Fecal Coliform TMDL Development

For

Scrabbletown Brook, Rhode Island

FINAL REPORT

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Description of Waterbody
Scrabbletown Brook is a second-order stream located entirely within the towns of East Greenwich and North Kingstown, Rhode Island. The watershed is approximately 1,653 acres in size and drains several wetland areas. Several smaller tributaries join the stream as it flows southeast, approximately 3.2 miles, towards its confluence with the Hunt River. Based on the most recent land use study (URI 1997), land use in the 1,653-acre watershed is 24% residential, 3% commercial-industrial, 6% agriculture, 38% forest, 19% wetland, and 3% roads.

Priority Ranking
Scrabbletown Brook is listed as a Group 1 (highest priority) Class A waterbody on the State of Rhode Island's 1998 303(d) list of water quality impaired waterbodies.

Pollutant of Concern
The pollutant of concern is pathogens, as indicted by fecal coliform. Measured fecal coliform concentrations have been found to exceed the state's water quality standards. As reported on the 1998 303(d) list, RIDEM has identified Scrabbletown Brook as being impaired by pathogens for a length of approximately 3.2 miles.

Pollutant Sources
Other than the presence of municipal storm sewer discharges, which are considered point sources by the U.S. Environmental Protection Agency (EPA), RIDEM has not identified any point sources contributing to the excessive fecal coliform levels found in Scrabbletown Brook. For purposes of this TMDL, storm sewer discharges were considered as nonpoint sources due to a lack of site specific data.

RIDEM has identified 4 major sources of fecal coliform bacteria in Scrabbletown Brook. These include stormwater runoff from highways and residential/commercial areas, pigeons roosting under Route 4, resident waterfowl upstream of Station SCe and SCh, and domestic pets and wildlife. All sources are summarized in Table 1. The largest dry weather source of bacteria comes from the roosting pigeons under Route 4. The largest wet weather source of bacteria to the watershed is stormwater runoff. Although the 'pigeon source' is significant during wet weather, stormwater runoff has a greater cumulative impact in the watershed. A detailed description of individual sources is presented by stream segment in the Water Quality Impairment Section of this report. Relative source strength by stream segment is presented in both Figure 1and Table 2.

Table 1. Summary of fecal coliform contamination in the Scrabbletown Brook watershed.

Station	Location	Dry Weather Sources	Wet Weather Sources
SCa	Pleasant Valley Rd.	Background levels (i.e. wildlife)	Wildlife contributions
SCb	Pleasant Valley Rd.	Background levels (i.e. wildlife)	Wildlife contributions
SCc	South Road	Background levels (i.e. wildlife)	Wildlife contributions Stormwater runoff
SCd	South Road	Background levels (i.e. wildlife)	Wildlife contributions Stormwater runoff
SCe	Scrabbletown Road	Resident waterfowl in upstream ponds.	Resident waterfowl Stormwater runoff from Scrabbletown Road.
SCh	Route 2	Resident waterfowl in upstream ponds.	Resident waterfowl Stormwater runoff from Scrabbletown Road and Routes 2 & 4
SC01	Stony Lane	Pigeons roosting at Route 4-Stony Lane overpass	Pigeons roosting at Route 4-Stony Lane overpass. Stormwater runoff from Stony Lane and Routes 2 & 4

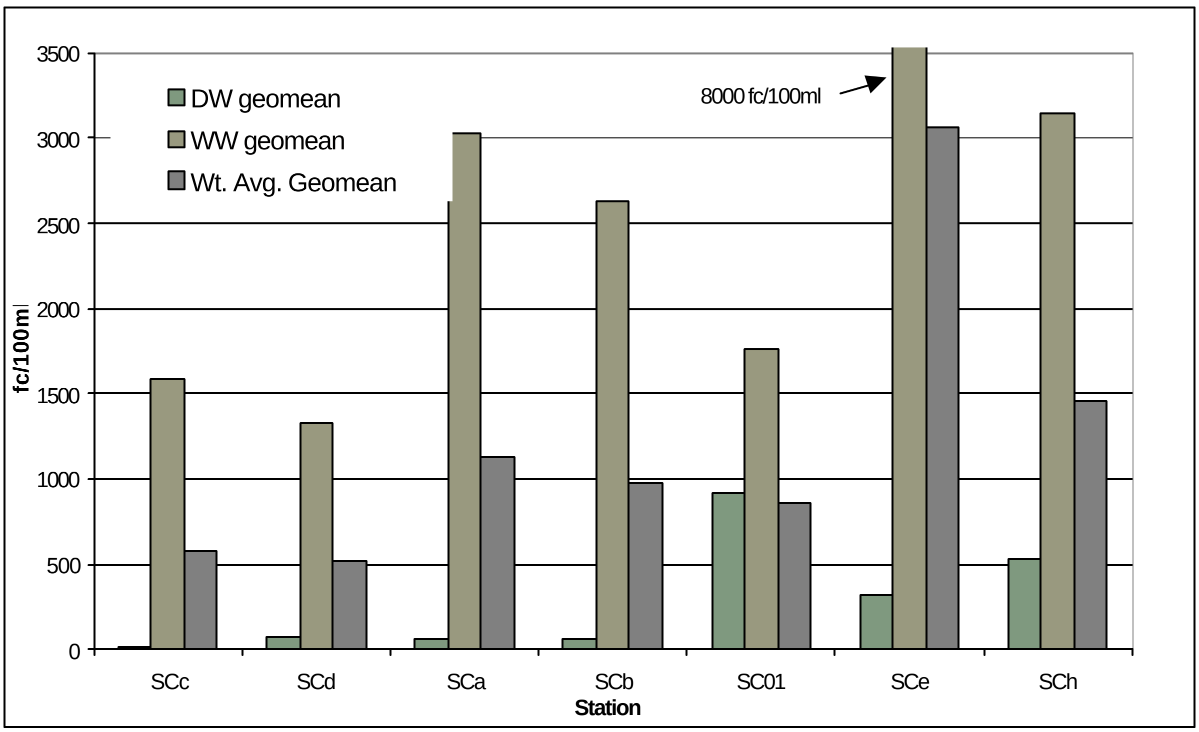


Figure 1. Relative pollution source strengths in the Scrabbletown Brook watershed.

