Assessment of Retrofit Feasibility Of Selected Storm Water Systems In Brush Neck Cove Watershed

Warwick, RI

Report Prepared by
Southern Rhode Island Conservation District
In partial fulfillment of the
Greenwich Bay Storm Water Management Project
(Contract 99-Water (NPS)-12)

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ABSTRACT

This report reviews the evaluation of storm water systems in Brush Neck Cove performed by the Southern RI Conservation District (SRICD) in 1999, and describes the work to be undertaken by the City of Warwick and SRICD under 319 grants to select, design and install retrofits. Anticipated effect of the proposed retrofits is estimated in terms of drainage area treated (acres). Existing and proposed treated areas total 475 acres, or 30% of the Brush Neck Cove watershed, which is less than the provisional target of 40%. Additional systems are recommended for future retrofits.

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*Data source RIGIS, 1997 orthophotography. Subwatersheds, systems & facilities coverages by SRICD.

1.0 INTRODUCTION

1.1 Purpose

Over the past few years, the Southern Rhode Island Conservation District (SRICD) has been working with its partners to develop a storm water management program for Greenwich Bay. Based on the experience of storm water managers in the Mid-Atlantic region, meaningful restoration is best done at a subarea scale of roughly 1,000 to 1,500 acres (Claytor, 1995). Brush Neck Cove was selected as the first subarea for local restoration efforts, and its storm water systems were inventoried and evaluated (SRICD, 1999). This report reviews the procedures and results of that project, and takes a closer look at those systems identified as having the highest potential pollutant loading, to determine Best Management Practices (BMPs) for reducing that load.

1.2 Area Description

Brush Neck Cove is an inlet on the north side of Greenwich Bay, which in turn lies on the west side of Narragansett Bay in Rhode Island (see Figure 1). The Brush Neck watershed encompasses 1,597[1] acres, entirely within the City of Warwick. The area is relatively flat, with elevations ranging from sea level to 50' NGVD. Soils are generally outwash, with high infiltration rates. Land use is primarily medium to high-density residential, with commercial uses along West Shore Road (Route 117). Portions of the area are sewered; sewer installation is on-going in the western part of the Brush Neck Cove watershed as this report is being written.

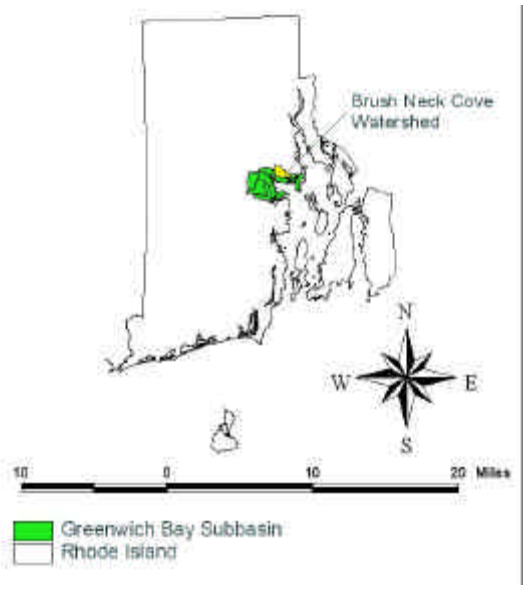

Figure 1. Locus Map

High levels of fecal coliform bacteria in Greenwich Bay have led to permanent closing of some shellfish beds. Storm events have led to temporary closings of additional shellfish beds. Harvesting shellfish from Brush Neck Cove is prohibited due to high levels of fecal coliform bacteria. In addition to violating the water quality standard for bacteria, Brush Neck Cove also violates nutrient and dissolved oxygen standards. The Rhode Island Department of Environmental Management (RIDEM) is currently developing a Total Maximum Daily Load (TMDL) for this area. The City of Warwick and the

[1] Acreages are based on Geographic Information System (GIS) data. Storm water systems identified in the Report to the City of Warwick (SRICD, 1999) were mapped as a shapefile using the RIGIS 1997 Orthophotography as a base map. Subwatershed and watershed boundaries were adjusted to reflect diversions to and from natural patterns. Acreages in this report may differ from those found in the Report, which used the dot grid technique of measuring.

Rhode Island Coastal Resources Management Council (CRMC) are also concerned about the impact of sediment.

Two perennial streams feed Brush Neck Cove: Tuscatucket Brook from the northwest and Carpenter Brook from the west. For the 1999 storm water evaluation, the watershed was divided into six subwatersheds: upper and lower portions of the brooks, and direct drainage to the Cove from the west and north/northeast (see Figure 2). (Note that the upper portions of the Tuscatucket and Carpenter Brook subwatersheds have been picked up by storm drains on Main Avenue and diverted to the Lower Tuscatucket.)

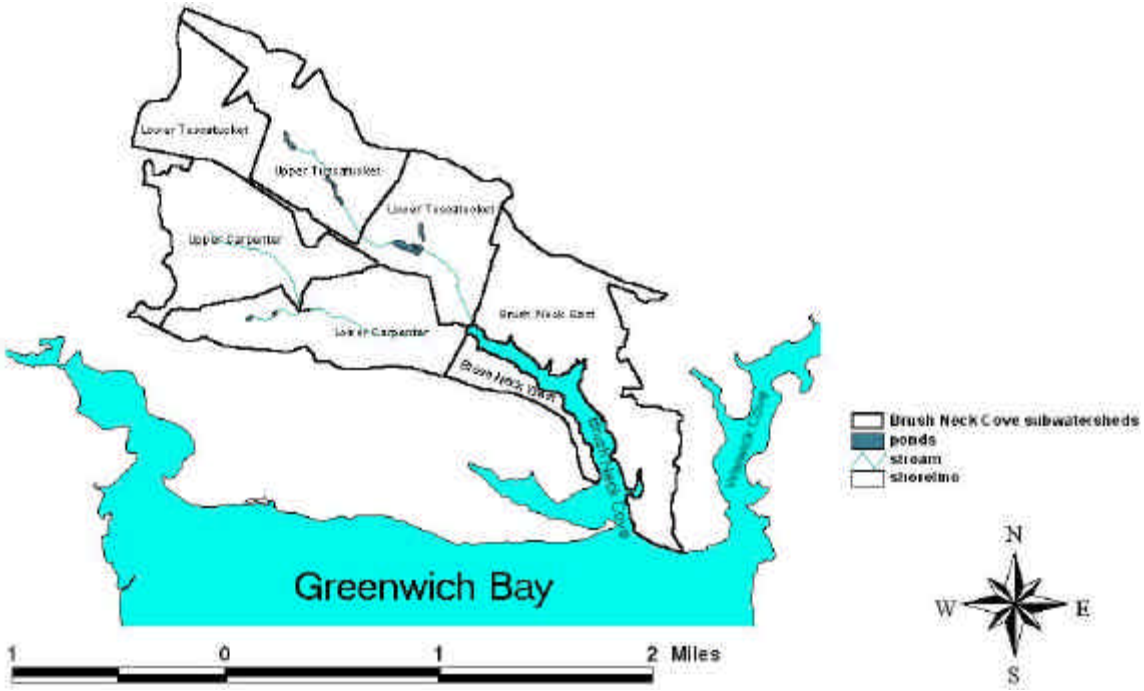

Figure 2. Subwatersheds of Brush Neck Cove

2.0 EXISTING RUNOFF CONDITIONS

2.1 Storm Water Inventory and Evaluation

In 1998 and 1999, under an Aqua Fund grant administered by RIDEM, the storm water conveyance systems in the Brush Neck Cove watershed were mapped and evaluated for their potential delivery of nonpoint source pollutants. A system was defined as the area draining to a discrete outfall (pipe or channel). The locations of vegetated and asphalt channels, pipe outlets, inlets and manholes were mapped on plat maps. Each system drainage area was also delineated on plat maps and topographic maps, and estimates were made (using a dot grid) of acreage and the amount of impervious cover. Vacant lots that might serve as future treatment areas ("potential retrofit sites") were located and evaluated. Each system was assigned a numeric identifier for future reference. Those systems whose outlets had been assigned a numeric identifier in wet weather studies by the University of Rhode Island's Department of Civil and Environmental Engineering (Wright, Fanning and Viator, 1998 and Wright & Viator, 1999) were given that same identifier to maintain continuity. They are the only systems with identifiers less than 100.

2.1.1 Existing storm water treatment

Existing facilities and their drainage areas were located and evaluated for their effectiveness in enhancing water quality. (Any existing structure that slows and/or treats runoff is called a "facility" in this report. The term "BMP" is used to denote future structures or practices.) The existing facilities in Brush Neck Cove watershed consist of one detention basin, one created wetland and a number of dry wells (catch basins with no outlet, i.e. infiltration structures). The evaluation of effectiveness of the existing facilities was based on twenty-plus years of experience and Table 7-2 of the US Environmental Protection Agency (EPA)'s handbook, Urban Runoff Pollution Prevention and Control Planning (US EPA, 1993). More recently, the Rhode Island Department of Transportation (RIDOT) published a similar table (RIDOT, 1999).

For the facility evaluation, it was assumed that a structure or practice listed on the EPA or RIDOT table as having high removal rates for the pollutants of concern to Brush Neck Cove (pathogens, nitrogen and sediment) could be said to be highly effective in treating runoff from its respective drainage area. This treated area could then be eliminated from consideration as a priority retrofitting site at this preliminary stage of planning for storm water management on a watershed basis.

Facilities listed on the EPA or RIDOT table as having medium removal rates were assumed to be providing some effect in treating runoff from their drainage area. Highly-effective facilities with drainage areas exceeding the optimum size noted in EPA's Table 7-2 (US EPA, 1993) and those judged to be in poor or fair condition were also ranked as providing some effect. For the purposes of selecting priorities for retrofitting, it was assumed that one half of the drainage areas of these facilities was treated.

2.1.2 System evaluation procedures

The information about each system, existing facility and potential retrofit site was loaded into a Microsoft Access database. The area treated by a facility (as discussed above) was subtracted from the appropriate system's drainage area by the database program. Systems were compared within each subwatershed based on the relative size of the (untreated) drainage area, relative imperviousness, and availability of sewers that would remove some of the pollutant load. Numerical rankings were assigned using the criteria shown in Table 1.

Table 1. Criteria for Ranking Systems

Relative[2] Size		Relative Imperviousness		Presence of Sewers	
Criteria	**Points**	**Criteria**	**Points**	**Criteria**	**Points**
Adjusted drainage area (area treated by facilities subtracted) is:					
Less than or equal to ½ the average drainage area (da) of systems in the subwatershed	1 point	No impervious surfaces	0 points		
Greater than 1/2 average da but less than average	2 points	% impervious is greater than 0, less than the average for systems in the subwatershed	1 point	More than 50% of the system is sewered	0 points
Greater than or equal to average da but less than 2 times average	3 points	% impervious is average for the subwatershed	2 points	Less than or equal to 50% of the system is sewered	1 point
Greater than or equal to 2 times average	4 points	% impervious is greater than average	3 points	No sewers	2 points

Note that systems are grouped and evaluated on a subwatershed basis; thus similar systems in different subwatersheds may have different numerical rankings.

Maps of each subwatershed were prepared using enlargements of the USGS topographic map. System drainage areas were delineated and numbered, then color-coded to reflect their relative ranking based on the criteria noted above.

2.1.3 Areas outside of defined systems

The 1998-1999 survey of storm water systems accounted for 1,160 of the 1,597 acres in the Brush Neck watershed. The remaining 437 acres that do not drain to an identified outlet are assumed to be in an "overland flow" condition, that is, diffuse runoff that discharges directly to the Cove or its streams. These areas are shown by land use (RIGIS coverage) in Figure 3.

[2] Each system is compared to other systems within its subwatershed.

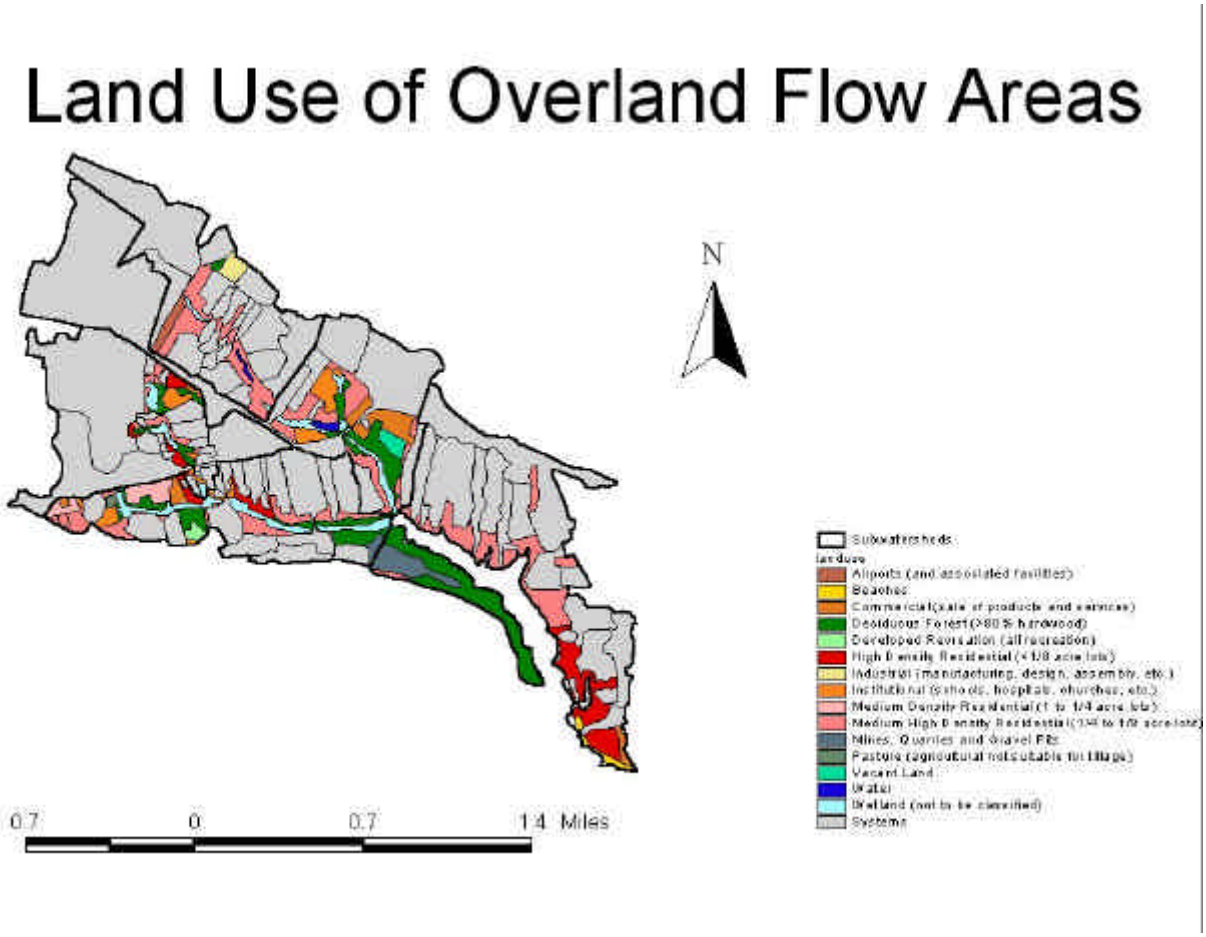

Figure 3. Land Use of Overland Flow Areas

Rather than evaluating each of the overland flow areas separately (that is, in a similar fashion to areas draining to systems), some general conclusions were drawn about these areas. It was observed that many of the areas were in low-intensity use, as shown in Table 2.

