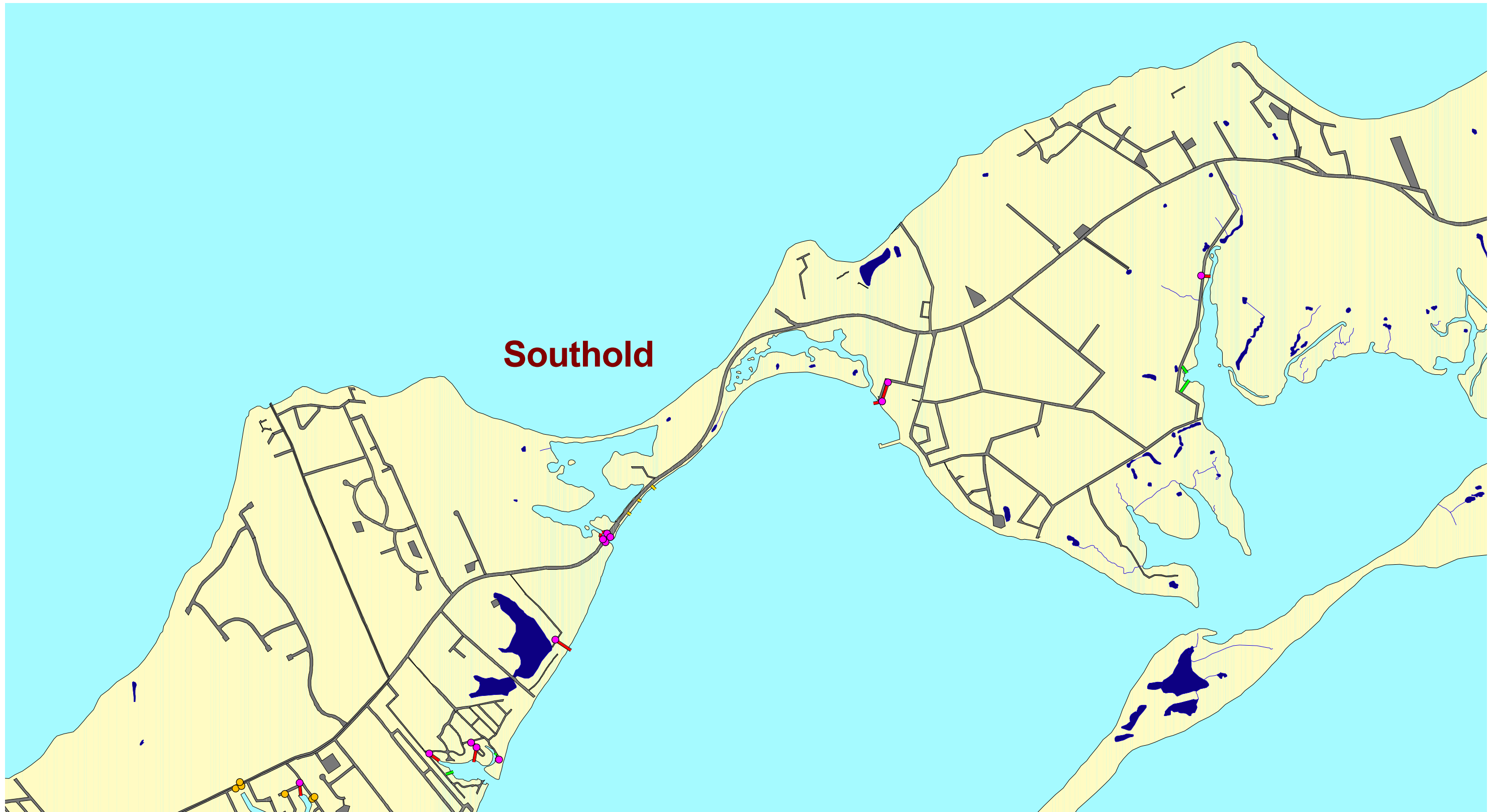
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Stormdrain Infrastructure Figures Reference Map

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Legend

- Inlet
- Dry Well
- Roads
- Lakes and Ponds
- Streams
- Road End
- Boat Launch
- Stormdrain Pipe