Table 2 ranks the pollution sources, in terms of source, strength, and rank, in the Scrabbletown Brook watershed for both dry and wet weather.

Table 2. Pollution sources, strengths, and rank for Scrabbletown Brook watershed.

Source	Segment Impacted	DW geometric mean (fc/100ml)	Rank
DRY WEATHER			
Route 4 overpass- Provides roosting habitat for large numbers of pigeons. Fecal matter directly deposited in stream.	Impacts are observed downstream at SC01. However, elevated bacteria concentrations are likely occurring further downstream and possibly impact the Hunt River.	SC01- 917	1
Pond upstream of SCe and SCh. This small pond supports a resident duck population of approximately 20-25 individuals.	Major tributary to Scrabbletown Brook, located just south of the mainstem. Impacts are measured at SCe and SCh, but are likely occurring further downstream.	SCe- 320 SCh- 526	2
Bacteria inputs from wildlife are considered "natural". When no anthropogenic sources of bacteria can be found, measured concentrations will be considered as "background"	Upstream of SCa, SCb, SCc, and SCd	SCa- 66 SCb- 65 SCc- 15 SCd- 71	3
WET WEATHER			
Source	**Segment Impacted**	**WW geometric mean (fc/100ml)**	**Rank**
Untreated stormwater runoff. This is a pollution source at all road-stream crossings, causing cumulative impacts in the watershed.	All stations showed elevated levels of fecal coliform bacteria during wet weather events. It is likely that most of the stream segments in the watershed are impacted by this source.	1321-8023 fc/100ml	1
Pond upstream of SCe and SCh. This small pond supports a resident duck population of approximately 20-25 individuals	Major tributary to Scrabbletown Brook, located just south of the mainstem. Impacts are measured at SCe and SCh, but are likely occurring further downstream.	SCe- 8023 SCh- 3149	2
Not identified. See "Water Quality Impairment" section of TMDL.	Stations SCa and SCb	SCa- 3032 SCb- 2625	3
Route 4 overpass- Provides roosting habitat for large numbers of pigeons. Fecal matter directly deposited in stream. Fecal matter deposited on banks and rocks is washed off during higher flows.	Impacts measured downstream at SC01. However, elevated bacteria concentrations are likely occurring further downstream and possibly impact the Hunt River, especially during increased flows and decreased travel times.	1765	4

Antidegradation Policy

Rhode Island's antidegradation policy requires that, at a minimum, the water quality necessary to support existing uses be maintained. If water quality is better than what is necessary to support the protection and propagation of fish, shellfish, and wildlife, and recreation in and out of the water, the quality should be maintained and protected unless, through a public process, some negative impact to water quality is deemed necessary to allow important economic and social development to occur. In waterbodies identified as having exceptional recreational and ecological significance, water quality should be maintained and protected (RIDEM 1997). Scrabbletown Brook is designated as a public drinking water supply. Designated and existing uses for Scrabbletown Brook also include fish and wildlife habitat and primary and secondary recreational activities. In addition, the waters of Scrabbletown Brook shall also be suitable for other uses including compatible industrial processes and cooling, hydropower, irrigation, and other agricultural uses. The goal of this TMDL is to restore all existing and designated uses to Scrabbletown Brook that are impacted by elevated levels of fecal coliform bacteria.

Natural Background

Based on field observations and review of land use information, natural background loads from wildlife and other sources are thought to make up a significant portion of the total fecal coliform load in the Scrabbletown Brook watershed. However, due to the limited amount of data regarding fecal coliform contributions from wildlife, natural background loads were not separated from the overall water quality calculations. Without detailed site-specific information on fecal coliform contributions from wildlife, it is difficult to meaningfully separate natural background from the total nonpoint source load.

2. Description of Applicable Water Quality Standards and Numeric Water Quality Target

Scrabbletown Brook is designated as a Class A water in the state water quality regulations. Class A waters are designated as a public drinking water supply. Designated uses for Scrabbletown Brook also include fish and wildlife habitat and primary and secondary recreational activities. Class A waters shall also be suitable for other uses including compatible industrial processes and cooling, hydropower, irrigation, and other agricultural uses.

The state's water quality standard for fecal coliforms in Class A waters, is as follows: "not to exceed a geometric mean value of 20 MPN/100ml and not more than 10% of the samples shall exceed a value of 200 MPN/100ml." In Scrabbletown Brook, the Class A fecal coliform standard was used as the applicable target.

3. Loading Capacity- Linking Water Quality and Pollutant Sources

Loading Capacity

As described in EPA guidance, a TMDL identifies the loading capacity of a waterbody for a particular pollutant. EPA regulations define loading capacity as the greatest amount of loading that a water can receive without violating water quality standards (40 C.F.R. 130.2) The loadings are required to be expressed as either mass-per-time, toxicity, or other appropriate measures (40 C.F.R. 130.2(i)). The loading capacity for this TMDL is expressed as a concentration set equal to the state water quality standard. For bacteria, it is appropriate and justifiable to express a TMDL in terms of concentration. Rationale for this approach is provided below:

1) Expressing a bacteria TMDL in terms of concentration provides a direct link between existing water quality and the numeric target.

2) Using concentration in a bacteria TMDL is more relevant and consistent with the water quality standards, which apply for a range of flow and environmental conditions.

3) Expressing bacteria TMDL in terms of daily loads can be confusing to the public and difficult to interpret, especially considering that the magnitude of allowable loads are highly dependent upon flow conditions.

4) Follow-up monitoring will compare concentrations, not loadings, to water quality standards.

Based on the Class A Standard, the loading capacity is set at a geometric mean of 20 fc/100ml with no more than 10% of the samples exceeding a concentration of 200 fc/100ml.