Table 2. Land Use, Acres and Nitrogen Loading Rates of Overland Flow Areas

Land Use (from RIGIS)	Acres	Nitrogen Loading Rate[3], lb N/Ac/Yr
High Density Residential (>8 units/acre)	45.1	11.9-14.3
Medium High Density Residential (4-7.9/ac)	151.6	7.3-11.9
Medium Density Residential (1-3.9/ac)	13.3	4.3-7.3
Commercial	26.8	2.0-20.0
Industrial	5.9	2.0-15.0
Airports	6.3	2.0-20.0
Recreation	3.1	1.5-4.0
Institution	23.2	7.3-11.9
Pasture	1.4	2.0-5.0
Forest	90.8	0.9-2.9
Wetland	38.9	0.0
Water	3.3	8.0
Barren (gravel pits, beaches)	22.3	0.9-2.9
Brush (vacant)	5.0	0.9-2.9
Total	**437.0**	

Using nitrogen loading as an indicator of general pollutant loading rates, the following uses were determined to have low loading rates: airports (in this case an adjacent mowed field), recreation, pasture, forest, wetland, barren (the large area shown in the Brush Neck West subwatershed is now a grassed portion of Warwick City Park) and brush. These land uses comprise approximately 38% of the land designated as overland flow areas.

A review of the aerial photography showed that, in most overland flow areas, lower intensity uses were buffering waterbodies from the sheet runoff from higher intensity uses. Buffer widths were measured on the photos, and were found to range from 35 to 200 feet. In general, greater than 50% removal standards can be met with vegetated buffers about 5 meters (16.4 feet) wide (Desbonnet, Pogue, Lee and Wolff, 1994).

The relatively high proportion of overland flow areas in or buffered by low intensity land use led to the conclusion that they could be evaluated as though they all flowed to facilities that provided some effect in treating runoff, through diffusion, infiltration and plant uptake. Using the same assumption as described in section 2.1.1, half of the overland flow acreage was counted as treated.

[3] Loading rates from URI's MANAGE program; see Appendix E of the Report to the City of Warwick (SRICD, 1999).

2.2 Treatment as of 1999

Seventy separate systems were identified within the Brush Neck Cove watershed (see Appendix A). Appendix B lists, by subwatershed, the overland flow areas and facilities, with the corresponding acreage assumed to be treated[4]. Figure 4 shows the location of the areas treated by facilities (dark tone) and overland flow areas (light tone).

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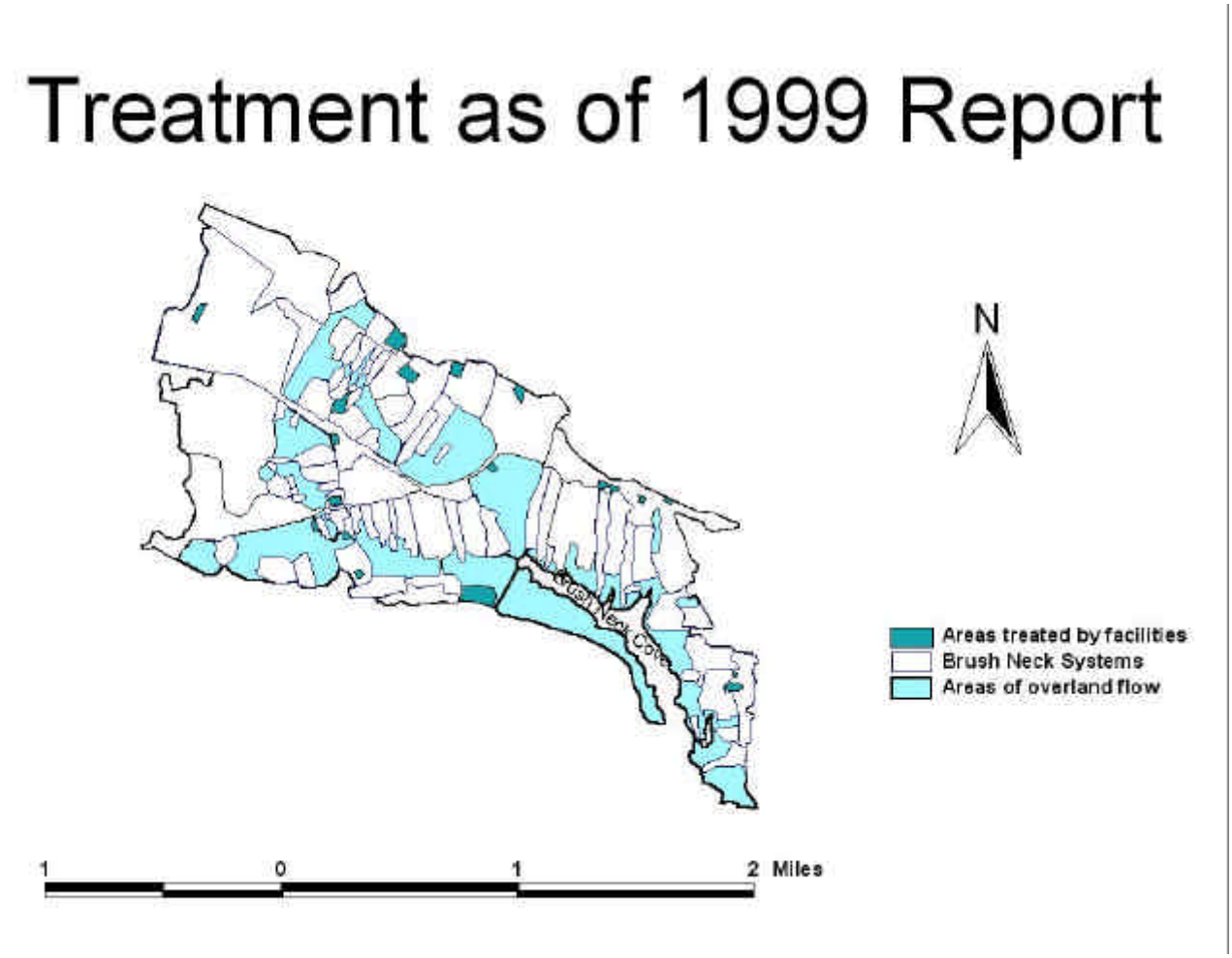

Figure 4. Treatment as of 1999 Report

Based on the evaluation of facilities and overland flow areas as described in section 2.1.1, roughly 15% of the Brush Neck Cove watershed was considered treated for the reduction of nonpoint source pollution in the Cove and its streams (see Table 3).

[4] This section addresses only those entries with "'99 inventory" in the Notes column.

Table 3. Summary of 1999 treatment

Subwatershed	Total Acres	Treated Acres	% Treated (treated acres divided by total acres, times 100)
Brush Neck East	344	46.6	14%
Lower Carpenter	261	63.7	24%
Upper Carpenter	277	19.0	7%
Lower Tuscatucket	391	53.3	14%
Upper Tuscatucket	264	31.4	12%
Brush Neck West	60	30.8	51%
Total Brush Neck	1597	**244.8**	**15%**

2.3 Systems Selected for Further Assessment

Numerical rankings of the systems within each subwatershed were derived by the database program developed to generate such rankings[5], based on the points shown in Table 1. Thirteen systems were identified as having the highest potential pollutant loading, and therefore priority areas for investigating the feasibility of retrofitting (see Figure 5). None of these is located in the Brush Neck West subwatershed, which covers the north portion of Warwick City Park, because only one system was identified in the entire subwatershed. Table 4 provides information on the location of each priority system and why it received a high numerical ranking.

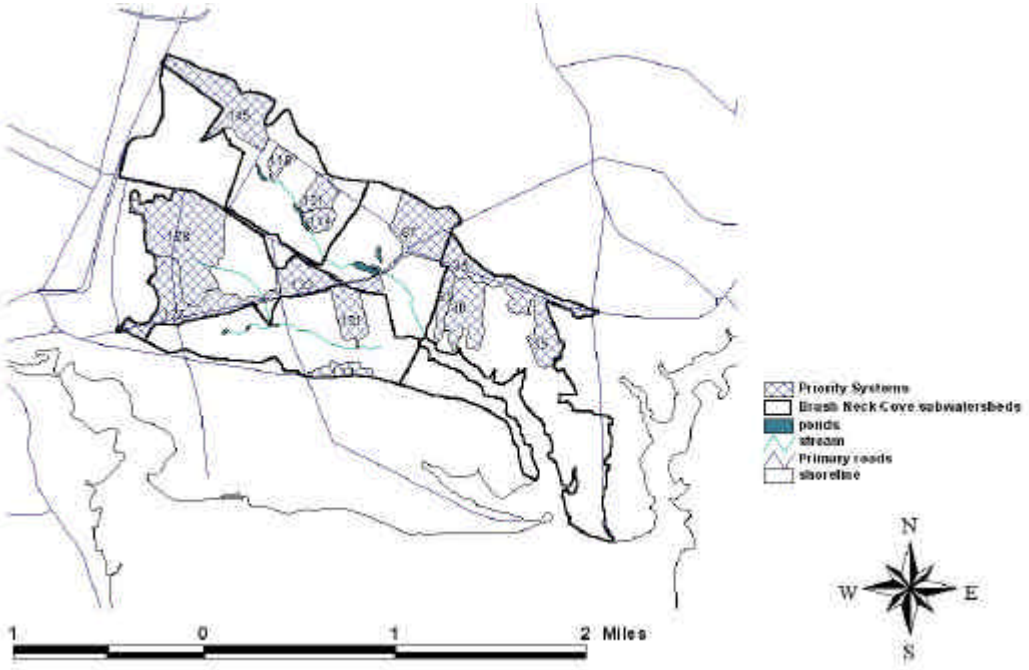

Figure 5. Priority Systems

[5] See A Tool for Setting Priorities (SRICD, 2000)

Table 4. Priority Systems

System #	Associated Road(s)	Subwatershed	Why priority?			Sampled?
			Large Drainage Area	Highly impervious	Lack of sewers	
131	White Avenue	Lower Carpenter	X		X	No
133	Boyle Avenue	Lower Carpenter	X	X	X	No
127	West Shore Road	Upper Carpenter	X		X	No
123	West Shore Road	Upper Carpenter	X		X	No
128	Wesleyan Avenue	Upper Carpenter	X		X	No
87	West Shore Road	Lower Tuscatucket	X	X		No
114	Burbank Drive	Upper Tuscatucket		X	X	No
121	Burbank Drive	Upper Tuscatucket		X	X	No
116	Burgess Drive	Upper Tuscatucket		X	X	No
145	Industrial Drive	Upper Tuscatucket	X		X	No
29	Cottage Grove Avenue	Brush Neck East	X		X	No
30	Shand Avenue	Brush Neck East	X		X	Yes (Wright, Fanning & Viator, 1998)
35	Gordon/Hawksley	Brush Neck East	X	X		Yes (Wright, Fanning & Viator, 1998)

3.0 EVALUATION OF SELECTED SYSTEMS FOR RETROFITTING

3.1 City of Warwick Project

The City of Warwick applied for a grant under section 319 of the Clean Water Act (hereinafter referred to as a section 319 grant) to install BMPs within five systems as noted in Figure 6 and Table 5.