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2000 0 2000 Feet

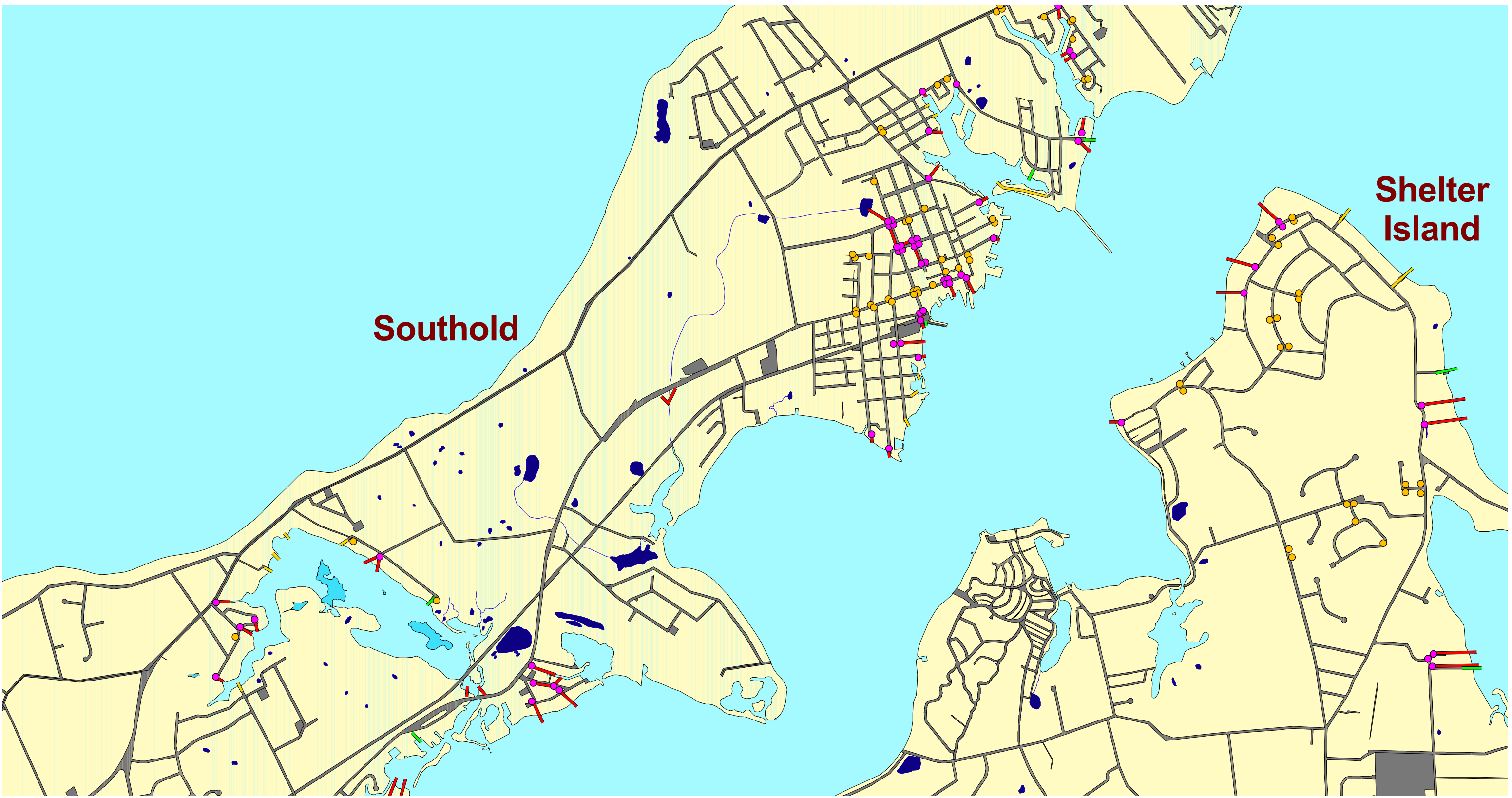


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Figure C-2

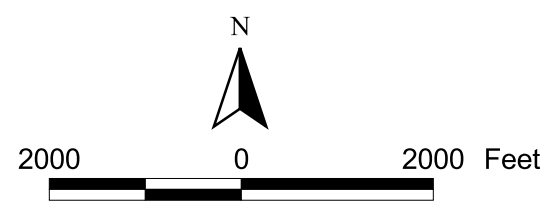


Southold

Shelter Island

- Legend**
- Inlet
 - Dry Well
 - Roads
 - Lakes and Ponds
 - Streams
 - Road End
 - Boat Launch
 - Stormdrain Pipe

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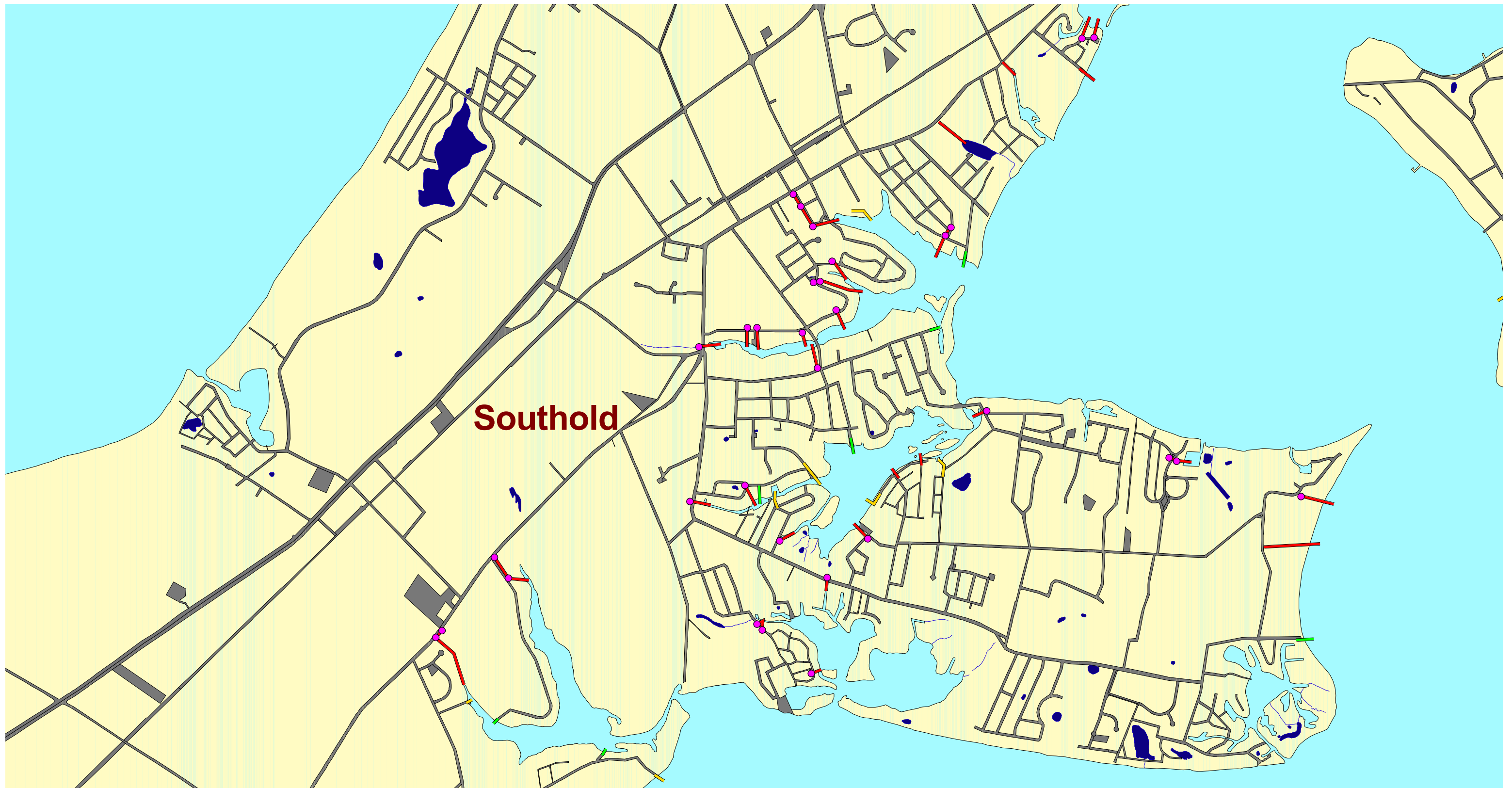


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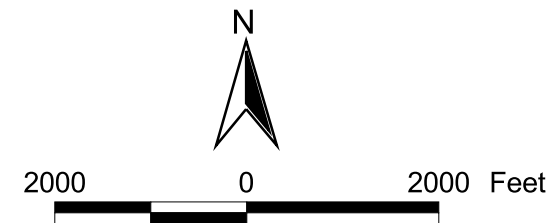
Figure C-3



Legend

- Inlet
- Dry Well
- Roads
- Lakes and Ponds
- Streams
- Road End
- Boat Launch
- Stormdrain Pipe