Linking water quality and pollutant sources

Knowledge of potential pollutant sources in the Scrabbletown Brook watershed and their transportation to the stream was gained from multiple site visits (during both wet and dry weather) and review of aerial photos, topographic maps, land use maps, and other GIS resources. RIDEM spent considerable time conducting wet weather investigations in many areas of Scrabbletown Brook. Sites of significant stormwater runoff to the channel were identified and documented. This information was used to link measured fecal coliform concentrations to pollution sources, which were discussed previously.

Supporting documentation for TMDL analysis

A more detailed description of the information used to develop this TMDL is provided in the following sections of this report. Another important supporting document is the final report of the URI water quality assessment project conducted for the Hunt River (Wright et al. 1999).

Strengths/Weaknesses in the overall analytical process

The Scrabbletown Brook TMDL was developed using both URI and RIDEM water quality and hydrologic data, collected through extensive wet and dry weather field surveys and land use investigations, and utilizing past meteorological records. Numerous site visits to the smaller sub-watersheds during wet weather solidified the link between pollution sources and the high fecal coliform counts measured during storm events by RIDEM.

Strengths:

- Approach utilized extensive knowledge of land use in the watershed.
- TMDL is based on extensive monitoring conducted during both dry and wet weather conditions
- Runoff and recovery parameters were derived from extensive databases, validated with field observations, and determined to be appropriate, yet conservative, for this application.

Weaknesses:

- Limited flow data and stage-discharge relationships for tributary streams.
- Majority of dry weather data collected during the summer of 1999 severe drought conditions (i.e. low flow conditions).

Critical Conditions

Water quality monitoring carried out by RIDEM in recent years has shown that fecal coliform concentrations in streams and rivers tend to be at their highest during the summer months. We expect that this trend holds true for Scrabbletown Brook. In addition, past monitoring has shown that fecal coliform levels increase significantly during wet weather and high flow events. Therefore, monitoring conducted in support of this TMDL focused on the critical summer season and included both wet and dry weather conditions.

4. Wasteload Allocations (WLAs)

As previously mentioned, there are no point sources in the watershed other than municipal storm sewers, which for purposes of this TMDL are considered nonpoint sources because of a lack of site-specific information. Therefore, the wasteload allocation for all existing and future point sources is zero.

5. Load Allocations

The load allocations were determined for each water quality station (i.e., stream segment or tributary) based on the comparison of current fecal coliform concentration data to the water quality standard and then calculating the percent reduction needed to meet the standard. Since there are two parts to the fecal coliform standard, two calculations must be made at each station. These two calculations are discussed below.

In addition, it is also important to note that the load allocations include all natural and background loads. These loads may not come from anthropogenic sources, and may not be controllable.

Comparison of the Weighted Average to the Geometric Mean Standard

Current bacterial conditions in Scrabbletown Brook were determined based on a "weighted average" calculation. The weighted average calculation incorporates the probability of occurrence of both dry and wet weather conditions to calculate a weighted average geometric mean value representative of the frequency of occurrence of wet and dry weather conditions in the watershed. This approach is explained in further detail in the attached supporting documentation.

For each water quality station, the weighted average is compared to the geometric mean portion of the water quality standard to determine if there is a violation. If so, a percent reduction is calculated.

Comparison of the Sample Dataset's 90th Percentile Value to the Percent Exceedence Standard

In order to address the second portion of fecal coliform standard, which states that "*not more than 10% of the samples shall exceed a value of 200 MPN/100ml,*" another calculation must be made. At each water quality station, the combined dataset of wet and dry weather samples was analyzed and the 90th percentile value calculated. This value was then compared to 200 fc/100 ml to determine whether a violation had occurred.

Calculation of Load Reductions

The approach of this TMDL is to calculate the reductions necessary to meet each part of the state's fecal coliform standard. The more conservative (i.e., the greater) of those two values will be the one upon which the TMDL will be based. The load reductions determined for each stream segment are presented below in Table 3.

Table 3. Weighted Average, 90th Percentile Values, and Load Reductions required for Scrabbletown Brook.

Station	Weighted Ave. (fc/100ml)	90th percentile of Combined Dataset	Reduction Needed To Meet Standards
SCa	1122	34440	99%
SCb	976	42200	99%
SCc	575	13700	97%
SCd	516	7400	96%
SCe	3062	26800	99%
SCh	1460	21510	99%
SC01	854	7200	98%

The implementation measures needed to reach the required reductions are discussed, in detail, in following sections of the TMDL report.

6. Margin of Safety (MOS)

For this analysis, an implicit MOS is provided. In other words, a separate value is not added to the TMDL "equation" to account for a MOS. Instead, the MOS is incorporated "implicitly" into estimates of current pollutant loadings, the targeted water quality goal (i.e., the instream numeric endpoint), and the load allocation. This is done by making conservative assumptions throughout the TMDL development process. Some of the key conservative assumptions are described below.

- Conservative estimates of both the amount of rainfall needed to produce runoff and recovery time were used in the weighted average geomean calculations.

- For some of the wet weather events included in the weighted average geomean calculation, enough time may not have elapsed since the preceding storm event for pollutant levels to return to the elevated levels represented by the wet weather data.

Similarly, other wet weather events may not be large enough, or long enough in duration, to generate the kind of loads represented by the wet weather data.

- The data used to calculate the 90th percentile values was conservatively biased, since a disproportionate percentage of the data for each station were collected during wet weather conditions.

- RIDEM 1999 Dry weather data was collected during drought conditions.

7. Seasonal Variation

The Scrabbletown Brook TMDL is protective of all seasons, as all fecal coliform data were collected during the summer months when instream fecal coliform concentrations are typically the highest.

8. Implementation Plans

This TMDL addresses the different segments of the Scrabbletown Brook watershed as defined by the water quality monitoring locations established as part of RIDEM’s supplementary monitoring program. Water quality was assessed, and load allocations set, for each of the segments. Similarly, RIDEM has developed recommendations for BMP implementation for each of those sub-watersheds.