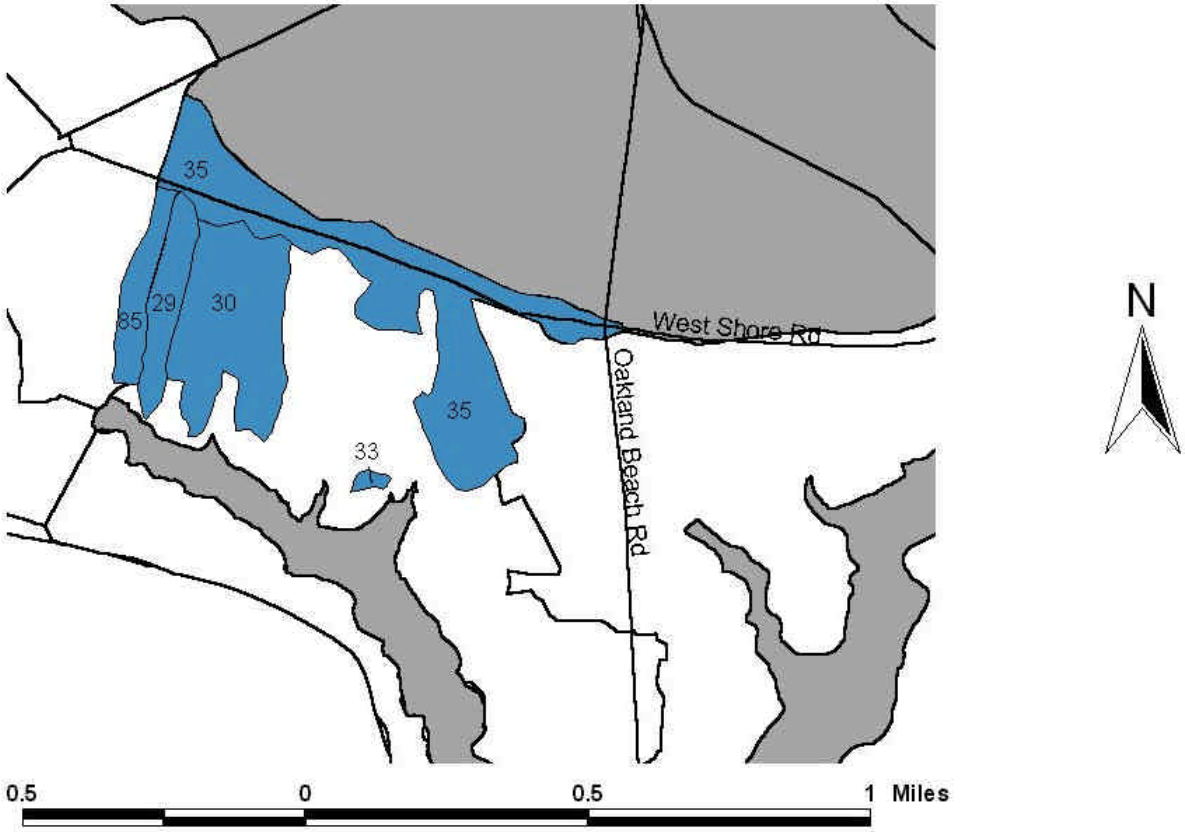

Figure 6. Systems to be Treated by Warwick's 319 grant

Installation began in the summer of 2001. The BMPs selected for these systems (swirl separators) remove significant amounts of sediment, oils and greases, but do little to treat the major pollutants affecting the Bay, i.e. nutrients and pathogens. If they had been installed at the time of the storm water inventory, they would have been evaluated as providing some effect on water quality. The treated acreage is therefore estimated as equivalent to 50% of the systems' drainage areas.

Table 5. Anticipated Effect of Warwick's BMP Installation under 319 grant

Subwatershed	System # (Street)	Acres Draining to System	Acres Treated	SRICD Ranking[1]
Brush Neck East	29 (Cottage Grove)	12.4	6.2	High
	30 (Shand)	39.1	19.6	High
	35 (Hawksley)	71.2	35.6	High
	33 (Canfield Ct)	4.8	2.4	Medium
Lower Tuscatucket	85 (Spring Grove)	10.2	5.1	Low

1 (SRICD, 1999)

Installation of these practices will increase the area treated in the Brush Neck East subwatershed by 63.8 acres, resulting in a total of 32% of that subwatershed being treated. Treated acreage in the Lower Tuscatucket subwatershed will total 15%; Brush Neck as a whole will increase to 20% treated.

3.2 SRICD Project

Under its 319 grant, SRICD agreed to assess the feasibility of treating the ten systems with high potential pollutant loads not addressed under Warwick's 319 grant (see Table 4), and to design two BMPs. SRICD staff reviewed the outfalls and drainage areas with Engineering Specialists from USDA Natural Resources Conservation Service (NRCS) in the summer and fall of 2000.

The ten systems are described below, with suggested BMPs for each. Using nitrogen as an indicator, pollutant loading rates are estimated using rates from the MANAGE program (SRICD, 1999). Nitrogen loading calculations for each of the priority systems are included as Appendix C. BMP pollutant reduction rates are based on the EPA (US EPA, 1993) and RIDOT (RIDOT, 1999) tables mentioned in section 2.1.1. The systems are grouped by subwatershed.

3.2.1 Lower Carpenter Subwatershed

3.2.1.1 System 131 – White Avenue

Outfall Location: At the bridge on White Avenue over Carpenter Brook.

Outfall Description: Asphalt chutes on both the east and west sides of the bridge. These chutes also serve as the outlet for system 150. A 24" corrugated metal pipe (CMP) discharging on the west side of White Avenue upstream of the bridge conveys subsurface flows only.

Drainage Area: 25.5 acres as shown on Figure 7, covering Union, Stone and White Avenues. 38% of this residential area has impervious cover (roads, driveways, rooftops). The area was unsewered at the time of the assessment.

Suggested BMP:

Assessor's Plat (AP) 363, Lot 523 is City owned and encompasses the Brook at the White Avenue crossing. The lot is 1.85 acres in size, but is long and narrow. This open area is mapped Walpole sandy loam in the Soil Survey of Rhode Island (USDA, 1981). Walpole soils are hydric, which means they are capable of supporting wetland vegetation. Most of the lot is also within 100 feet of the Brook. BMP design will require on-site soils investigation and careful consideration of wetlands regulations.

Curbing along White Avenue could be removed to allow diversion of the runoff to a small settling basin, then to level spreaders and vegetated filter area or created wetlands prior to entering Carpenter Brook. These practices will provide both settling and uptake of pollutants.

According to Schueler (Schueler, 1992), the minimum ratio of wetland area to watershed area is 0.01:1. Therefore, the wetland would need to be 0.26 acres, or 11,326 square feet in size. There is insufficient room between White Avenue, Brush Neck Cove and the north edge of the stream for a BMP of this size without obtaining easements from the property owners to the north. Or, some of the flow could be directed to a twin wetland on the west side of the bridge, where there is more room but reverse gradient.

Soils in the watershed are such that infiltration trenches or dry wells may be placed in the upper reaches to reduce the drainage area, and thus reduce the size of the streamside BMP while providing similar pollutant attenuation. Such infiltration practices will require submission to the RIDEM Underground Injection Control (UIC) Program.

Alternatively, surface inlets could be installed to tie in to the existing pipe. In-line innovative storm water treatment technologies (such as Vortechnics, Stormceptor, etc.) could be placed within the pipe to capture sediments, oils and greases. These practices provide only minimal treatment of pathogens or nitrogen.

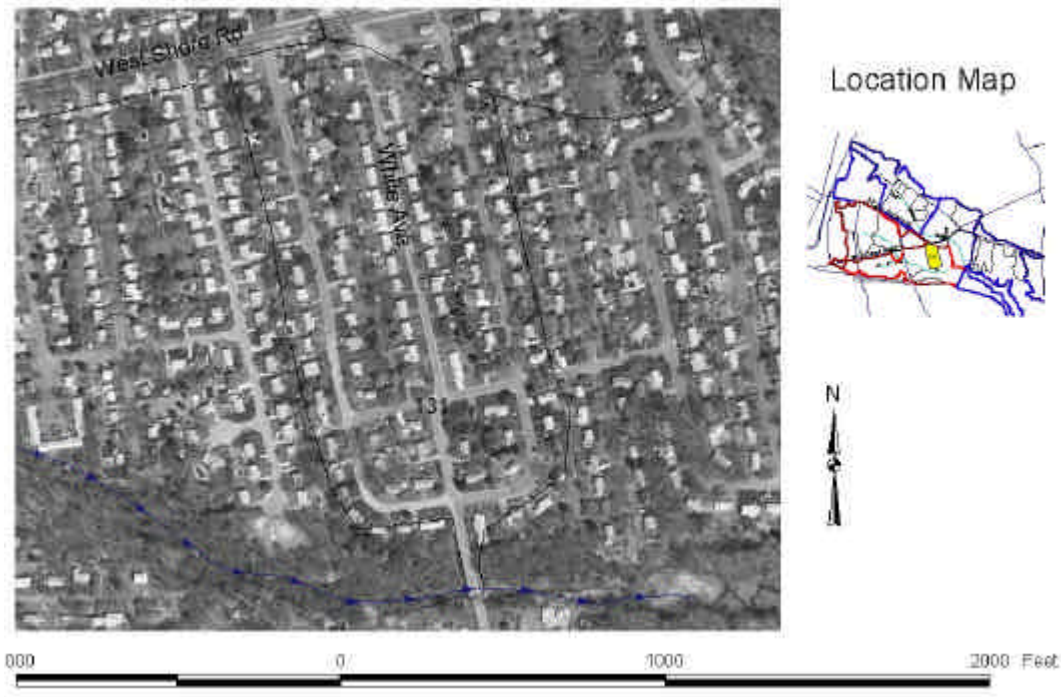

Figure 7. Lower Carpenter Subwatershed, System 131

Table 6. Nitrogen Loading and BMP Removal Rates for System 131

Proposed BMP	Nitrogen		Total Suspended Solids	Pathogens
	Loading lbs/yr	Percent Removal	Percent Removal	Percent Removal
Constructed Wetlands[6]	146 - 239	60-70%	80-99%	90-99%
Vegetated Filter	146 - 239	30-65%	30-65%	Less than 30%
Infiltration	146 - 239	60-70%	60-90%	65-99%
In-line Treatment	146 - 239	25-50%	60-90%	(no data)

[6] Pollutant removal rates for constructed wetlands are based on RIDOT information only (RIDOT, 1999)

3.2.1.2 System 133 – Boyle Avenue

Outfall Location: At the north end of Boyle Avenue adjacent to Carpenter Brook.

Outfall Description: 15-inch reinforced concrete pipe (RCP).

Drainage Area: Approximately12 acres as shown on Figure 8, encompassing Asylum Road and portions of Wellington Avenue. An estimated 44% of this medium-high density residential area has impervious cover. The area was unsewered at the time of the assessment. Runoff is collected in catch basins and piped down Boyle Avenue, which is a paper street for a few blocks.

Suggested BMP:

The City-owned AP 363 Lot 523 abuts Boyle Avenue to the east at streamside. There appears to be room for a created/enhanced wetland (5,227 square feet needed) or vegetated filter with a small forebay for settling and uptake of pollutants. Soils in the watershed are such that infiltration trenches or dry wells (requiring UIC permits) may be placed in the upper reaches to reduce the drainage area, and thus reduce the size of the streamside BMP. In-line innovative storm water treatment technologies could capture sediments, oils and greases.

Lot 523 is mapped Walpole sandy loam on the Soil Survey. Walpole soils are hydric, which means they are capable of supporting wetland vegetation. The potential retrofit site is also within 100 feet of the Brook. BMP design will require on-site soils investigation and careful consideration of wetlands regulations.

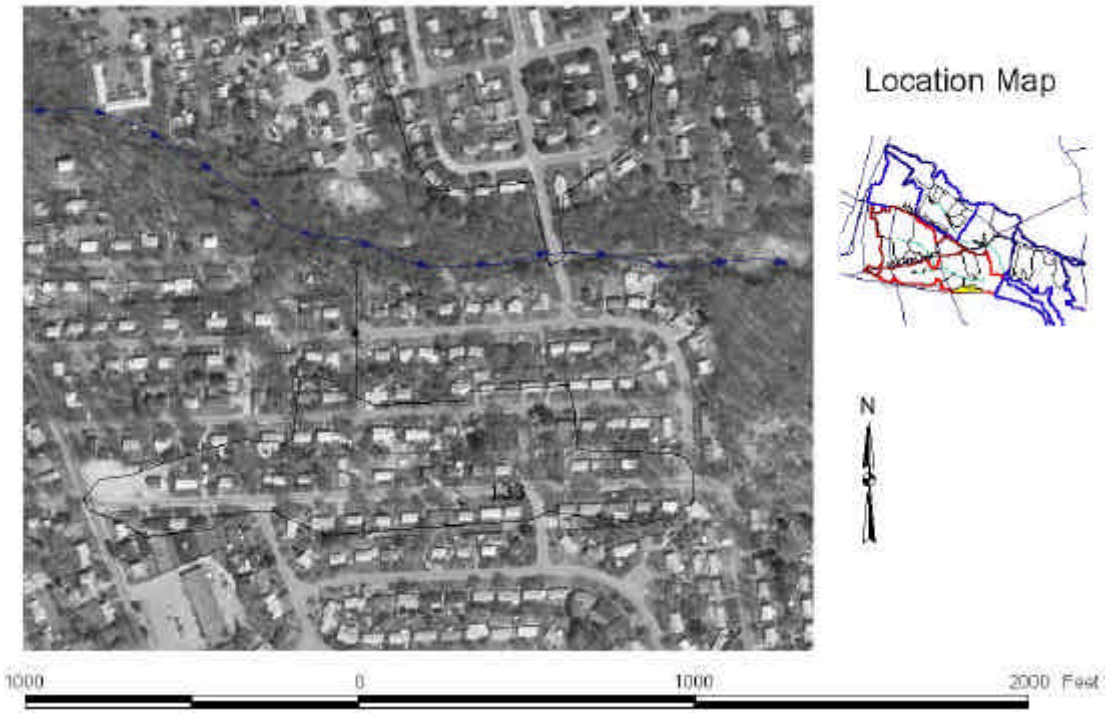

Figure 8. Lower Carpenter Subwatershed, System 133

Table 7. Nitrogen Loading and BMP Removal Rates for System 133

Proposed BMP	Nitrogen		Total Suspended Solids	Pathogens
	Loading lbs/yr	Percent Removal	Percent Removal	Percent Removal
Constructed Wetlands	88-143	60-70%	80-99%	90-99%
Vegetated Filter	88-143	30-65%	30-65%	Less than 30%
Infiltration	88-143	60-70%	60-90%	65-99%
In-line Treatment	88-143	25-50%	60-90%	(no data)

3.2.2 Upper Carpenter Subwatershed

3.2.2.1 System 127 – West Side West Shore Road

Outfall Location: At the West Shore Road (Route 117) crossing of Carpenter Brook.

Outfall Description: Pipe of unknown size drops directly into the culvert carrying the brook under the road. The culvert ends as a 36-inch RCP; it also carries runoff from Systems 128, 123 and 159.