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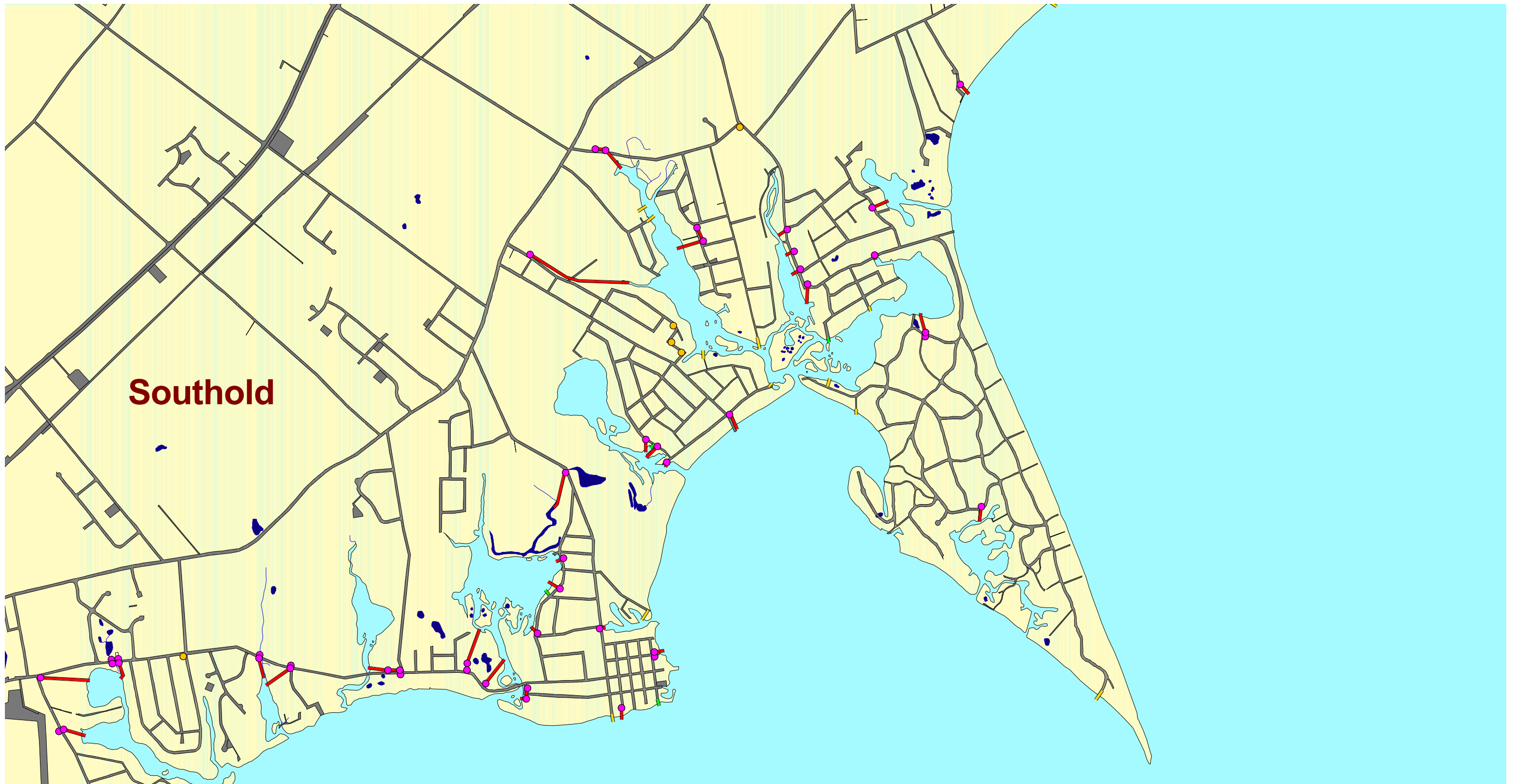


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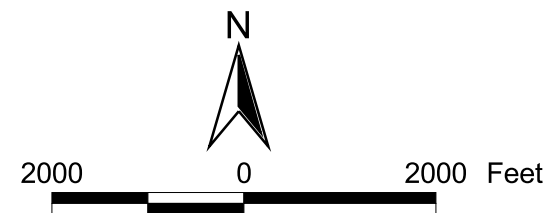
Figure C-4



Legend

- Inlet
- Dry Well
- Roads
- Lakes and Ponds
- Streams
- Road End
- Boat Launch
- Stormdrain Pipe

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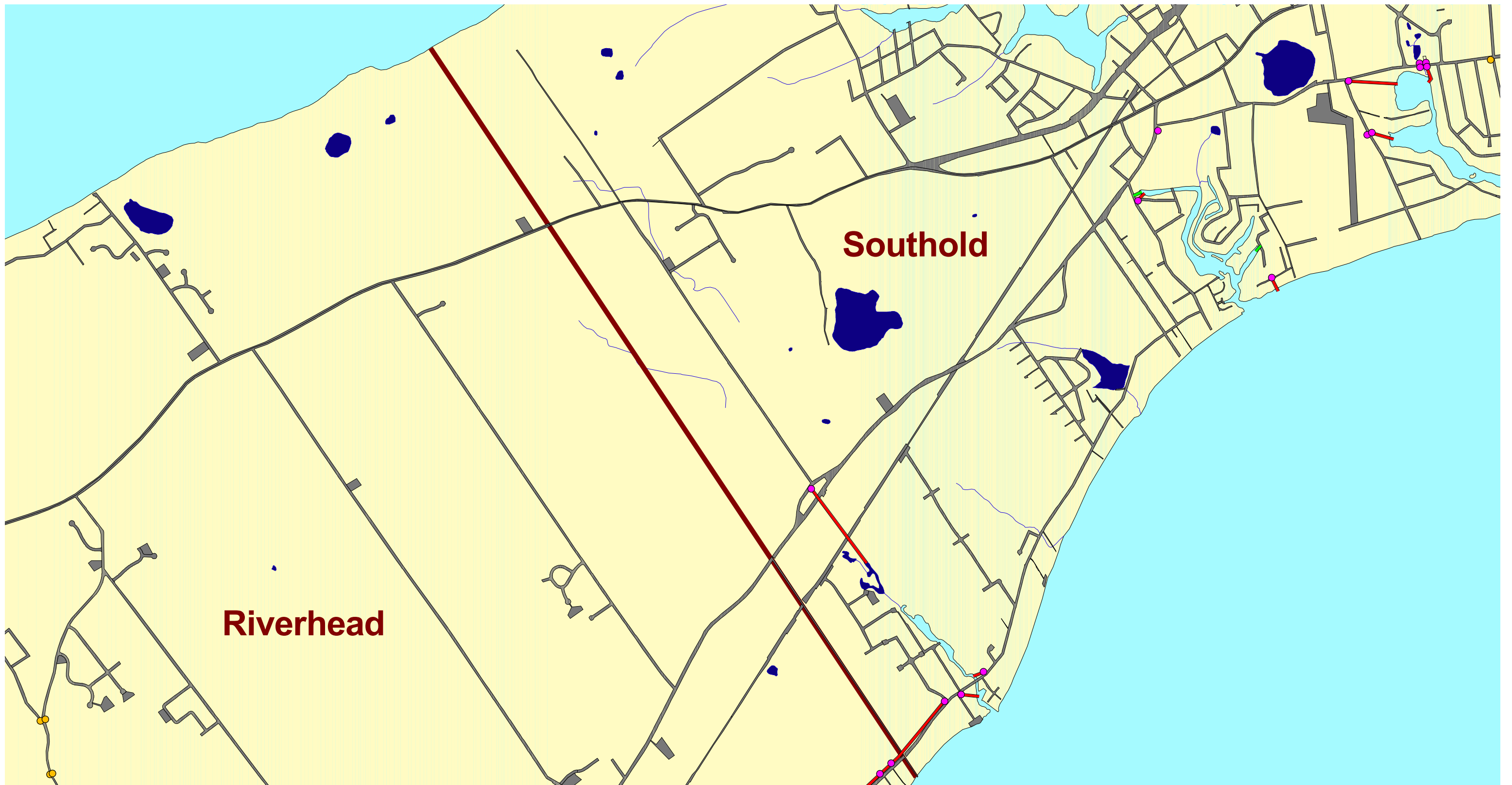


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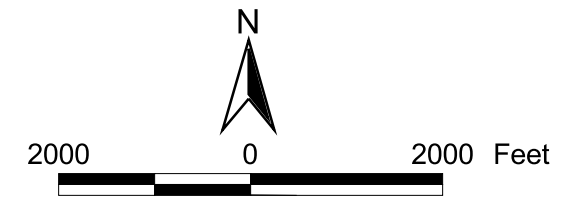
Figure C-5



Legend

- Inlet
- Dry Well
- Roads
- Lakes and Ponds
- Town Line
- Streams
- Road End
- Boat Launch
- Stormdrain Pipe