The Scrabbletown Brook TMDL relies upon phased implementation to reach its water quality goals. As BMPs are installed, the corresponding response in fecal coliform bacteria concentrations will be measured. If standards are not met after the BMPs recommended herein are implemented, then additional measures will be set forth.

RIDEM expects BMPs to be implemented on a voluntary basis by the responsible parties. However, if this does not occur, RIDEM may use its permitting authority, or other enforceable means, to require implementation.

Table 4 summarizes the recommendations for BMPs that are made in section 7.0 of this TMDL. Structural BMPs are expected to reduce fecal coliform bacteria loads to the maximum extent practicable (MEP).

Table 4. BMP recommendations for Scrabbletown Brook TMDL.

Recommended BMP	Location	Responsible Entity	Station or River Segment Impacted
Structural Stormwater Management BMP(s)	Scrabbletown Brook intersection with Stony Lane.	Town of North Kingstown	Scrabbletown Brook downstream of Stony Lane.
Pigeon Deterrent System	Scrabbletown Brook intersection with Route 4.	RIDOT	Scrabbletown Brook downstream of Route 4.
Reduce or remove populations of resident waterfowl.	Impoundments in Scrabbletown Brook tributary upstream of Routes 2 and 4.	Residents and property owners.	Scrabbletown Brook downstream of ponds and Route 4.
Public outreach program.	Watershed-Wide	Towns of North Kingstown and East Greenwich	Watershed-Wide
Structural Stormwater Management BMP(s)	Scrabbletown Brook tributary intersection with Scrabbletown Road.	Town of East Greenwich	Scrabbletown Brook downstream of Scrabbletown Road.
Structural Stormwater Management BMP(s)	Scrabbletown Brook intersection with Routes 2 and 4.	RIDOT	Scrabbletown Brook downstream of Routes 4 and 2.
Structural Stormwater Management BMP(s)	Scrabbletown Brook **tributary** intersection with Routes 2 and 4.	RIDOT	Scrabbletown Brook **tributary** downstream of Routes 2 and 4.
Catchment delineation and structural stormwater management BMP(s)	Scrabbletown Brook intersections with South Road.	Town of East Greenwich	Scrabbletown Brook downstream of intersections with South Road

In addition to the recommended BMPs in Table 4, RIDEM recommends the formation of a public outreach program in the watershed.

Public Outreach

The public outreach program should be aimed at informing and educating citizens in the watershed about the sources of bacteria in streams and ways to eliminate or reduce these sources. The Towns of East Greenwich and North Kingstown would be responsible for carrying out this program.

The public outreach program in the Scrabbletown Brook watershed should focus on educating the public about the negative water quality impacts that resident waterfowl can have and the potential health risks associated with encouraging the presence of these waterfowl in local ponds and impoundments. Additionally, educational information concerning the importance of ISDS maintenance and cleaning up pet waste should be distributed in the watershed.

Stormwater Phase II Permit Program
Over the next several years, RI Department of Transportation (RIDOT) and the Towns of East Greenwich and North Kingstown will be required to meet Phase II Stormwater Program requirements. Federal program regulations recently adopted by EPA require that permitted municipalities develop stormwater management programs, control runoff from small construction sites, investigate and eliminate illicit discharges, utilize pollution prevention/good housekeeping practices, and educate and involve the public in stormwater related issues. These aspects of the Phase II program should have a positive impact on water quality in the Scrabbletown Brook watershed. However, it is very difficult to assign a load reduction to these programs.

Since Scrabbletown Brook is an impaired waterbody, RIDEM anticipates that special emphasis will be placed on addressing stormwater impacts to this stream from municipal separate storm sewer systems (MS4s). This TMDL identifies those highway crossings and storm sewer outfalls associated with elevated bacteria levels in-stream, and where appropriate recommends structural BMPs to reduce pollutant loads. Actions to achieve the required reductions can be taken voluntarily by the Towns and RIDOT prior to the issuance of Phase II Stormwater Permits, or will be required by the Phase II permits.

9. Monitoring Plan for TMDLs Developed Under the Phased Approach

A phased approach is appropriate for fecal coliform TMDLs, considering the highly variable nature of nonpoint source pollutant loads. This approach allows the TMDL to be refined, if necessary, as new information becomes available following implementation of recommended controls (i.e. BMP's). RIDEM, in coordination with the entities responsible for BMP implementation, will monitor water quality at key locations in the Scrabbletown Brook watershed in order to assess BMP effectiveness. This monitoring plan is summarized in the TMDL report.

10. Public Participation

The public participation associated with this TMDL has two components: open meetings and opportunity for public review and comment. An initial meeting was held prior to TMDL development on December 13, 1999. All interested public, private, and government entities were invited to attend. The meeting was held to disseminate information regarding the TMDL issues in the watershed as well as to solicit input regarding pollution sources and/or other concerns.

A second public meeting was held on September 27, 2000 to initiate a 30-day public comment period. RIDEM staff presented the draft TMDL and solicited input, however, no comments were received by the end of the comment period.

THE SCRABBLETOWN BROOK TMDL FOR FECAL COLIFORM

1.0 INTRODUCTION

The State of Rhode Island's 1998 303 (d) List of Impaired Waters identified the Hunt River, Fry Brook, and Scrabbletown Brook as being impaired by pathogens, as evidenced by the presence of high fecal coliform concentrations. The purpose of this report is to establish a Total Maximum Daily Load (TMDL) addressing fecal coliform loads Scrabbletown Brook. This TMDL serves as a restoration plan aimed at abating fecal coliform sources so that bacteria standards can be attained.

1.1 Background

Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies that are not meeting designated uses. The objective of a TMDL is to establish water-quality based limits for pollutant loadings to reduce pollution from both point and nonpoint sources in order to restore and maintain the quality of the state's waters.

The TMDL analysis examines point and nonpoint sources of pollution, such as industrial and wastewater treatment facility discharges, runoff from agricultural areas, and stormwater discharges from municipal separate stormwater systems (MS4's). Natural background levels are also included in the analysis, along with a margin of safety to account for any modeling or monitoring uncertainties. The ultimate goal of this process is to reduce pollutant loading to a waterbody in order to improve water quality to the point where State Water Quality Standards are met.