Drainage Area: Approximately 63 acres as shown on Figure 9. With approximately 41% impervious cover, the area extends along West Shore Road to George Arden Avenue, and also picks up drainage from Gertrude and Groveland Avenues. The predominant land use is medium-high residential, with some commercial along the state highway. The area was unsewered at the time of the assessment; plans for extending sewers do not cover the entire drainage area.

Suggested BMP:

Unfortunately, there is very little open space for structural BMPs within this drainage area. There is a pocket park at the intersection of Groveland Avenue and West Shore Road where a small structure might be installed, but the drainage area to it appears to be quite large. In-line innovative storm water treatment technologies could be used to capture sediments, oils and greases. A soils investigation would be needed to determine the feasibility of infiltration structures placed throughout the area to reduce pollutant loading and/or the catchment to the system or to another structure. The feasibility of placing structures under a high-traffic volume road such as West Shore Road will also need study.

There may be room for wetland enhancement a few hundred feet downstream of West Shore Road, however, this would have to treat the entire Upper Carpenter subwatershed, and perhaps part of Lower Carpenter as well.

Of these options, it is suggested that in-line innovative technologies and infiltration structures be investigated first.

Table 8. Nitrogen Loading and BMP Removal Rates for System 127

Proposed BMP	Nitrogen		Total Suspended Solids	Pathogens
	Loading lbs/yr	Percent Removal	Percent Removal	Percent Removal
Infiltration	480 - 746	60-70%	60-90%	65-99%
In-line Treatment	480 - 746	25-50%	60-90%	(no data)
Constructed Wetlands	480 – 746 (plus in-stream load)	60-70%	80-99%	90-99%

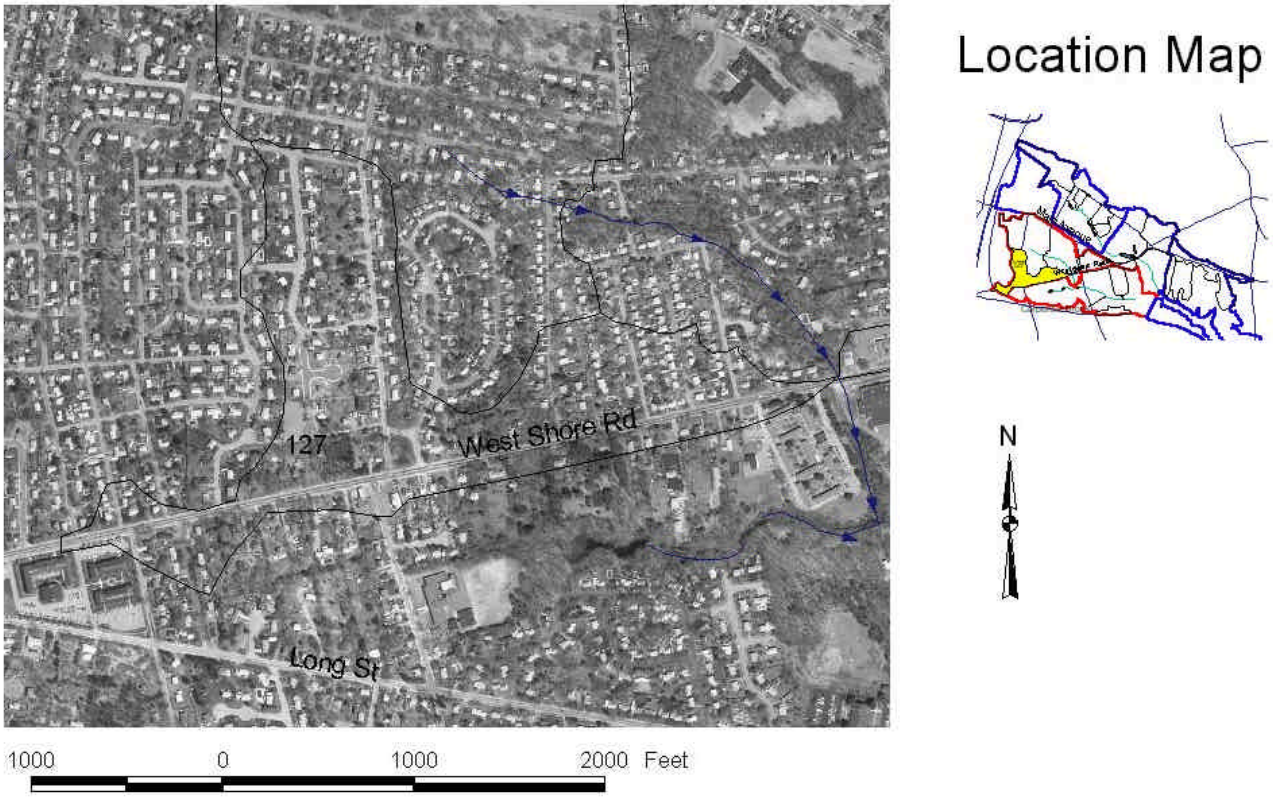

Figure 9. Upper Carpenter Subwatershed System 127

3.2.2.2 Systems 123 and 159 – East Side West Shore Road

Outfall Location: At the West Shore Road (Route 117) crossing of Carpenter Brook.

Outfall Description: Pipe of unknown size drops directly into the culvert carrying the brook under the road. The culvert ends as a 36-inch RCP; it also carries runoff from Systems 127 and 128.

Drainage Area: (See Figure 10.) System 123 is a 31-acre drainage area to the east of the stream crossing, encompassing the triangle formed by West Shore Road, Main Avenue and Carpenter Street, and extending southwest toward Buttonwoods Avenue. Roughly 40% of the area has impervious cover. The area was unsewered at the time of the assessment. Runoff is collected in catch basins along West Shore Road and piped directly to the Brook.

System 159 also discharges directly to the Brook at the crossing. Runoff from the north portion of a shopping center parking lot flows to a single inlet directly over the Route 117 culvert. The one-acre drainage area is 100% impervious. The area was unsewered at the time of the assessment. This system ranked in the low-potential loading category due to its size; however, treatment of any system which outlets near the stream crossing will most likely involve treating all of them.

Suggested BMP:

Again, there is little to no open space for structural BMPs within these drainage areas. In-line innovative storm water treatment technologies could be used to capture sediments, oils and greases. There may be room for wetland enhancement a few hundred feet downstream; however, this would have to treat the entire Upper Carpenter subwatershed, and perhaps part of Lower Carpenter as well. A soils investigation would be needed to determine the feasibility of infiltration structures placed throughout the area to reduce pollutant loading and/or the catchment to the system or to another structure. The feasibility of placing structures under a high-traffic volume road such as West Shore Road will also need study. The same downstream potential wetland enhancement noted in the discussion about System 127 could treat these systems as well.

Table 9. Nitrogen Loading and BMP Removal Rates for System 123

Proposed BMP	Nitrogen		Total Suspended Solids	Pathogens
	Loading lbs/yr	Percent Removal	Percent Removal	Percent Removal
Infiltration	226 - 418	60-70%	60-90%	65-99%
In-line Treatment	226 - 418	25-50%	60-90%	(no data)
Constructed Wetlands	226 – 418 (plus in-stream load)	60-70%	80-99%	90-99%

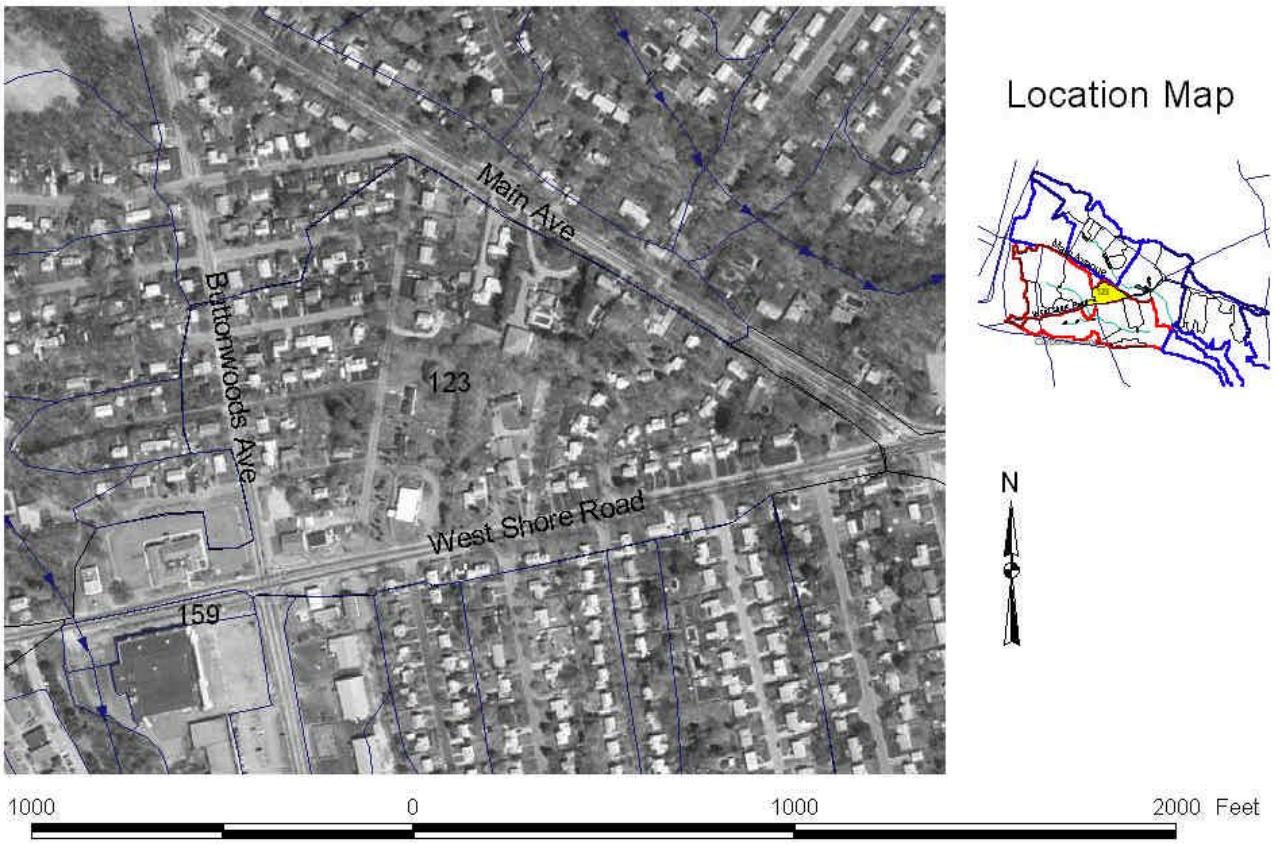

Figure 10. Upper Carpenter Subwatershed Systems 123 & 159

3.2.2.3 System 128 – Wesleyan Avenue

Outfall Location: Behind a private residence on Wesleyan Avenue, forming the beginning of Carpenter Brook.

Outfall Description: Pipe is of unknown size and composition.

Drainage Area: Roughly 111 acres, as shown on Figure 11, extending from Normandy Drive to Main Avenue. At the time of the assessment, the area was 35% impervious cover (some houses have since been removed by the Airport). The area was unsewered at the time of the assessment. Runoff is collected in a complex system of catch basins and pipes that tie together to outlet off of Wesleyan.

Suggested BMPs:

Removal of houses in the upper part of the drainage area increases ability of runoff to infiltrate, and reduces those activities that may introduce pollutants. According to James Zisiades, Manager of Environmental Affairs at the RI Airport Corporation (personal communication, October 2000), additional houses may be removed, which will further protect water quality. Removing the catch basins in the recently-created open area and regrading the roadsides to allow runoff to flow across the grass areas may result in reducing the size of this drainage area. In-line innovative storm water treatment technologies could be used to capture sediments, oils and greases in the lower sections of the drainage area. Or, small infiltration structures (leaching chambers) could be placed throughout the area, should soils investigations demonstrate their feasibility.

Table 10. Nitrogen Loading and BMP Removal Rates for System 128

Proposed BMP	Nitrogen		Total Suspended Solids	Pathogens
	Loading lbs/yr	Percent Removal	Percent Removal	Percent Removal
Infiltration	560 - 1215	60-70%	60-90%	65-99%
In-line Treatment	560 - 1215	25-50%	60-90%	(no data)
Vegetated Filter	560 - 1215	30-65%	30-65%	Less than 30%
Land Use Change (Medium High Density Residential to Developed Recreation)	7.3 – 11.9 lbs/acre/yr	65-80%	(Not estimated)	(Not estimated)

Figure 11. Upper Carpenter Subwatershed System 128

3.2.3 Lower Tuscatucket Subwatershed

3.2.3.1 System 87 – West Shore Road

Outfall Location: A complex pipe system outlets directly into Tuscatucket Brook on the north side of West Shore Road, and adjacent to the Brook on the south side (pipe interconnections make it infeasible to separate the two outlets into two systems).

Outfall Description: North pipe size and composition unknown, drops directly into the culvert carrying the brook under the road. South pipe is a 30" RCP.

Drainage Area: Approximately 64 acres, as shown on Figure 12, extending from the intersection of Main Avenue and West Shore Road east to the intersection of Sandy Lane and Frawley Street. The watershed land use is a mixture predominated by residential and commercial; 54% of the area has impervious cover. At the time of the assessment, sewers serviced roughly 16% of the area.

Suggested BMPs:

It may be possible to divert a significant portion of the flows from the east side of the drainage area to a large lot that borders the brook (AP 362, Lot 34), and to install a created wetland (approx. 17,500 square feet needed), infiltration (depending on soils analysis) and/or extended detention structure for settling and uptake of pollutants. Much of this privately-owned 6.8-acre lot is mapped as having upland soils. However, a development proposal was in discussion phase with the City's Planning Board (Dan Geagan, Planning Dept., personal communication, July 2000). The fact that the land would have to be purchased makes these options impractical at this time.

There does not appear to be any suitable site for diverting and treating flows from the smaller, west side of the drainage area. In-line innovative storm water treatment technologies could be used in any portion of the entire drainage area to capture sediments, oils and greases. A soils investigation would be needed to determine the feasibility of infiltration structures placed throughout the area to reduce pollutant loading and/or the size of the catchment. The feasibility of placing structures under a high-traffic volume road will also need investigation.