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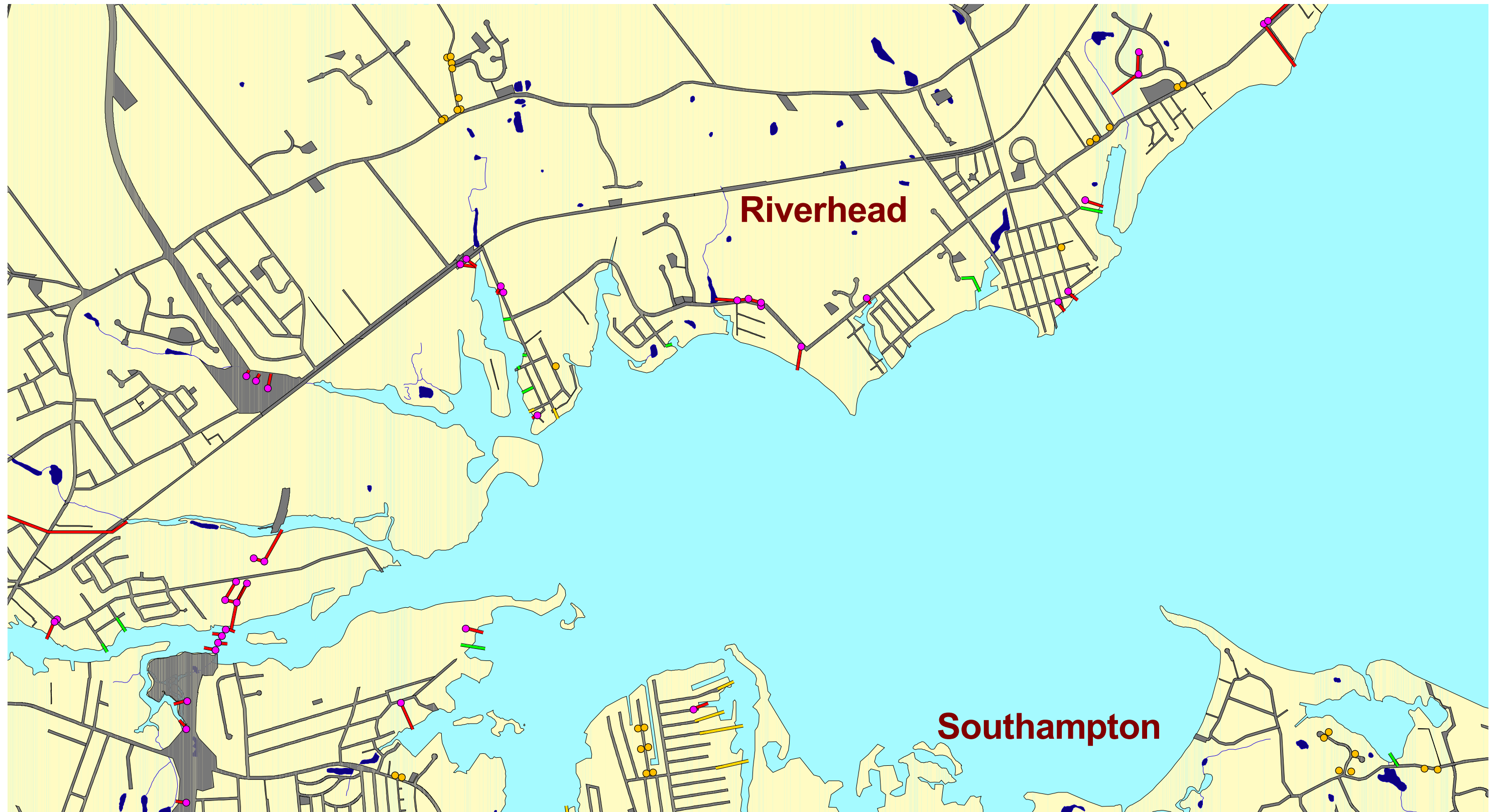


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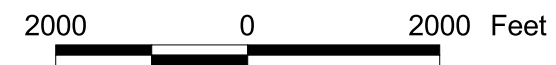
Figure C-6



Legend

- Inlet
- Dry Well
- Roads
- Lakes and Ponds
- Streams
- Road End
- Boat Launch
- Stormdrain Pipe

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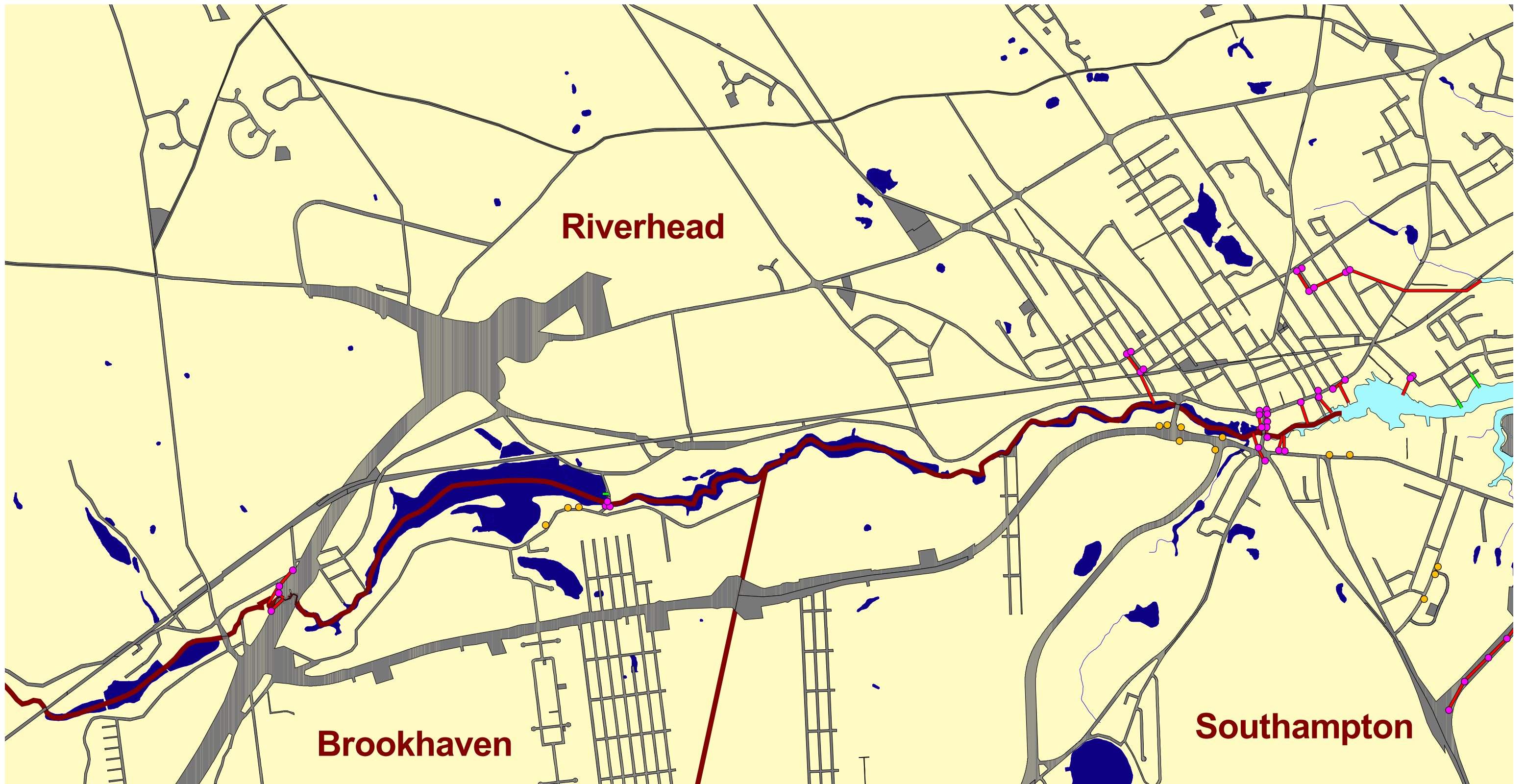