1.2 Pollutant of Concern

The pollutant of concern is fecal coliform. As reported on the 1998 303(d) list, RIDEM has identified Scrabbletown Brook as being impaired by pathogens for a length of approximately 3.2 miles.

1.3 Applicable Water Quality Standards

All surface waters of the state have been categorized according to a system of water use classification based on consideration for public health, recreation, propagation and protection of fish and wildlife, and economic and social benefit. Each class is identified by the most sensitive, and therefore governing, water uses to be protected. Surface waters may be suitable for other beneficial uses, but are regulated to protect and enhance designated water uses. It should be noted that water use classifications reflect water quality goals for a waterbody, which for waterbodies considered impaired, may not represent existing water quality conditions (Water Quality Regulations 1997).

The water quality designation for Scrabbletown Brook is Class A, which are waters designated not only as a public drinking water supply, but also for such uses as fish and wildlife habitat and primary and secondary recreational activities. In addition, Class A waters shall be suitable for compatible industrial processes and cooling, hydropower, aquacultural uses, navigation, and irrigation and other agricultural uses. These waters shall also have good aesthetic value. The state's water quality standard for fecal coliform in Class A waters is as follows: " *not to exceed a geometric mean value of 20 MPN/100ml and not more than 10% of the samples shall exceed a value of 200 MPN/100ml*" (Water Quality Regulations 1997).

2.0 DESCRIPTION OF THE SCRABBLETOWN BROOK WATERSHED

Scrabbletown Brook is a second-order stream located entirely within the towns of East Greenwich and North Kingstown, Rhode Island (Figure 2.1). The watershed is approximately 1,653 acres in size and drains several wetland areas. Scrabbletown Brook originates in a wetland area near Cooks Corner, as well as the southernmost section of Bear Swamp. Several smaller tributaries join the stream as it flows southeast, approximately 3.2 miles, towards its confluence with the Hunt River.

Closer to its mouth, Scrabbletown Brook flows through outwash plains, which consist chiefly of well-sorted sand and local deposits of coarse gravel. Nearly all of Scrabbletown Brook's tributaries originate in wetland areas or springs. During wet weather, flow is augmented by runoff from impervious areas and is conveyed via ditches and roads to the channel.

Stream flow in Scrabbletown Brook and its tributaries is derived from the combination of surface water runoff moving into streams from the adjacent landmass and groundwater discharge up through streambeds. For the streams and associated ponds and wetlands, water level and flow decrease throughout the summer as evapotranspiration increases. As recharge to the groundwater slows, the volume of groundwater in storage declines and the water table lowers, causing stream flow and pond levels decline.

2.1 Soils

The headwaters of Scrabbletown Brook flow through gravel, sands, and silts, as well as swamp and marsh deposits consisting of partly decomposed organic material, commonly mixed or bedded with sand and silt.

Most of the soils in Rhode Island have formed from material that was transported from the site of the parent rock and redeposited at the new location through the action of ice, water, wind, or gravity. Glacial ice was particularly important in transporting and depositing parent materials from which Rhode Island soils, including those in the Scrabbletown Brook watershed, formed.

The principal parent materials of the Scrabbletown Brook watershed soils are glacial till and glacial outwash. A small percentage of soils have developed from organic deposits. Organic deposits form the parent materials for peat and muck soils. These organic deposits generally occur in small, very poorly drained depressions and are particularly thick in large lowland swamps such as those along the lower reaches of Scrabbletown Brook, near it's confluence with the Hunt River.

2.2 Land Use

Based on the most recent land use study (URI 1997), current land use in the 1,653-acre watershed is 24% residential, 3% commercial-industrial, 6% agriculture, 38% forest, 19% wetland, 3% roads. A comparison of current land uses versus build-out in the watershed are shown in Figure 2.2.

Changes in land use in the Scrabbletown Brook watershed are those typically associated with the conversion of forest land to urban land. The associated impacts of most concern in the watershed are (1) the increase in the number of septic systems installed in limiting soils, and (2) increases in the amount of impervious surfaces within the drainage areas.