Table 11. Nitrogen Loading and BMP Removal Rates for System 87

Proposed BMP	Nitrogen		Total Suspended Solids	Pathogens
	Loading lbs/yr	Percent Removal	Percent Removal	Percent Removal
Constructed Wetlands	269 - 1000	60-70%	80-99%	90-99%
Extended Detention	269 - 1000	30-65%	30-65%	Less than 30%
Infiltration	269 - 1000	60-70%	60-90%	65-99%
In-line Treatment	269 - 1000	25-50%	60-90%	(no data)

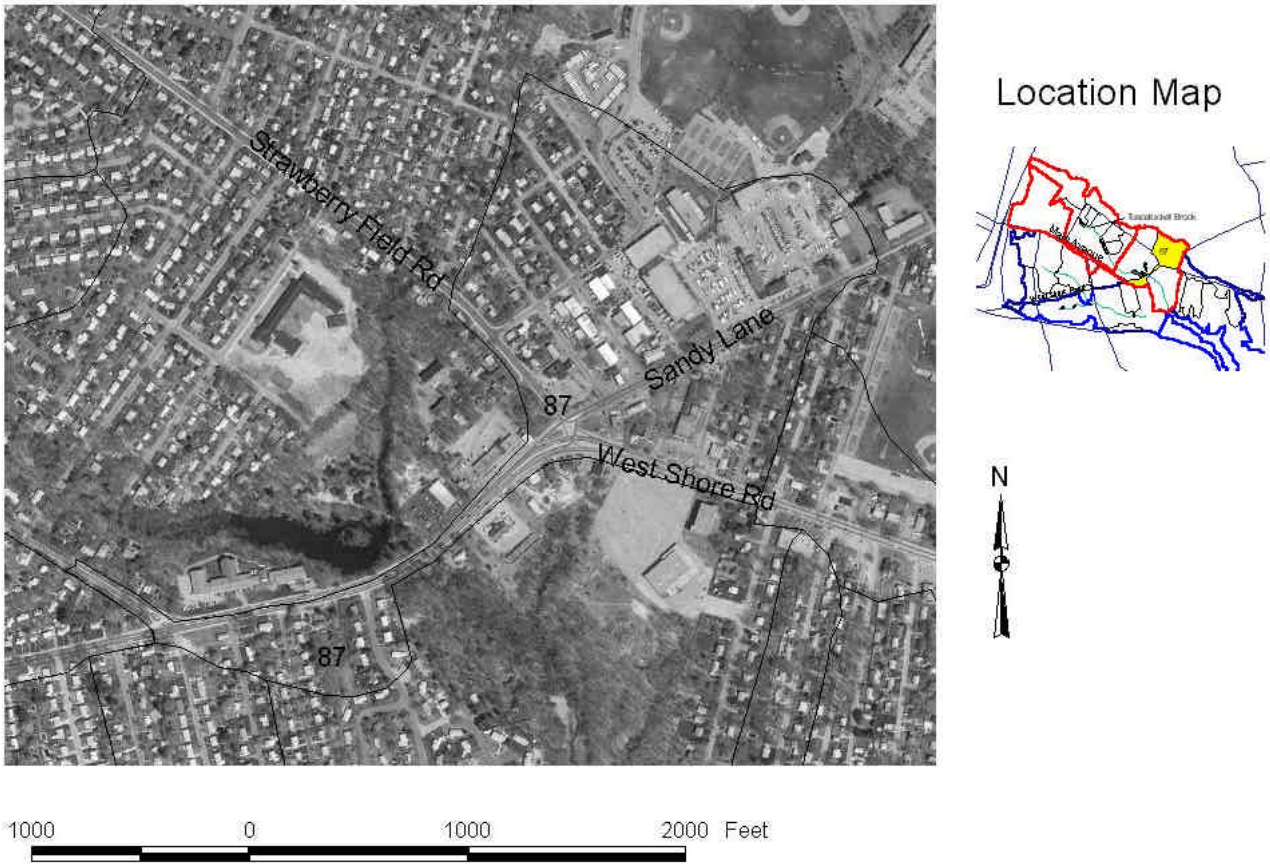

Figure 12. Lower Tuscatucket Subwatershed System 87

3.2.4 Upper Tuscatucket Subwatershed

3.2.4.1 System 114 – Burbank Drive (South)

Outfall Location: Behind private residences on Burbank Drive (AP348, Lots 915 & 868).

Outfall Description: 15" CMP.

Drainage Area: Roughly 10 acres, as shown on Figure 13, covering portions of Perkins Street, Deerfield, Tarawa and Burbank Drives, which are residential roads. Approximately 40% of the area has impervious cover. The area was unsewered at the time of the assessment. Runoff is collected in catch basins on Burbank, then piped across private property to outlet in a dammed portion of the Brook.

Suggested BMPs:

There is no open space for a structural BMP at the outlet of this system. In-line innovative storm water treatment technologies could be used to capture sediments, oils and greases. A soils investigation would be needed to determine the feasibility of infiltration structures placed throughout the catchment.

Table 12. Nitrogen Loading and BMP Removal Rates for System 114

Proposed BMP	Nitrogen		Total Suspended Solids	Pathogens
	Loading lbs/yr	Percent Removal	Percent Removal	Percent Removal
Infiltration	73 - 119	60-70%	60-90%	65-99%
In-line Treatment	73 - 119	25-50%	60-90%	(no data)

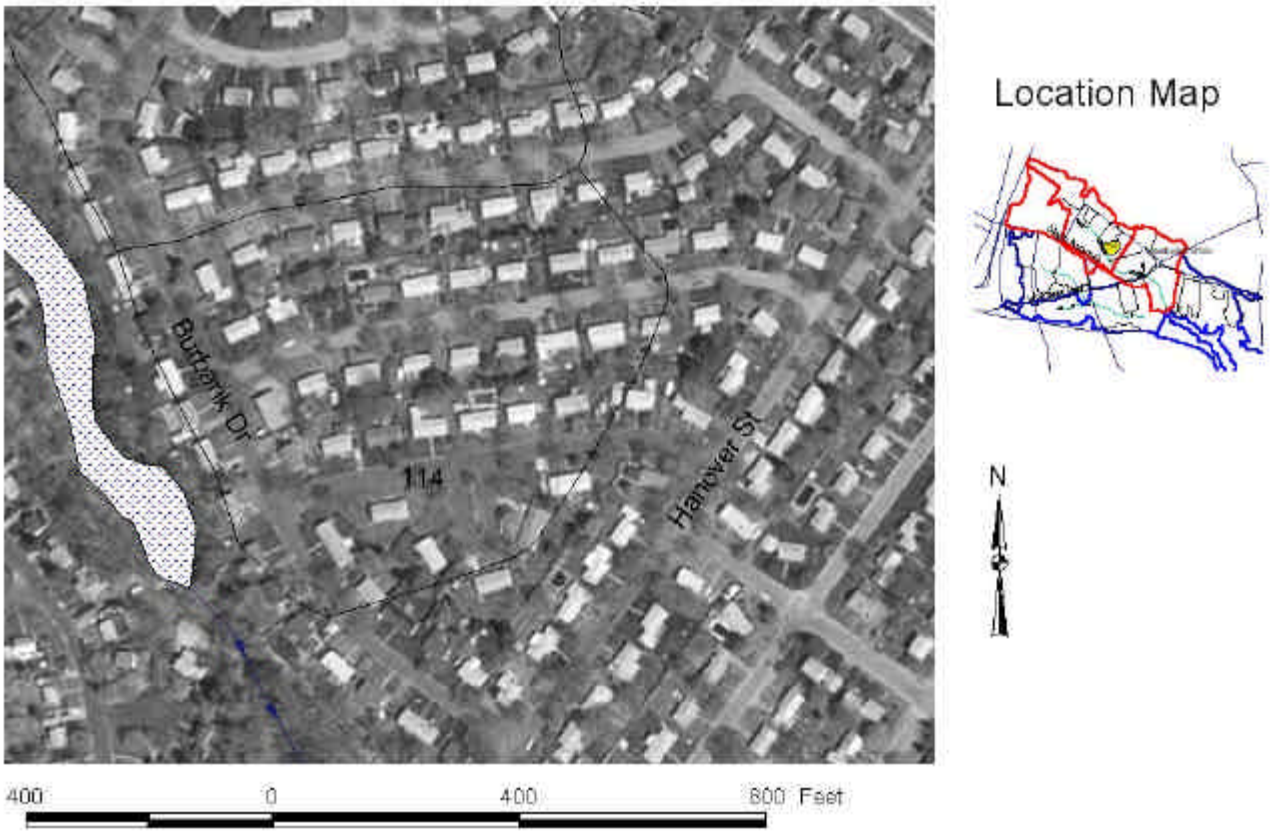

Figure 13. Upper Tuscatucket Subwatershed System 114

3.2.4.2 System 121 – Burbank Drive (North)

Outfall Location: Behind private residences on Burbank Drive (AP 348, Lots 850 & 974)

Outfall Description: 15" CMP

Drainage Area: 16.8 acres, as shown on Figure 14, encompassing the west end of Burbank Drive, Hoyt Street and the west side of Tarawa Drive. This includes a small area served by a dry well near the corner of Hoyt and Sheppard. 43% of the area has impervious cover. The area was unsewered at the time of the assessment. Runoff is collected in a pipe system that crosses private property to outlet near a ponded portion of the Brook.

Suggested BMPs:

It appears that years of sediment have built up at the outfall to create a diversion, so flows now travel an additional 100 feet or so before entering the pond. While it may be possible to enhance conditions at the outfall, it is not considered feasible due to limited access and ownership issues. In-line innovative storm water treatment technologies could be used to capture sediments, oils and greases. A soils investigation would be needed to determine the feasibility of infiltration structures placed throughout the catchment.

Table 13. Nitrogen Loading and BMP Removal Rates for System 121

Proposed BMP	Nitrogen		Total Suspended Solids	Pathogens
	Loading lbs/yr	Percent Removal	Percent Removal	Percent Removal
Infiltration	116 - 202	60-70%	60-90%	65-99%
In-line Treatment	116 - 202	25-50%	60-90%	(no data)

Figure 14. Upper Tuscatucket Subwatershed System 121

3.2.4.3 System 116 – Burgess Drive

Outfall Location: Runoff is collected in catch basins and piped down Burgess Drive and through private property to outlet on City-owned property a short distance from the Brook.

Outfall Description: 12" RCP

Drainage Area: 8.8 acres, as shown on Figure 15, covering Carney Road, Burgess Drive and a small section of Strawberry Field Road. 43% of the area has impervious cover. The area was unsewered at the time of the assessment.

Suggested BMPs:

Limited room and access make outfall renovations unfeasible. In-line innovative storm water treatment technologies could be used to capture sediments, oils and greases. A soils investigation would be needed to determine the feasibility of infiltration structures placed throughout the catchment. According to the RI Airport Corporation (J. Zisiades, October 2000), some houses on the west side of the drainage area may be removed, which should reduce availability of pollutants and increase infiltration.

Table 14. Nitrogen Loading and BMP Removal Rates for System 116

Proposed BMP	Nitrogen		Total Suspended Solids	Pathogens
	Loading lbs/yr	Percent Removal	Percent Removal	Percent Removal
Infiltration	62 - 104	60-70%	60-90%	65-99%
In-line Treatment	62 - 104	25-50%	60-90%	(no data)
Land Use Change (Medium High Density Residential to Airport facilities)	7.3 – 11.9 lbs/acre/yr	Minus 68 to plus 73% (airports can have higher loading than residential)	(Not estimated)	(Not estimated)

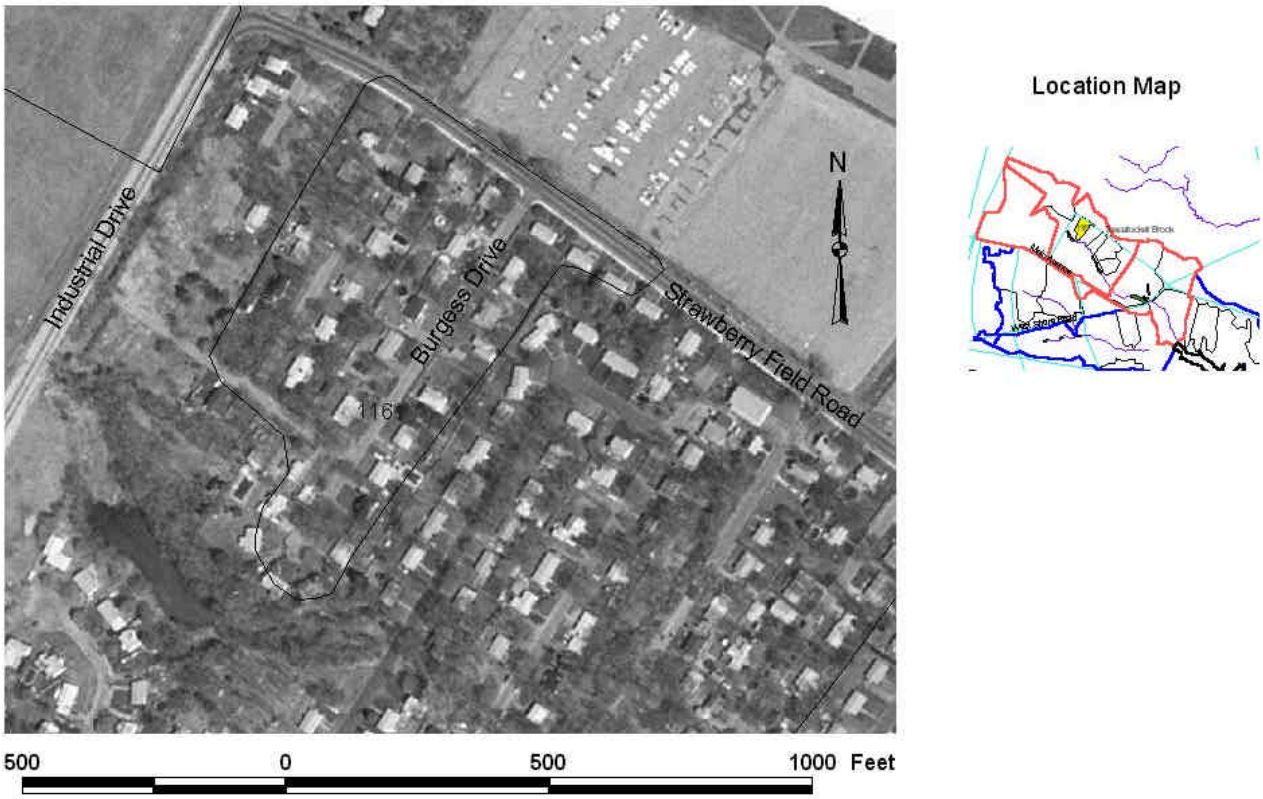

Figure 15. Upper Tuscatucket Subwatershed System 116

3.2.4.4 System 145 – Industrial Drive

Outfall Location: A pipe system runs from the parking lot just north of Strawberry Field Road to outlet in the Brook adjacent to Industrial Drive.