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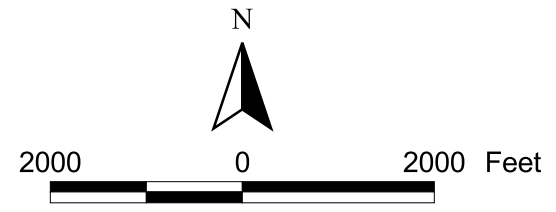
Figure C-7



Legend

- Inlet
- Dry well
- Roads
- Lakes and Ponds
- ~ Town Line
- ~ Streams
- ~ Road End
- ~ Boat Launch
- ~ Stormdrain Pipe

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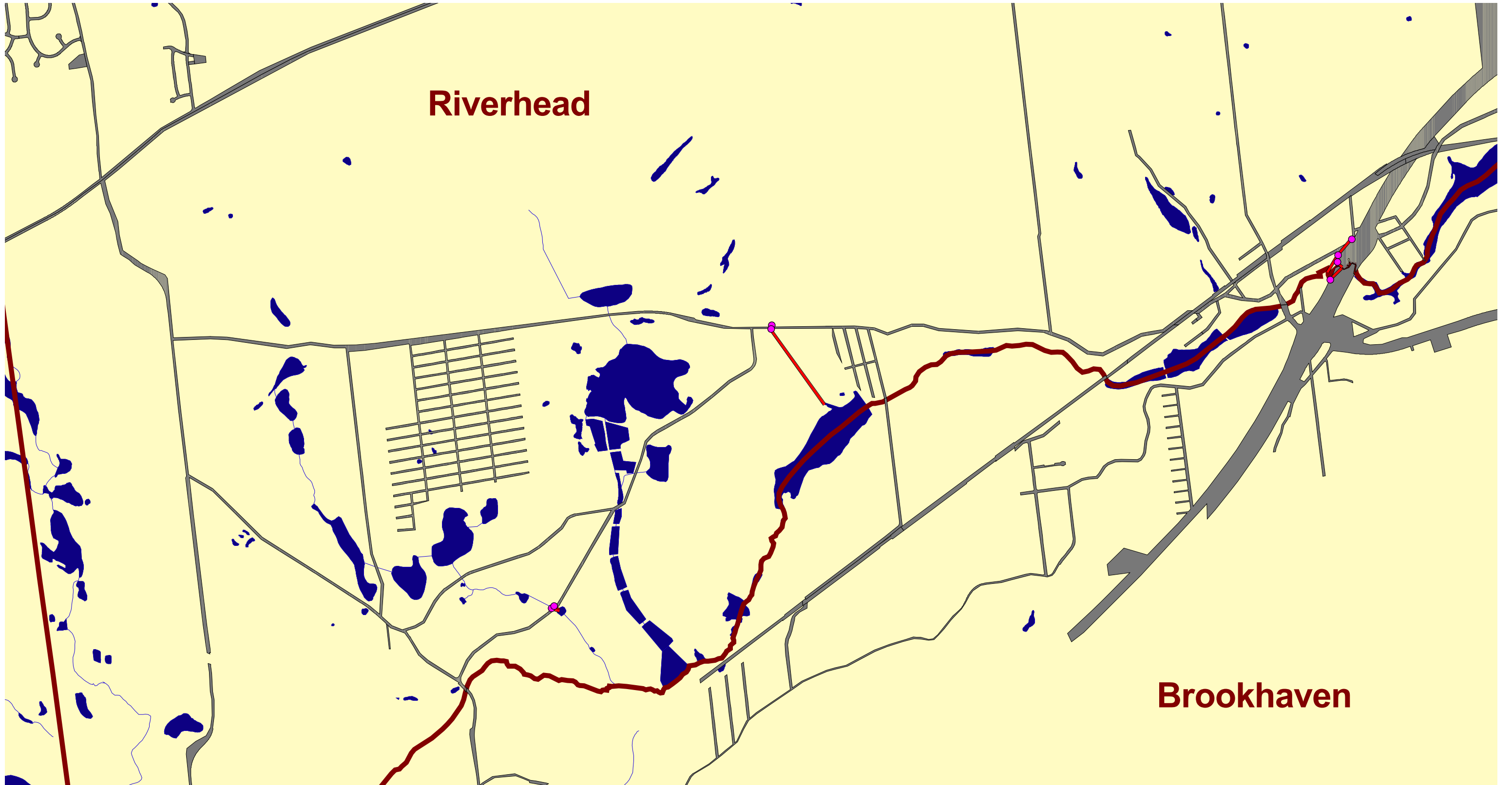
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Figure C-8

Riverhead

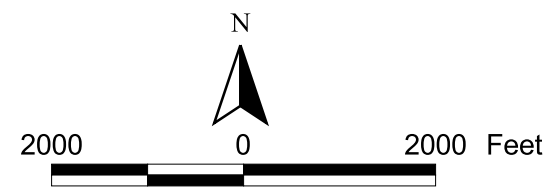
Brookhaven



Legend

- Inlet
- Dry well
- Roads
- Lakes and Ponds
- Town Line
- Streams
- Road End
- Boat Launch
- Stormdrain Pipe

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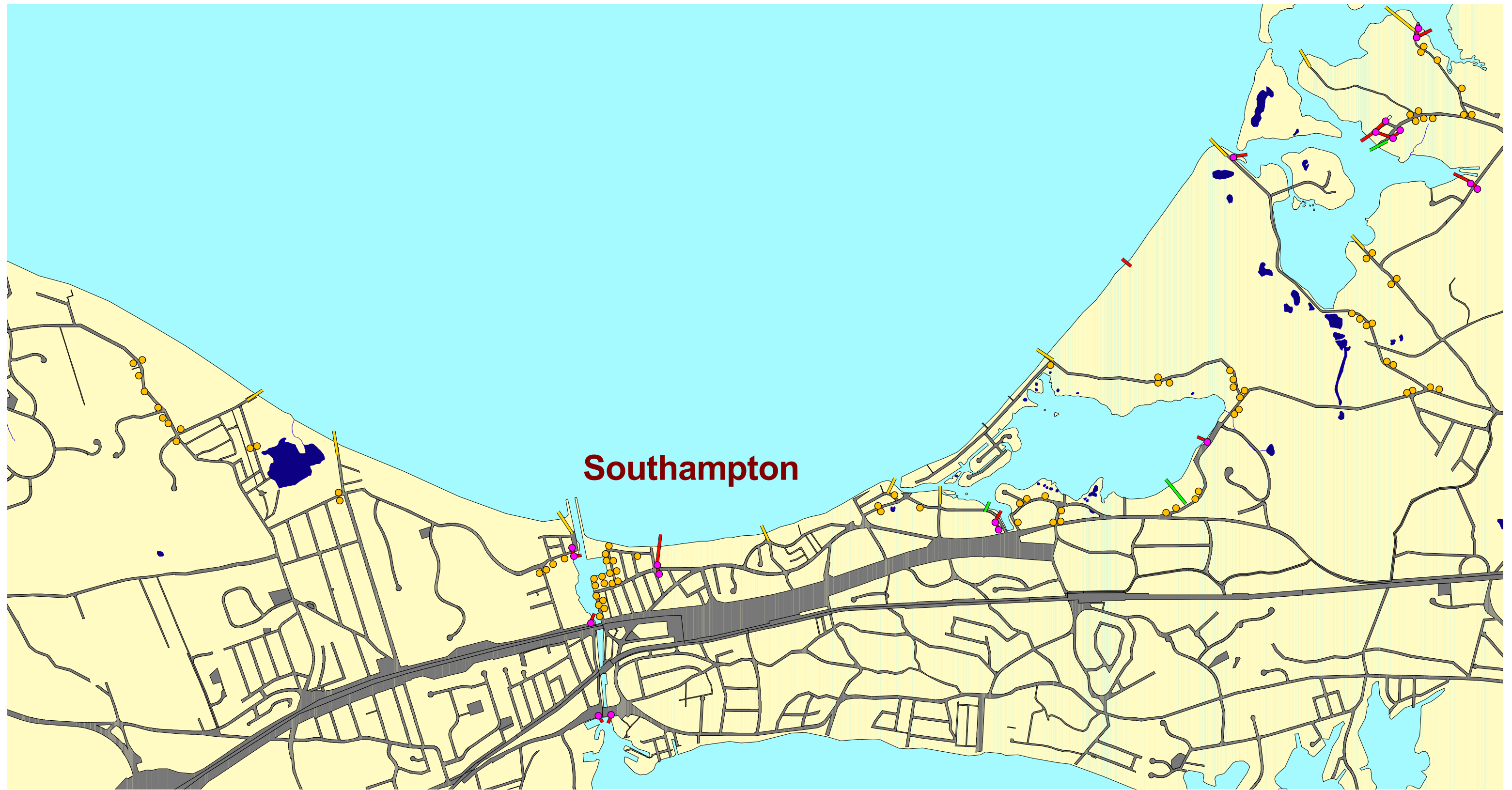