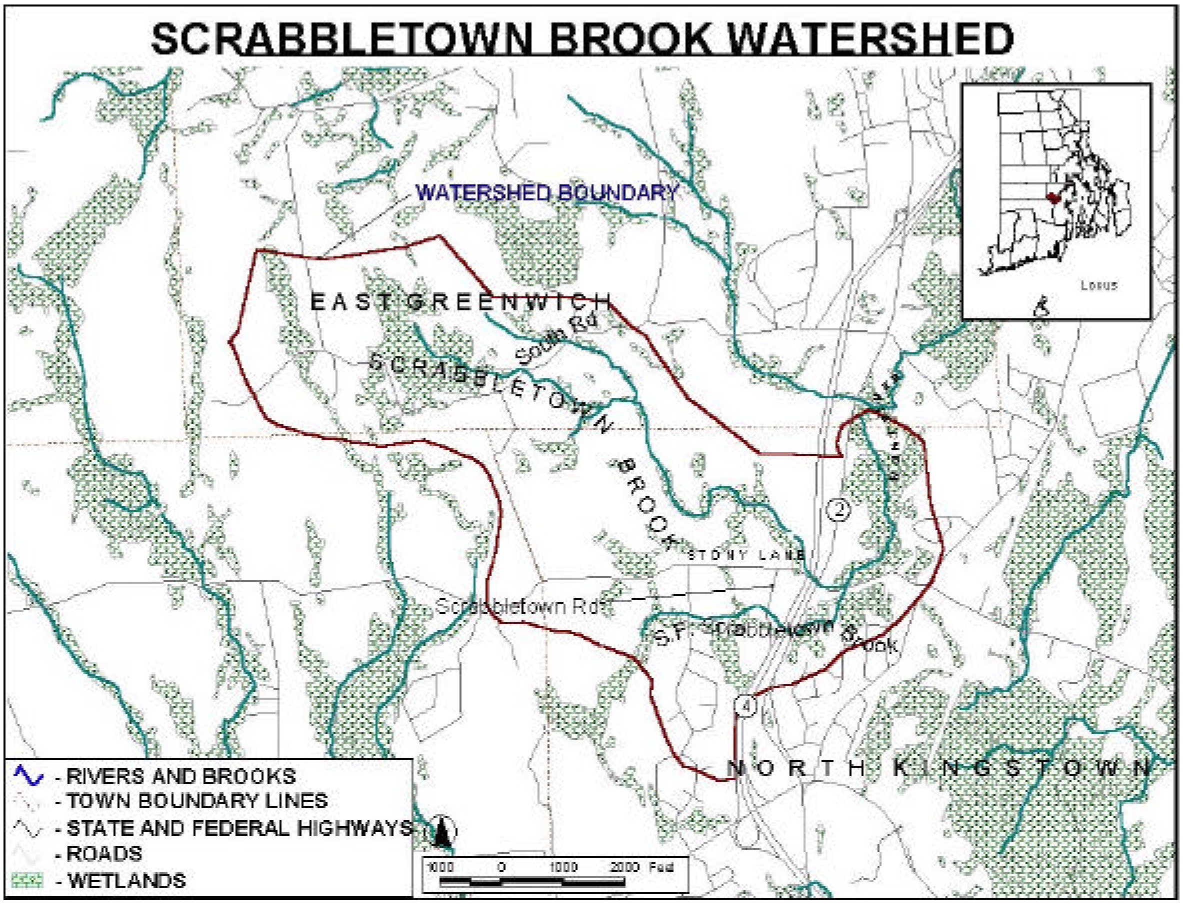
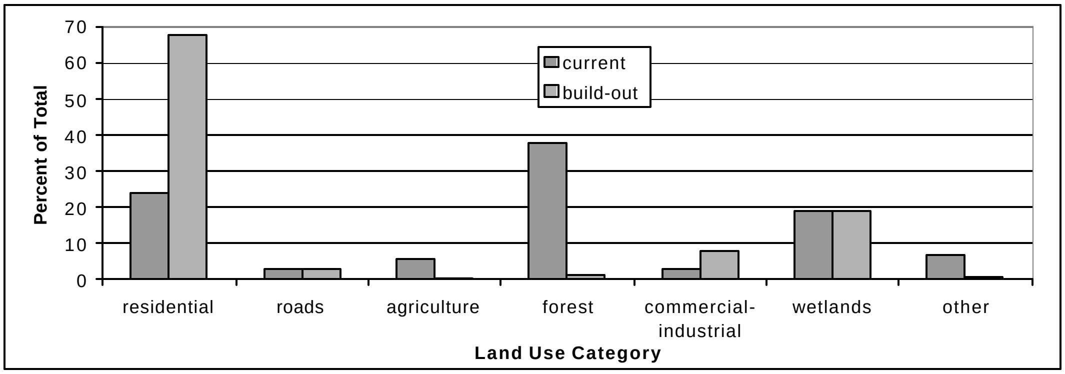


Figure 2.1. Scrabbletown Brook Watershed.

Figure 2.2. Changes in land use with build-out in the Scrabbletown Brook watershed (URI 1997).



The conversion of rural and forest land to urban land is usually accompanied by increases in the discharge and volume of storm runoff, as well as any associated pollutants, in a watershed. In urbanizing watersheds, the amount of impervious surfaces, including roads, sidewalks, parking lots, and buildings, increases. This leads to decreased infiltration of precipitation and decreases in groundwater levels near affected stream channels.

Because less runoff infiltrates into underlying groundwater, reduced baseflow in streams may be observed during times of little or no precipitation. Lower baseflow levels may worsen water quality conditions, as the dilution capacity of the stream is limited when less water is in the channel.

Mallin (1999) found that the most important anthropogenic factor associated with fecal coliform abundance was percent watershed impervious surface coverage. A study conducted by Burnhart (1991) attempted to identify land uses in industrial, commercial, and residential areas, which were the largest contributors of fecal coliform. Burnhart found that the primary contributor of fecal coliform bacteria in industrial and commercial areas was parking lots. In the residential areas, the primary contributors of fecal coliform loads were streets.

Schueler (1987) maintains that bacterial levels in urban runoff exceed public health standards for water contact recreation almost without exception. Schueler further states that although nearly every urban and suburban land use exports enough bacteria to violate health standards, older and more intensively developed urban areas typically produce the greatest export.

Pitt (1998) reports a mean fecal coliform concentration in stormwater runoff of about 20,000 fc/100ml based on 1,600 storm runoff samples largely collected during the Nationwide Urban Runoff Program (NURP) in the early 1980's. Pitt also reported a nearly identical mean fecal coliform concentration of about 22,000 fc/100ml, derived from a second database containing 25 additional stormwater monitoring studies conducted since NURP.

The Center for Watershed Protection has recently developed a third database containing 34 more recent urban stormwater monitoring studies. An analysis of the Center's database indicates a slightly lower mean concentration of fecal coliform in urban stormwater of about 15,000 fc/100ml (CWP 1999).

3.0 WATER QUALITY MONITORING ACTIVITIES IN THE SCRABBLETOWN BROOK WATERSHED

3.1 URI Study (1996-1997)

The most extensive water quality assessment of the Hunt River watershed was conducted by researchers from the University of Rhode Island's Civil and Environmental Engineering Department (Wright et al. 1999). This study of the Hunt-Potowomut River basin, under contract to RIDEM, was conducted during 1996 and 1997. Scrabbletown Brook, at SC01, was one of the five tributaries monitored throughout the survey. Both dry and wet weather water quality data were collected during this study.

The URI study was divided into two phases: a preliminary site assessment (dry weather water quality monitoring program) and a wet weather characterization. The location of SC01 is shown in Section 3.2, Figure 3.1. Dry weather monitoring consisted of 6 surveys, each sampling 21 stations, with 4-8 samples completed over a 24-hour period. For this study, a dry day was defined as a day with rainfall totals no greater than 0.03 inches and less than 0.5 inches of rainfall during the previous seven days.