Outfall Description: 30" RCP

Drainage Area: Roughly 68 acres, as shown on Figure 16, encompassing a portion of T. F. Green Airport west of the intersection of Warwick Industrial Drive and Strawberry Field Road. Approximately 30% of the area has impervious cover (runway, taxiway and parking lots).

Suggested BMPs:

According to the RI Airport Corporation (J. Zisiades, October 2000), in-line treatment practices have been installed in the parking areas. The runway widths have been reduced, the pavement is crowned to create sheet flow to the sides, and leaching chambers have been installed to further promote infiltration.

Using the facility evaluation procedures described in Section 2.1.1, installation of these practices result in 11.6 acres treated in system 145. Most of the rest of the land in the system is presently maintained in meadow, a land use which tends to produce low amounts of pollutants. No additional BMPs are recommended for this system under these conditions.

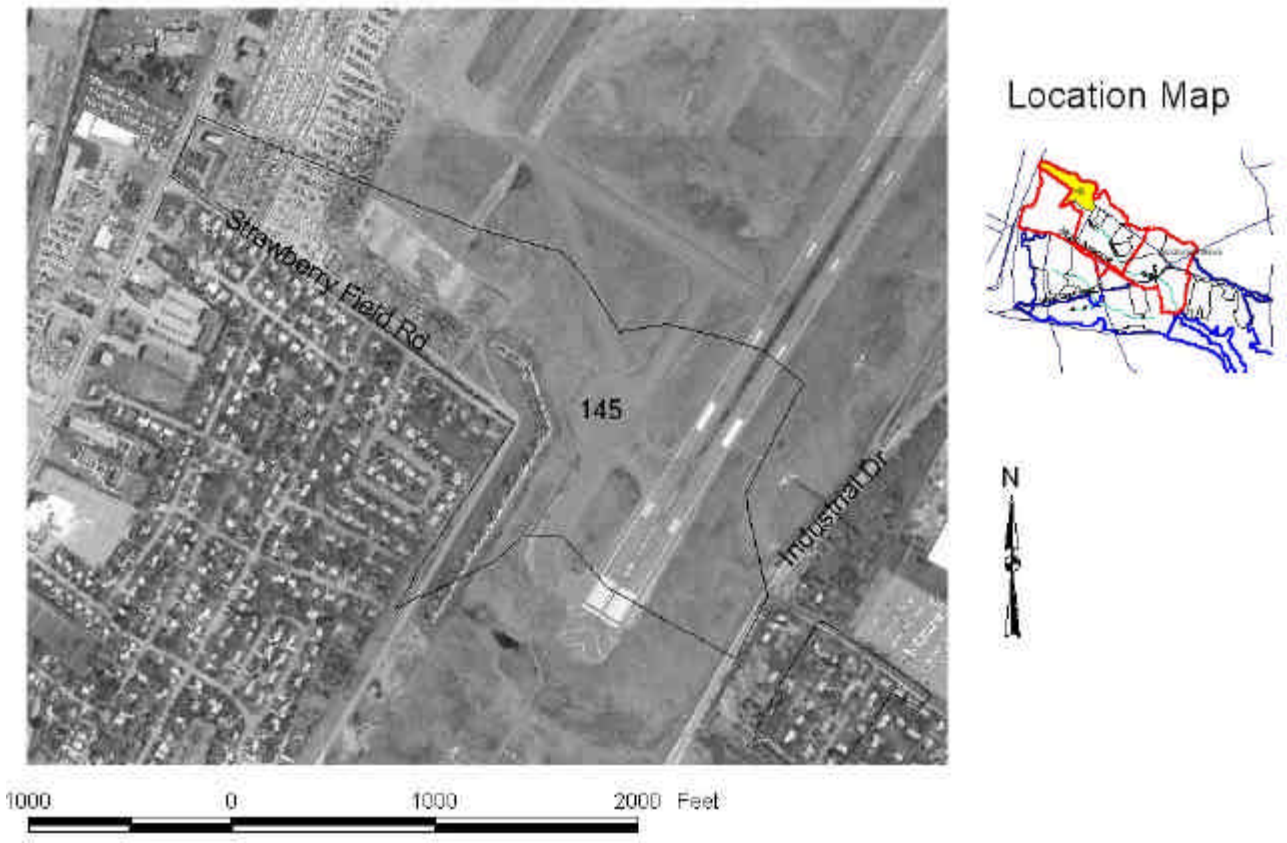

Figure 16. Upper Tuscatucket Subwatershed System 145

3.3 Retrofit Site Selection

The evaluation of the ten systems was reviewed with staff from Warwick Planning, Warwick Public Works and a representative of the consulting engineer on sewer design (Gordon R. Archibold, Inc.) in early November, 2000. Based on this review, the City selected systems 131 (White Avenue) and 133 (Boyle Street), both in the Lower Carpenter subwatershed, for retrofit design by SRICD. SRICD has signed an Engineering Services Agreement with NRCS to complete the designs. The City also decided to incorporate retrofits of systems 114 (south Burbank), 116 (Burgess) and 121 (north Burbank), in the Upper Tuscatucket subwatershed into the sewer project for that area. The retrofit of these systems will most likely be in-line innovative technologies. The sewer project design is ongoing.

Using the facility evaluation procedures described in Section 2.1.1, the anticipated effect of retrofitting these systems is shown in Table 15.

Table 15. Summary of Potential Retrofits

System #	Suggested Practice	Effect	Acres Treated	Rough Estimate Implementation Cost[1]	Approximate Schedule
131 (White)	Diversion/level spreader/Created wetland w/ infil	high	25.5	$100-150,000	2002-03
133 (Boyle)	Pocket wetland w/infiltration	high	12.0	$70-100,000	2002-03
114 (s. Burbank)	In-line practice	some	5.0	$25-30,000	2001-02 (w/sewer inst)
121 (n. Burbank)	In-line practice	some	8.4	$25-50,000	2001-02 (w/sewer inst)
116 (Burgess)	In-line practice	some	4.4	$25-30,000	2001-02 (w/sewer inst)

[1]Cost estimates for wetlands from NRCS, estimates for in-line practices from City of Warwick

4.0 ESTIMATION OF FUTURE WATERSHED CONDITIONS

4.1 Restoration Target

While reviewing the evaluation of potential retrofits with the City of Warwick, the question arose, "When will we be done with Brush Neck Cove?" With more than 22,000 acres covering portions of two major basins, the City is facing a large workload in storm water management. While awaiting the results of the TMDL study, the City wished to establish a simple method of measuring progress in addressing nonpoint source issues on a watershed basis.

Ideally, this 319 project would be one action in a Watershed Action Plan developed and maintained by a partnership of agencies and organizations. The Partners would establish goals, indicators and targets for watershed protection/restoration, and establish a process for measuring progress. While the City of Warwick Strategic Plan for the Reclamation of Greenwich Bay (Warwick Department of Planning, 1994) includes a number of recommendations which have driven a number of projects, including this one, the Partnership has become inactive due to changes in agency priorities and staff, among other reasons. One gets the sense some are waiting for results of the TMDL before discussing renewal of the Partnership, or restoration targets. So SRICD and the Warwick Department of Public Works looked for examples of storm water targets in other watershed protection projects.

The Anacostia River Restoration Project in the Mid-Atlantic (upon which this program is loosely based) discussed "basin-wide implementation of the retrofit program" in its 1989 Status Report, and appeared to measure progress in terms of treating 824 acres of a 55% impervious watershed area (EPA, 1995, Appendix A). Their retrofit program uses 40% control (i.e. 40% of the watershed drainage area is treated) as the goal for the first round of implementation (T. Schueler, personal communication, 1994). The Anacostia's restoration partners recently set specific restoration indicators and targets to be achieved by 2010; percent of developed land with stormwater management controls is included as an indicator, with the 2010 target of approximately double the amount of older watershed areas controlled (Metropolitan Washington Council of Governments, 2001).

Area treated by BMPs is relatively easy to measure, using the process described in Section 2.1.1 above. Increasing the amount of treated area in the watershed from 15% to 40% seemed to be a reasonable provisional target for beginning to restore the health of Brush Neck Cove. Using a conservative estimate, this could result in a 10-12% reduction in pollutant delivery to the Cove (additional BMPs would treat 25% of the watershed, assume 40-50% pollutant removal performance). It is recognized this target will be revised based on the results of the TMDL study.

4.2 Measuring Progress Toward Meeting the Provisional Target

4.2.1 Assessment update and revision

The 1999 database of systems was updated to reflect revised acreages from GIS, the installation of sewers, and additional on-ground or proposed BMPs. The additional facilities were added to Appendix B. The summary of the database update is shown in Appendix D. See Appendix H of the Report to the City of Warwick (SRICD, 1999) for comparison.

Note that the planned or actual installation of sewers has lowered the sewer score of most systems to 0. All but the northwest corner of Brush Neck Cove's watershed will be sewered within a few years. As a result of the lower sewer scores, the highest ranking system now has a score of 6, as compared to previous high scores of 8.

Most of the systems where BMPs are planned show lower adjusted drainage area scores, reflecting the reduction in untreated drainage areas. One exception is system 35 (Hawksley), because even with the reduction the drainage area remains one of the largest in the Brush Neck East subwatershed.

In reviewing the systems and database, some existing and proposed permanently protected open spaces were noted within some systems. Further reflection led to adding these areas as facilities that provide some treatment, since they are in low-intensity land uses. Facilities #1032 and #1033 are the front yard and portion of a ball field of the Veteran's Memorial High School (Figure 17). Facilities # 1034 through #1042 are portions of Airport property that are maintained as meadow (Figures 18 and 19). Facilities #1043 through #1045 are areas that the RI Airport Corporation indicated as new buy-out areas (J. Zisiades, October 2000); the map of these areas is not available to the public at this time.

System 145 (Industrial Drive) continues to have a high ranking; even with its effective drainage area cut to less than half due to the facilities installed by the RI Airport Corporation and the open space accounting, it is much larger than the average drainage area for the Upper Tuscatucket subwatershed.

Figure 17. Facilities (Permanent Open Spaces) at Veteran's Memorial High School

Figure 18. Airport Facilities North of Main Avenue

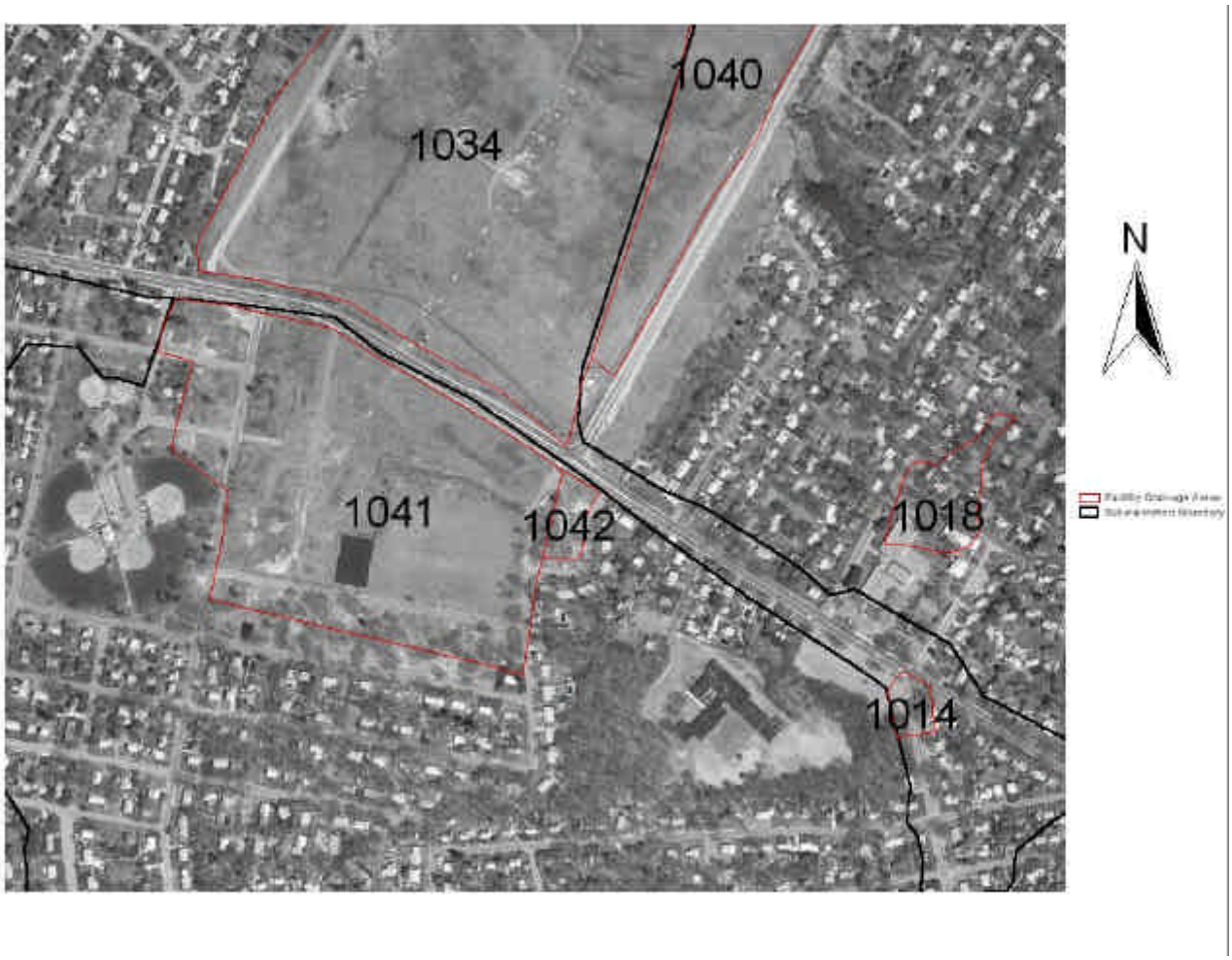

Figure 19. Airport Facilities South of Main Avenue

4.2.2 Estimate of effects

Based on the updates and revisions noted in Section 4.2.1, Table 16 below summarizes the progress toward achieving the provisional target of 40% of the watershed area treated.