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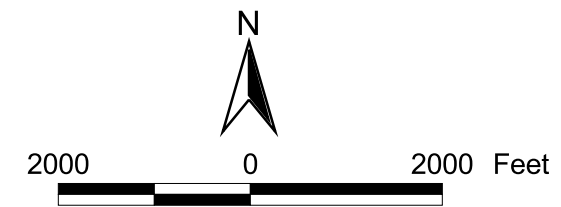
Figure C-9



Legend

- Inlet
- Dry Well
- Roads
- Lakes and Ponds
- Streams
- Road End
- Boat Launch
- Stormdrain Pipe

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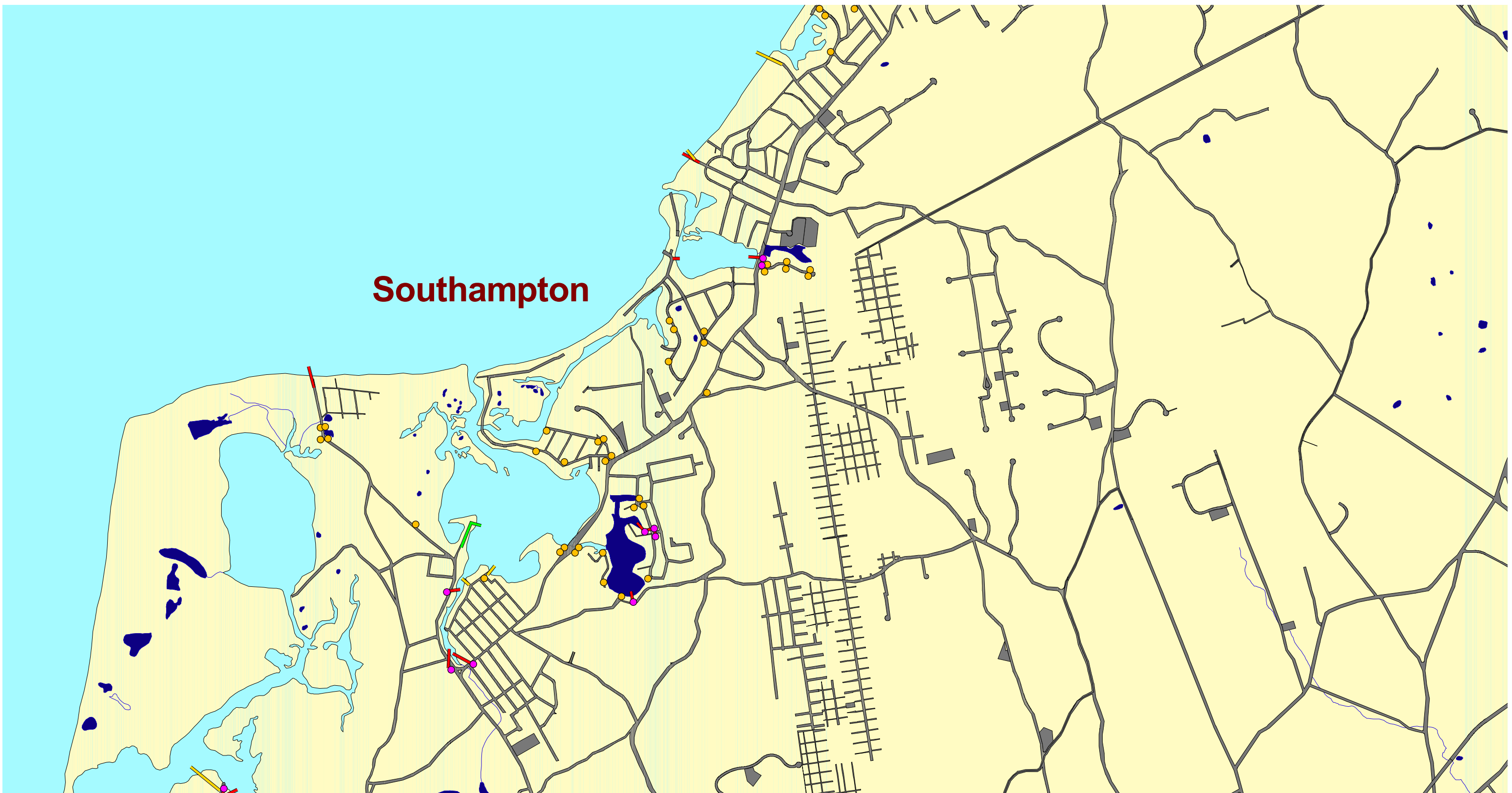


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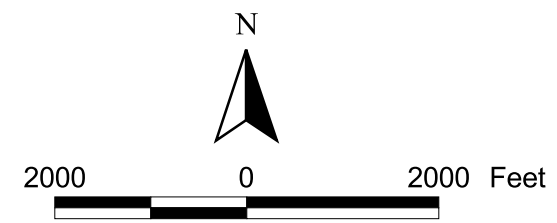
Figure C-10



Legend

- Inlet
- Dry Well
- Roads
- Lakes and Ponds
- Streams
- Road End
- Boat Launch
- Stormdrain Pipe

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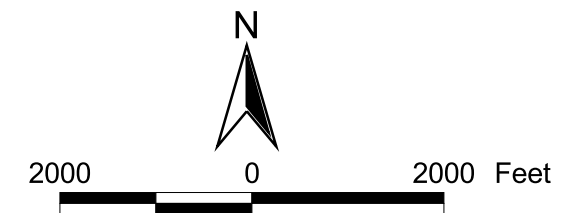
Figure C-11



Legend

- Inlet
- Dry Well
- Roads
- Lakes and Ponds
- ⋈ Town Line
- ⋈ Streams
- ⋈ Road End
- ⋈ Boat Launch
- ⋈ Stormdrain Pipe