Wet weather monitoring consisted of four storm event surveys that sampled 10 stations. Wet weather field sampling began with a pre-storm sample taken approximately 3 hours before the storm, with subsequent sampling hourly for the first 12 hours and at two-hour intervals for the next 12 hours. The following rainfall criteria were used for the URI wet weather study:

- Minimum rainfall total of 0.5 inches in a 24-hr period.
- Minimum rainfall duration of 5 hours
- Minimum antecedent dry period of 3 days
- Minimum number of 2 post-storm days

A summary of the dry and wet weather data that was collected by URI is provided below. A more detailed analysis of the data is available in the project final report (Wright et al., 1999).

Dry Weather Data

Six dry weather surveys were completed in 1996-1997. Twenty-eight samples were collected at SC01 (Table 3.1). Minimum and maximum fecal coliform concentrations were 25 and 1000 fc/100ml, respectively. The geometric mean at SC01was 258 fc/100ml.

Table 3.1 Results from URI Dry Weather Monitoring.

Survey/Date	Run	Concentration (fc/100ml)
Survey # 1 (April 25-26, 1996)	1	41
	2	86
	3	59
	4	25
Survey # 2 (July 29-30, 1996)	1	420
	2	270
	3	260
	4	600
	5	370
	6	350
	7	330
	8	380
Survey # 3 (October 15-16, 1996)	1	750
	2	310
	3	240
	4	140
Survey # 4 (June 5-6, 1997)	1	132
	2	139
	3	99
	4	159
Survey # 5 (July 30-31, 1997)	1	210
	2	930
	3	820
	4	1000
Survey # 6 (November 19-20, 1997)	1	660
	2	360
	3	230
	4	740

Wet Weather Data

Four wet weather events were monitored: April 12-13, 1997 (WWS#1), August 13-15, 1997 (WWS#2), November 7-10, 1997 (WWS#3), and November 7-10, 1997 (WWS#4). The total rainfall and duration for each storm was 1.02 inches/12 hrs, 0.60 inches/4 hrs, 1.56 inches/28 hrs, and 2.02 inches/24 hrs, respectively. A total of 36 fecal coliform samples were collected from the four wet weather events. The data are presented in the final Hunt River TMDL. Minimum and maximum fecal coliform bacteria levels were 61 and 20000 fc/100ml, respectively. The geometric mean for all wet weather data collected at SC01 is 1406 fc/100ml. All wet weather data are presented below in Table 3.2.

Table 3.2 Results from URI Wet Weather Monitoring at station SC01.*

Wet Weather Survey # 1

Run	Date	Time	fc/100ml
P	4/12/97	1720	37
1	4/12/97	1830	NS
2	4/12/97	1920	61
3	4/12/97	2050	NS
4	4/12/97	2140	380
5	4/12/97	2230	NS
6	4/12/97	2320	380
7	4/13/97	0010	NS
8	4/13/97	0155	240
9	4/13/97	0255	NS
10	4/13/97	0350	280
11	4/13/97	0445	NS
12	4/13/97	0540	140
13	4/13/97	0655	NS
14	4/13/97	1315	70

Wet Weather Survey # 3

Run	Date	Time	fc/100ml
P	11/1/97	0717	2300
1	11/1/97	1200	960
2	11/1/97	1500	2800
3	11/1/97	1800	8700
4	11/1/97	2150	4000
5	11/2/97	0020	3100
6	11/2/97	0300	1100
7	11/2/97	1100	1500
8	11/3/97	0845	510

Wet Weather Survey # 2

Run	Date	Time	fc/100ml
P	8/13/97	1400	890
1	8/13/97	1530	9500
2	8/13/97	1715	20000
3	8/13/97	1925	3200
4	8/13/97	2120	11000
5	8/14/97	0300	6200
6	8/14/97	0530	3500
7	8/14/97	0730	1600
8	8/14/97	1230	1500
9	8/15/97	0005	4700
10	8/15/97	1240	1700

Wet Weather Survey # 4

Run	Date	Time	fc/100ml
P	11/7/97	0800	1600
1	11/7/97	1530	2400
2	11/7/97	1845	4000
3	11/7/97	2130	1200
4	11/7/97	2340	1800
5	11/8/97	0330	2800
6	11/8/97	0615	2200
7	11/8/97	1230	800
8	11/8/97	1830	850
9	11/9/97	0615	870
10	11/9/97	1805	590
11	11/11/97	0700	1200

** P = Pre-storm sample. NS = Not Sampled.*

3.2 RIDEM Supplementary Monitoring (1999)

In 1999, RIDEM staff conducted supplemental monitoring in the Hunt River watershed to support the development of fecal coliform TMDLs for the Hunt River and Fry and Scrabbletown Brooks. This effort included ambient monitoring for fecal coliform at 34 sampling stations located along the mainstem of the Hunt River and many of its tributaries Dry weather samples were collected from three to eight times at each station during the spring, summer, and fall of 1999. Wet weather samples were collected from two separate storms: September 30- October 1 and Oct 17-18, 1999.

Dry Weather Data
Four dry-weather surveys were completed by RIDEM in the summer and fall of 1999. Fecal coliform data were collected at seven locations in the Scrabbletown Brook watershed. The locations of these stations are shown in Figure 3.1. The dry weather data, including two preliminary site visits, collected in the Scrabbletown Brook watershed are summarized below in Table 3.3.