Table 16. Summary of Progress toward Achieving the "40%" Provisional Target

Subwater-shed	Total Area (acres)[a]	Area Treated as of '99 Report (acres)	Open Space[b] & Airport BMPs[c] (acres)	Planned Projects by Party Responsible			Estimated Effects Post Construction	
				Warwick 319 Grant (acres)	Sewer Project (acres)	SRICD 319 Grant (acres)	Total Area Treated (acres)	Percent of Total Area
Brush Neck East	344	46.6	1.1	63.8			111.5	32%
Lower Carpenter	261	63.7				37.5	101.2	39%
Upper Carpenter	277	19	22.7				41.7	15%
Lower Tuscatucket	391	53.3	48.4	5.1			106.8	27%
Upper Tuscatucket	264	31.4	33.5		17.8		82.7	31%
Brush Neck West	60	31					31	51%
Total Brush Neck[a]	1597	245	106	69	18	38	**475**	**30%**

[a]numbers rounded to nearest acre
[b]Existing and proposed dedicated open spaces within systems (airport, school) were considered to provide some treatment. See Section 4.2.1
[c]See Section 3.2.4.4

Planned projects will treat about 8% of the Brush Neck Cove watershed. The area to be treated by implementation of the projects designed under this 319 grant represents about 2% of the watershed.

4.3 Work Remaining

As shown by the numbers in the table above, more work remains to be done to attain the 40% provisional target, which amounts to approximately 640 acres treated. An additional 166 acres would need to be treated to attain the goal.

Until the TMDL study and recommendations are published, the City may want to consider using the system evaluation procedures described in Section 2.1.2 to select additional areas for treatment. A review of the numerical rankings of systems generated from the assessment update led to a new list of systems with the highest potential pollutant loading (Table 17).

Note that the four systems from the original list that were not addressed remain high priority. As discussed in Section 4.2.1, systems 35 and 145 are so large that they remain on the list despite a reduction in their effective drainage areas; monitoring of their outfalls may indicate whether or not further treatment is needed. Systems 163, TB01 and the eastern portion of 112 are primarily airport open space.

It is suggested that future efforts be focused on those subwatersheds with smaller percentages of treated areas, i.e. Upper Carpenter and Lower Tuscatucket. Special emphasis should be placed on systems 127 (West Shore Road) & 128 (Wesleyan Ave), which are not planned to be fully sewered. These systems lie in the Upper Carpenter subwatershed. In the Lower Tuscatucket subwatershed, systems 87 (West Shore Road) and 112 (Main Ave) have large drainage areas with little space for BMPs; a combination of in-line innovative technologies and/or infiltration and outreach for source reduction[7] is recommended. System 123 (Buttonwoods/West Shore Rd) in the Upper Carpenter subwatershed is also a good candidate for in-line/infiltration technology. Most of these systems include state highway in their drainage area, thus a retrofit project should be eligible for funding under RIDOT's Enhancement Program.

[7] Outreach for source reduction is another facet of the Greenwich Bay Storm Water Management Project. Anticipated benefits in terms of acres treated are not available at this time; no benefits have been assumed in the evaluations contained in this report.

Table 17. Updated List of Priority Systems

System #	Associated Road(s)	Subwatershed	Why priority?			Sampled?
			Large Drainage Area	Highly impervious	Lack of sewers	
139	MacArthur Dr	Lower Carpenter		X		No
127	West Shore Road	Upper Carpenter	X			No
123	West Shore Road	Upper Carpenter	X			No
128	Wesleyan Avenue	Upper Carpenter	X		X	No
87	West Shore Road	Lower Tuscatucket	X	X		No
112	Main Avenue	Lower Tuscatucket	X			No
145	Industrial Drive	Upper Tuscatucket	X		X	No
TB01	Industrial Drive	Upper Tuscatucket	X		X	Yes (Wright & Viator, 1999)
163	Industrial Drive	Upper Tuscatucket	X		X	No
110	Strawberry Field Road	Upper Tuscatucket	X	X		No
38	Mohawk Avenue	Brush Neck East	X	X		Yes (Wright, Fanning & Viator, 1998)
35	Gordon/ Hawksley	Brush Neck East	X			Yes (Wright, Fanning & Viator, 1998)
104	Northup Street	Brush Neck East		X		No

Appendix A

Brush Neck Cove Watershed
Storm Water Systems

system ID	subwatershed	location	plat(s)	system type	surface DA	% impervious	% sewered
100	BN East	Pine Grove	361	conc	1.6	55%	100%
101	BN East	Haswill St	361	conc	11.4	34%	100%
102	BN East	Mohawk Ave	375	conc	3.3	47%	100%
103	BN East	Canfield Ave	361	conc	8.3	40%	100%
104	BN East	Northup St	360	conc	13.2	44%	100%
105	Low Tusc	Cove Ave	362	conc	9.7	38%	100%
106	Low Tusc	Strawberry	342, 348	pipe	24.3	39%	100%
107	Low Tusc	Almy St	348	pipe	9.6	31%	100%
108	Up Tusc	Carolyn St	343	pipe	11.4	33%	100%
109	Up Tusc	Everglade Ave	348	conc	2.2	40%	100%
110	Up Tusc	Brentwood Ave	348, 342	pipe	11.1	97%	100%
111	Low Tusc	Liverpool St	348	pipe	8.1	42%	100%
112	Low Tusc	Main Ave	343-5, 347-8,	pipe	167.8	27%	67%
113	Up Tusc	Hanover St	342, 348	pipe	24.1	32%	100%
114	Up Tusc	Burbank St	348	pipe	10	40%	100%
115	Up Tusc	Adrian St	343	pipe	6.8	38%	100%
116	Up Tusc	Burgess Dr	343	pipe	8.7	*36%	100%
117	Up Tusc	Parkway Dr	348	pipe	9.9	34%	100%
118	Up Tusc	Parkway Circle	348	pipe	4	30%	100%
119	BN East	Wilcox St	375	conc	2.2	40%	100%
120	Up Tusc	Inman Ave	348	conc	5.8	42%	100%
121	Up Tusc	Burbank Dr	348	pipe	16.7	43%	100%
122	Low Carp	City Park	371	OL	6.4	10%	100%
123	Up Carp	West Shore Rd	347	pipe	31	40%	100%
124	Up Carp	McKinley St	347	pipe	6.8	35%	100%
125	Up Carp	Vera St	347	pipe	8.8	32%	100%
126	Up Carp	Juliet St	347	pipe	5.5	55%	100%
127	Up Carp	West Shore Rd	346, 347	pipe	62.9	41%	45%

system ID	subwatershed	location	plat(s)	system type	surface DA	% impervious	% sewered
128	Up Carp	Wesleyan Ave	321, 345-7	pipe	111.3	*31%	0%
129	Low Carp	Buttonwoods	363	pipe	11.7	40%	100%
130	Low Carp	Marshall Ave	363	pipe	10.5	36%	100%
131	Low Carp	White Ave	363	conc	25.5	38%	100%
132	Low Carp	East of	363	pipe	2.8	96%	100%
133	Low Carp	Asylum &	363, 370	pipe	12	44%	100%
134	Low Carp	Warwick Hsng	363	OL	0.6	75%	100%
135	Low Carp	Sunny Cove Dr	363	pipe	7.4	37%	100%
136	Low Carp	Kerri Lyn Rd	363	pipe	10.6	33%	100%
137	Low Carp	Mystic Dr	363	conc	3.4	52%	100%
138	Low Carp	Keystone Dr	363	pipe	7.3	36%	100%
139	Low Carp	MacArthur Dr	363	conc	4	44%	100%
140	Low Carp	Larson Dr	364	pipe	6.2	27%	100%
141	Low Carp	Long View Dr	364	pipe	9.9	34%	100%
142	Low Carp	Dunbar Ct	364	pipe	6.1	38%	100%
143	Up Carp	Warwick Hsng	363	pipe	1.8	90%	100%
144	Up Tusc	Everglade	348	OL	2.6	40%	100%
145	Up Tusc	Industrial Dr	321	pipe	68.1	30%	100%
146	Up Tusc	Everglade Ave	348	pipe	1.3	40%	100%
147	Up Carp	West Shore Rd	363	conc	0.4	100%	100%
148	Up Carp	Buttonwoods	363	conc	3.4	100%	100%
149	Low Carp	Buttonwoods	363	conc	2	90%	100%
150	Low Carp	White Ave	363	conc	8.3	38%	100%
151	Up Carp	Wilmar St	347	pipe	1.5	35%	100%
152	Up Carp	Grant St	347	pipe	1.9	35%	100%
153	Low Carp	Off	363	OL	0.7	0%	100%
154	Up Carp	Wicks Ct	347	pipe	1.2	40%	100%
155	Up Carp	Gladys Ct	345	pipe	1.9	32%	100%
156	Up Carp	Larkin @ Link	347	pipe	1	48%	100%
157	Up Carp	Larkin St	347	pipe	0.5	50%	100%

system ID	subwatershed	location	plat(s)	system type	surface DA	% impervious	% sewered
158	Up Carp	Woodwind Ct	347	pipe	1	50%	100%
159	Up Carp	West Shore Rd	363	pipe	1	100%	100%
160	Low Tusc	West Shore Rd	362	OL	0.7	100%	100%
161	Up Tusc	Brentwood Ave	348	conc	7.5	38%	100%
162	Low Tusc	Turner St	348	conc	1.6	49%	100%
163	Up Tusc	St Fld Rd & W.	321, 343	pipe	9.7	20%	0%
29	BN East	Cottage Grove	362	pipe	12.4	45%	100%
30	BN East	Shand Ave	361/362	pipe	39.1	41%	100%
33	BN East	Canfield Ct	361	pipe	1.1	46%	100%
34	BN East	Gordon Ave	361	pipe	12.6	43%	100%
35	BN East	Hawksley Ave	349-50, 352,	pipe	71.2	43%	100%
36	BN East	Wilcox St	360, 375	pipe	20.8	40%	100%
37	BN East	Ottawa Avew	375	pipe	16	38%	100%
38	BN East	Mohawk Ave	375	pipe	19.2	47%	100%
39	BN East	Sea View Dr	375	pipe	1.6	50%	100%
40	BN East	Strand Ave	375	pipe	6.8	43%	100%
59	BN East	Pettis Dr	361	pipe	16.7	29%	100%
85	Low Tusc	Spring Grove	362	pipe	10.2	31%	100%
87	Low Tusc	West Shore Rd	348-9, 362-3	pipe	64.2	54%	100%
88	Low Carp	Mocassin Dr	362	pipe	14.1	36%	100%
TB01	Up Tusc	Industrial Dr	321	pipe	15.1	15%	100%

Notes: - Drainage area measurements from GIS (calculation of area of polygons)

* - The ‘buy-out” areas in systems #116 & 128 were assumed to revert to pervious condition; %impervious is adjusted accordingly

Appendix B

Update of Storm Water Treatment Facilities and Overland Flow Areas

Facility # or Overland Flow Area	System ID	Drainage Area	Type of Facility	Water Quality Effect	Acres Treated	Notes
Brush Neck East Subwatershed						
Overland Flow Areas		86.0	Diffusion, infiltration, buffer, etc.	some	43.0	’99 inventory
1001	35	0.8	Dry well	high	0.8	’99 inventory
1002	35	0.6	Dry well	high	0.6	’99 inventory
1003	35	0.5	Dry well	some	0.3	’99 inventory (poor condition)
1004	35	0.4	Dry well	high	0.4	’99 inventory
1007	38	0.2	Dry well	high	0.2	’99 inventory
1008	38	1.3	Dry well	high	1.3	’99 inventory
1019	35	71.2	Swirl separator	some	35.6	proposed City 319
1020	33	4.8	Swirl separator	some	2.4	proposed City 319
1021	30	39.1	Swirl separator	some	19.6	proposed City 319
1022	29	12.4	Swirl separator	some	6.2	proposed City 319
1032	35	1.2	Low-intensity land use	some	0.6	HS front lawn
1033	35	1	Low-intensity land use	some	0.5	HS field
Lower Carpenter						
Overland Flow Areas		111.2	Diffusion, infiltration, buffer, etc.	some	55.6	’99 inventory
1005	129	0.7	Dry well	high	0.7	’99 inventory
1006	153	0.7	Created wetland	some	0.4	’99 inventory (poor condition)
1009	122	6.4	Dry well, low-intensity land use	high	6.4	’99 inventory
1010	134	0.6	Dry well	high	0.6	’99 inventory
1024	131	25.5	Infil. & water quality swale	high	25.5	proposed SRICD design
1025	133	12	Infil. & water quality swale	high	12.0	proposed SRICD design