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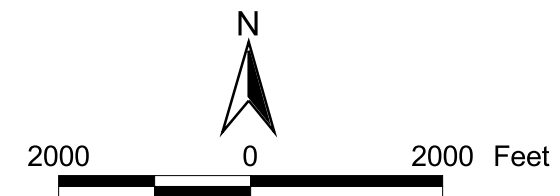
Figure C-12



Legend

- Inlet
- Dry Well
- Roads
- Lakes and Ponds
- ⋈ Town Line
- ~ Streams
- ⋈ Road End
- ⋈ Boat Launch
- ⋈ Stormdrain Pipe

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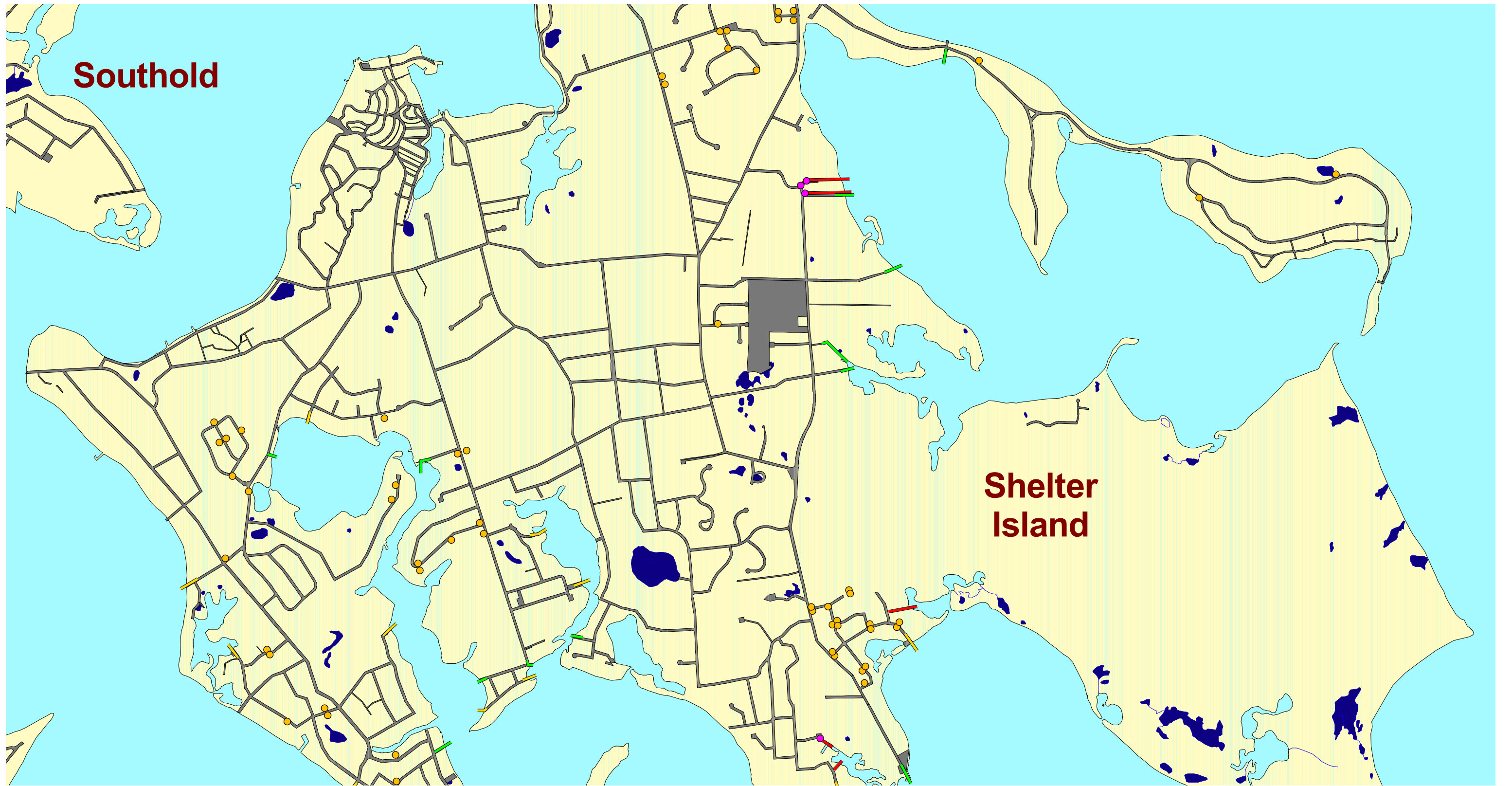


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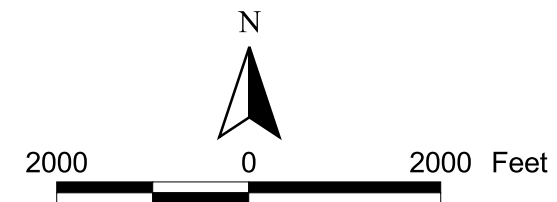
Figure C-13



Legend

- Inlet
- Dry Well
- Roads
- Lakes and Ponds
- Streams
- Road End
- Boat Launch
- Stormdrain Pipe

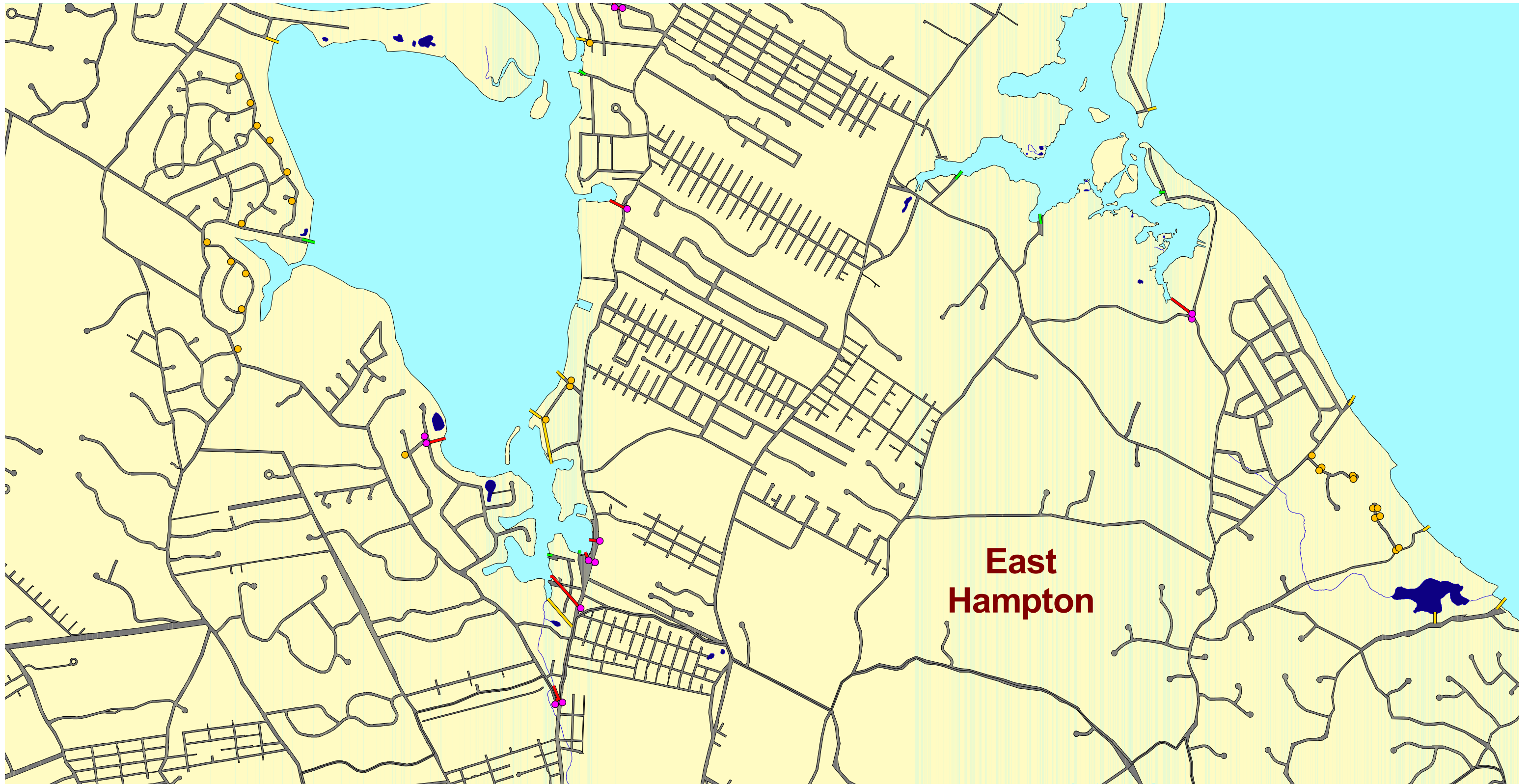
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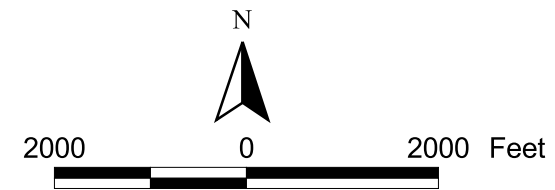
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Legend

- Inlet
- Dry well
- Roads
- Lakes and Ponds
- Streams
- Road End
- Boat Launch
- Stormdrain Pipe

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Figure C-15

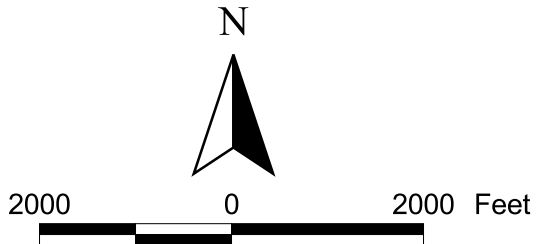
East Hampton



Legend

- Inlet
- Dry well
- Roads
- Lakes and Ponds
- Streams
- Road End
- Boat Launch
- Stormdrain Pipe

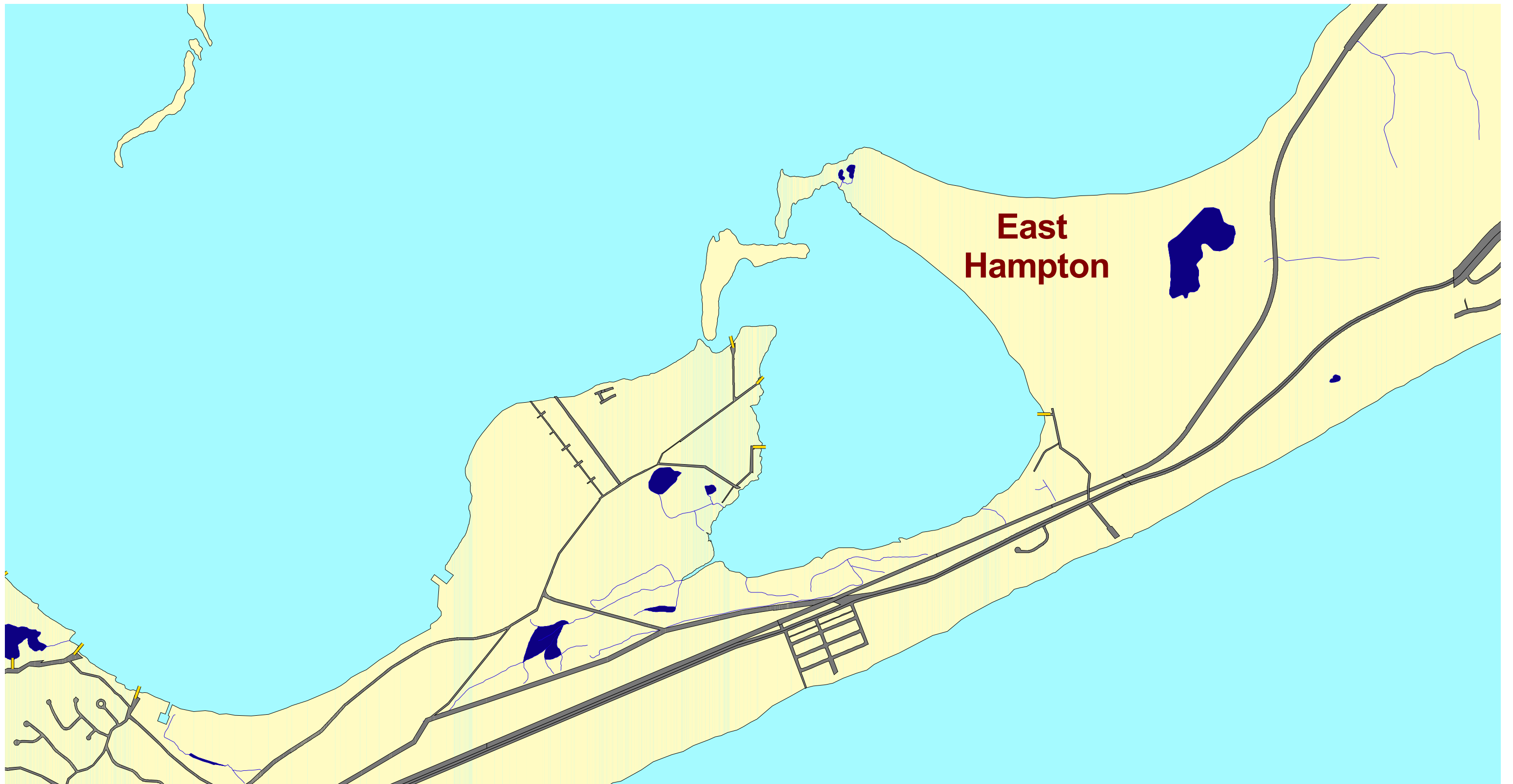
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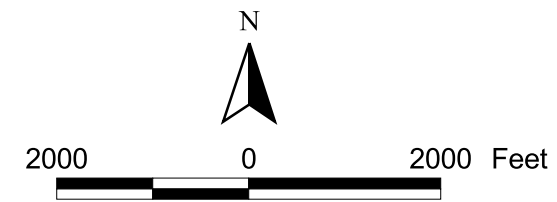
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Legend

- Inlet
- Dry well
- Roads
- Lakes and Ponds
- Streams
- Road End
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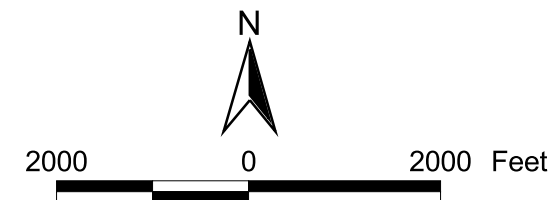
Figure C-17



Legend

- Inlet
- Dry well
- Roads
- Lakes and Ponds
- Streams
- Road End
- Boat Launch
- Stormdrain Pipe

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Figure C-18