Facility # or Overland Flow Area	System ID	Drainage Area	Type of Facility	Water Quality Effect	Acres Treated	Notes
Upper Carpenter						
Overland Flow Areas		35.6	Diffusion, infiltration, buffer, etc.	some	17.8	'99 inventory
1016	123	1.2	Dry well	high	1.2	'99 inventory
1041	128	29.3	Low-intensity land use	some	14.7	Airport buy-out
1042	155	0.9	Low-intensity land use	some	0.5	Airport buy-out
1045	128	15	Low-intensity land use	some	7.5	proposed buy-out
Lower Tuscatucket						
Overland Flow Areas		94.6	Diffusion, infiltration, buffer, etc.	some	47.3	'99 inventory
1011	87	1.4	Dry well	high	1.4	'99 inventory
1012	106	1.8	Dry well	high	1.8	'99 inventory
1013	112	1.4	Dry well	high	1.4	'99 inventory
1014	112	0.7	Dry well	high	0.7	'99 inventory
1015	160	0.7	Dry well	high	0.7	'99 inventory
1023	85	10.2	Swirl separator	some	5.1	proposed City 319
1034	112	49.1	Low-intensity land use	some	24.6	Airport field
1044	112	47.5	Low-intensity land use	some	23.8	proposed buy-out
Upper Tuscatucket						
Overland Flow Areas		49.4	Diffusion, infiltration, buffer, etc.	some	24.7	'99 inventory
44	110	3.3	Detention basin	some	1.7	'99 inventory
1017	121	2.5	Dry well	high	2.5	'99 inventory
1018	144	2.5	Dry well	high	2.5	'99 inventory
1026	114	10	Swirl separator	some	5.0	potential sewer project
1027	121	16.7	Swirl separator	some	8.4	potential sewer project
1028	116	8.7	Swirl separator	some	4.4	potential sewer project
1029	145	9.6	Oil/grease separators	some	4.8	Airport BMP
1030	145	6.8	Infiltration	high	6.8	Airport BMP
1031	TB01	1.4	Infiltration	high	1.4	Airport BMP

Facility # or Overland Flow Area	System ID	Drainage Area	Type of Facility	Water Quality Effect	Acres Treated	Notes
1035	145	9.5	Low-intensity land use	Some	4.8	Airport field
1036	145	3	Low-intensity land use	Some	1.5	Airport field
1037	145	2.4	Low-intensity land use	Some	1.2	Airport field
1038	145	9.1	Low-intensity land use	Some	4.6	Airport field
1039	163	2.8	Low-intensity land use	Some	1.4	Airport field
1040	TB01	10.4	Low-intensity land use	Some	5.2	Airport field
1043	116	3.5	Low-intensity land use	Some	1.8	proposed buy-out

Appendix C

Estimates of Nitrogen Loading For Priority Systems Using MANAGE Loading Rates & 1997 Land Use

Nitrogen Loading
System #29

95 Land Use Code	Description	Acres	N-Loading Rate – lb/ac/yr		N-Loading – lb/yr	
			Low	High	Low	High
112	MH Density Residential (1/4 to 1/8 acre lots)	12.4	7.3	11.9	91	148

Nitrogen Loading
System # 30

95 Land Use Code	Description	Acres	N-Loading Rate – lb/ac/yr		N-Loading – lb/yr	
			Low	High	Low	High
112	MH Density Residential (1/4 to 1/8 acre lots)	35.8	7.3	11.9	261	426
120	Commercial	3.3	2	20	7	66
Total System #30		**39.1**			**268**	**492**

Nitrogen Loading
System # 35

95 Land Use Code	Description	Acres	N-Loading Rate – lb/ac/yr		N-Loading – lb/yr	
			Low	High	Low	High
112	MH Density Residential (1/4 to 1/8 acre lots)	35.8	7.3	11.9	261	426
161	Developed Recreation	3.0	1.5	4.0	4	12
170	Institutional	3.8	7.3	11.9	28	45
120	Commercial	28.1	2.0	20.0	56	561
111	High Density Residential (<1/8 acre lots)	0.3	11.9	14.3	4	5
750	Transitional Areas (urban open)	0.2	0.9	2.0	0	0
Total System #35		**71.1**			**353**	**1049**

Nitrogen Loading
System # 131

95 Land Use Code	Description	Acres	N-Loading Rate – lb/ac/yr		N-Loading – lb/yr	
			Low	High	Low	High
112	MH Density Residential (1/4 to 1/8 acre lots)	20	7.3	11.9	146	238
310	Deciduous Forest	0.5	0.9	2.9	0	1
Total System #131		**20.5**			**146**	**239**

Nitrogen Loading
System # 133

95 Land Use Code	Description	Acres	N-Loading Rate – lb/ac/yr		N-Loading – lb/yr	
			Low	High	Low	High
112	MH Density Residential (1/4 to 1/8 acre lots)	12	7.3	11.9	88	143

Nitrogen Loading
System # 127

95 Land Use Code	Description	Acres	N-Loading Rate – lb/ac/yr		N-Loading – lb/yr	
			Low	High	Low	High
112	MH Density Residential (1/4 to 1/8 acre lots)	35.2	7.3	11.9	257	419
111	High Density Residential (<1/8 acre lots)	14.6	11.9	14.3	174	209
310	Deciduous Forest	0.6	0.9	2.9	1	2
120	Commercial	2.0	2.0	20.0	4	41
113	Medium Density Residential (1 to ¼ acre lots)	10.2	4.3	7.3	44	75
170	Institutional	0.0	7.3	11.9	0	1
Total system #127		**62.8**			**480**	**746**

Nitrogen Loading
System # 123

95 Land Use Code	Description	Acres	N-Loading Rate – lb/ac/yr		N-Loading – lb/yr	
			Low	High	Low	High
112	MH Density Residential (1/4 to 1/8 acre lots)	19.1	7.3	11.9	139	227
111	High Density Residential (<1/8 acre lots)	5.4	11.9	14.3	65	77
310	Deciduous Forest	0.0	0.9	2.9	0	0
120	Commercial	4.6	2.0	20.0	10	93
170	Institutional	1.8	7.3	11.9	13	22
Total System #123		**31.0**			**226**	**418**

Nitrogen Loading
System # 128

95 Land Use Code	Description	Acres	N-Loading Rate – lb/ac/yr		N-Loading – lb/yr	
			Low	High	Low	High
142	Airports	16.1	2.0	20.0	32	322
112	MH Density Residential (1/4 to 1/8 acre lots)	58.3	7.3	11.9	425	693
161	Developed Recreation	16.4	1.5	4.0	24	65
210	Pasture	9.5	2.0	5.5	19	52
750	Transitional Areas	6.4	0.9	2.9	6	19
600	Wetland	0	0	0	0	0
111	High Density Residential (<1/8 acre lots)	4.5	11.9	14.3	53	64
Total system #128		**111.1**			**560**	**1215**

Nitrogen Loading
System # 87

95 Land Use Code	Description	Acres	N-Loading Rate – lb/ac/yr		N-Loading – lb/yr	
			Low	High	Low	High
112	MH Density Residential (1/4 to 1/8 acre lots)	26.2	7.3	11.9	191	312
161	Developed Recreation	3.1	1.5	4.0	5	12
147	Other Transportation	9.5	2.0	20.0	19	191
600	Wetland	0.2	0	0	0	0
120	Commercial	23.6	2.0	20.0	47	472
310	Deciduous Forest	0.6	0.9	2.9	0	2
170	Institutional	0.9	7.3	11.9	6	10
Total system #87		**64.1**			**269**	**1000**

Nitrogen Loading
System # 114

95 Land Use Code	Description	Acres	N-Loading Rate – lb/ac/yr		N-Loading – lb/yr	
			Low	High	Low	High
112	MH Density Residential (1/4 to 1/8 acre lots)	10.0	7.3	11.9	73	119

Nitrogen Loading
System # 121

95 Land Use Code	Description	Acres	N-Loading Rate – lb/ac/yr		N-Loading – lb/yr	
			Low	High	Low	High
112	MH Density Residential (1/4 to 1/8 acre lots)	15.5	7.3	11.9	113	184
130	Industrial	1.2	2.0	15.0	2	18
Total System #121		**16.7**			**116**	**202**

Nitrogen Loading
System # 116

95 Land Use Code	Description	Acres	N-Loading Rate – lb/ac/yr		N-Loading – lb/yr	
			Low	High	Low	High
112	MH Density Residential (1/4 to 1/8 acre lots)	8.5	7.3	11.9	62	101
130	Industrial	0.2	2.0	15.0	0	3
Total system #116		**8.7**			**62**	**104**

Nitrogen Loading
System # 116

95 Land Use Code	Description	Acres	N-Loading Rate – lb/ac/yr		N-Loading – lb/yr	
			Low	High	Low	High
142	Airports	68.1	2.0	20.0	136	1362

Appendix D

Summary of Database Update

systems summary - with BMPs

subwatershed	system ID	system type	adj. drng area score	% imp score	sewer score	Total Score
BN East						
	38	**pipe**	3	3	0	6
	35	**pipe**	4	2	0	6
	104	**conc**	2	3	0	5
	100	**conc**	1	3	0	4
	59	**pipe**	3	1	0	4
	39	**pipe**	1	3	0	4
	36	**pipe**	3	1	0	4
	34	**pipe**	2	2	0	4
	102	**conc**	1	3	0	4
	30	**pipe**	3	1	0	4
	29	**pipe**	1	3	0	4
	37	**pipe**	3	1	0	4
	33	**pipe**	1	3	0	4
	40	**pipe**	1	2	0	3
	103	**conc**	2	1	0	3
	101	**conc**	2	1	0	3

(see end of report for ranking criteria)

subwatershed	system ID	system type	adj. drng area score	% imp score	sewer score	Total Score
	119	**conc**	1	1	0	2
Low Carp						
	139	**conc**	2	3	0	5
	136	**pipe**	3	1	0	4
	132	**pipe**	1	3	0	4
	88	**pipe**	3	1	0	4
	150	**conc**	3	1	0	4
	149	**conc**	1	3	0	4
	141	**pipe**	3	1	0	4
	137	**conc**	1	3	0	4
	130	**pipe**	3	1	0	4
	134	**OL**	1	3	0	4
	133	**pipe**	1	3	0	4
	129	**pipe**	3	1	0	4
	138	**pipe**	2	1	0	3
	140	**pipe**	2	1	0	3
	142	**pipe**	2	1	0	3

(see end of report for ranking criteria)

subwatershed	system ID	system type	adj. drng area score	% imp score	sewer score	Total Score
	135	**pipe**	2	1	0	3
	122	**OL**	1	1	0	2
	131	**conc**	1	1	0	2
	153	**OL**	1	0	0	1
Low Tusc						
	87	**pipe**	3	3	0	6
	112	**pipe**	4	1	0	5
	162	**conc**	1	3	0	4
	160	**OL**	1	3	0	4
	106	**pipe**	2	1	0	3
	105	**conc**	1	1	0	2
	107	**pipe**	1	1	0	2
	85	**pipe**	1	1	0	2
	111	**pipe**	1	1	0	2
Up Carp						
	128	**pipe**	4	1	2	7

(see end of report for ranking criteria)

subwatershed	system ID	system type	adj. drng area score	% imp score	sewer score	Total Score
	127	**pipe**	4	1	1	6
	123	**pipe**	4	1	0	5
	159	**pipe**	1	3	0	4
	126	**pipe**	1	3	0	4
	143	**pipe**	1	3	0	4
	147	**conc**	1	3	0	4
	148	**conc**	1	3	0	4
	125	**pipe**	2	1	0	3
	157	**pipe**	1	1	0	2
	156	**pipe**	1	1	0	2
	155	**pipe**	1	1	0	2
	152	**pipe**	1	1	0	2
	151	**pipe**	1	1	0	2
	124	**pipe**	1	1	0	2
	158	**pipe**	1	1	0	2
	154	**pipe**	1	1	0	2

(see end of report for ranking criteria)

Up Tusc

subwatershed	system ID	system type	adj. drng area score	% imp score	sewer score	Total Score
	110	**pipe**	2	3	0	5
	163	**pipe**	2	1	2	5
	145	**pipe**	4	1	0	5
	121	**pipe**	1	3	0	4
	120	**conc**	1	3	0	4
	146	**pipe**	1	3	0	4
	144	**OL**	1	3	0	4
	113	**pipe**	3	1	0	4
	115	**pipe**	2	2	0	4
	109	**conc**	1	3	0	4
	161	**conc**	2	2	0	4
	114	**pipe**	1	3	0	4
	117	**pipe**	2	1	0	3
	108	**pipe**	2	1	0	3
	TB01	**pipe**	2	1	0	3
	118	**pipe**	1	1	0	2
	116	**pipe**	1	1	0	2

Scoring System

Adjusted Drainage Area Score		% Impervious Score		Sewer Score	
<=1/2 avg for subwatershed	1 point	imperviousness = 0	0 points %	system is>50% sewered	0 points
>1/2 avg, <avg	2 points	imp>0, <subwatershed avg	1 point %	system is <=50% sewered	1 point
>= avg, <avgX2	3 points	imp=avg	2 points %	no sewers	2 points
>=avgX2	4 points	imp > avg	3 points		

Appendix E

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Appendix F

Glossary

Words can easily have different meanings in the arena of storm water management. The following definitions are consistent with SRICD's use of the terms throughout the Greenwich Bay Project.

Best Management Practice (BMP) – A planned structure or treatment to slow and/or treat storm water.

Catch basin – A chamber or well, usually built at the curb line of a street, for the admission of surface water to a storm sewer.

Drainage area – The land contributing runoff to a point of interest. Also denotes the size of an area in acres.

Dry well – A catch basin with no outlet; runoff is expected to exfiltrate into the surrounding soil.

Facility – An existing structure that captures runoff before it reaches the system's outlet. In the Brush Neck Cove area, facilities are usually dry wells, but could also be detention basins, filter strips, created wetlands, etc.

Subwatershed – An area between 50 and 500 acres in size draining to a waterbody which may be of significance to the neighborhood.

System – That area which drains to a specific outlet (usually a pipe or channel), ranging in size from less than 1 acre to 100 acres or more.

Watershed – An area of roughly 1,000 to 1,500 acres, which drains to a locally-significant waterbody.