Table 3.3 Summary of RIDEM 1999 Dry Weather Data.*

Water Quality Station	Preliminary Site Visit #1 5/21/99)	Preliminary Site Visit #2 (6/2/99)	Preliminary Site Visit # 3 (6/9/99)	DW Survey 1 6/17/99	DW Survey 2 7/19/99	DW Survey 3 8/17/99	DW Survey 4 9/14/99
SC01	170	130	520	2500	1600	5300	1200
SCa	14	22	34	90	270	91	130
SCb	17	22	28	120	99	98	71
SCc		2		100			
SCd	29	10		260			220
SCe		59	780	380	250	1900	130
SCh			650	550	330		

** All data are in units of fc/100ml.*

Wet Weather Data
The following rainfall guidelines were used for the RIDEM wet weather study:

- Minimum rainfall total of 0.5 inches in a 24-hr period.
- Minimum rainfall duration of 5 hours
- Minimum antecedent dry period (ADP) of 3 days
- Minimum number of 2 post-storm days

These rainfall criteria are similar to those employed by the Narragansett Bay Commission and the Narragansett Bay Project in their recent efforts to quantify nonpoint source pollution to the Providence River. These rainfall criteria were also applied to EPA monitoring efforts on the Blackstone River. The rainfall figure of 0.5 inches is an assurance that there will be sufficient rainfall to cause a runoff event. The minimum duration of 5 hours rules out short, high-intensity rainfall events commonly associated with summer thunderstorms, and directs the storm collection to a more extensive storm system, making it somewhat easier to forecast and increasing the probability of capturing a successful storm. The 2-day post-storm criterion was used to prevent back to back storms and avoid the problem associated with the separation of multiple storm signals in the data.

Seven stations (Figure 3.1) were sampled during two separate storms: Sept 30- Oct 1, 1999 and Oct 17th-18th, 1999. One storm was a high-intensity short duration event (0.56 inches/3 hours, average intensity = 0.19 in/hr), and the other storm was a medium-intensity longer duration event (1.68 inches/10 hours, average intensity = 0.16 in/hr). All six stations had significant increases in fecal coliform geometric mean concentrations compared to dry weather conditions. Wet weather data collected in Scrabbletown Brook are summarized below in Tables 3.4 and 3.5. Station SCe was not sampled during the second wet weather event.

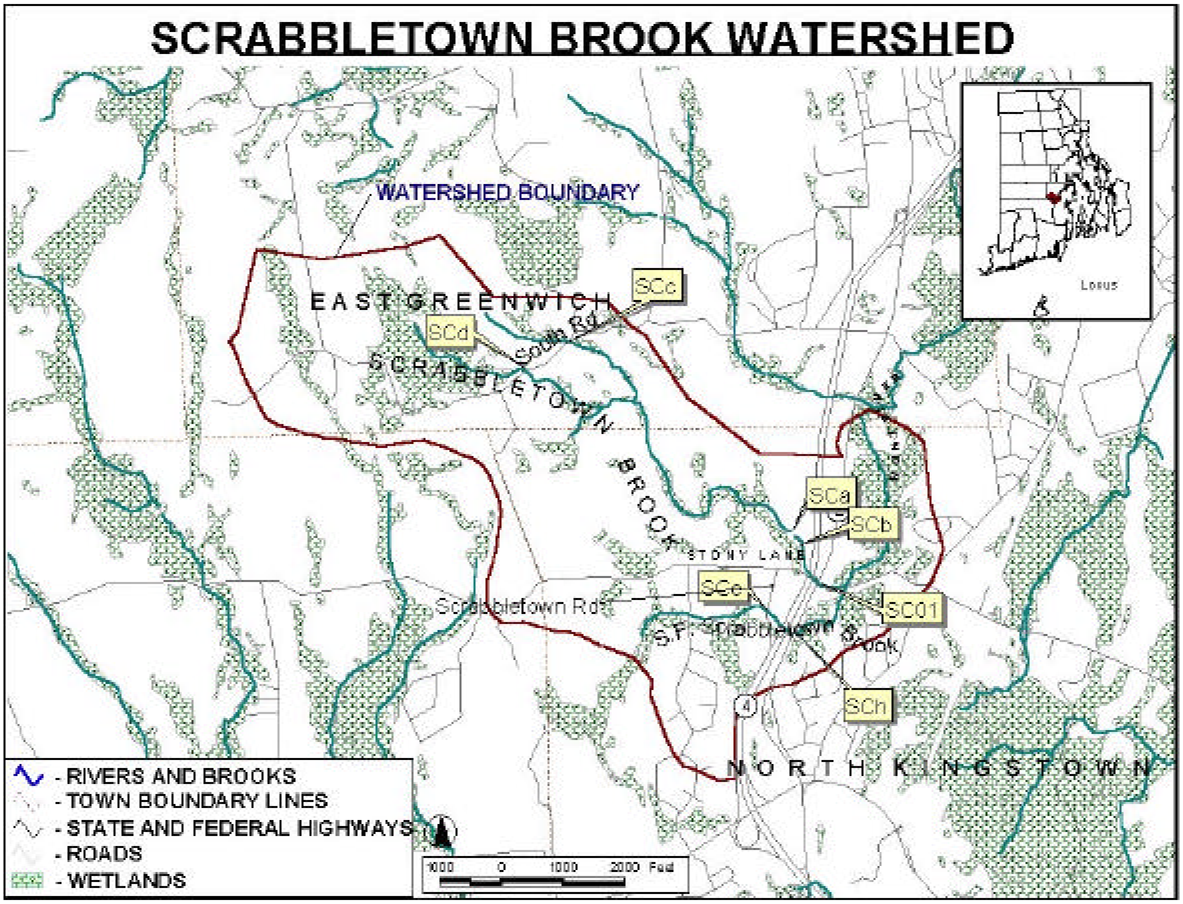


Figure 3.1. RIDEM Scrabbletown Brook Watershed Sampling Locations (1999)

Table 3.4 RIDEM 1999 Data for Wet Weather Event # 1.[a]

Sample	Collection Date	Collection Time	No. of Hours After Pre-Storm Sample	Concentration (fc/100ml)
SCa-0	9/30/99	0759	0.0	120[b]
SCa-02	9/30/99	1015	3.0	200,000
SCa-03	9/30/99	1120	4.0	33,000
SCa-04	9/30/99	1228	5.0	40,000
SCa-06	9/30/99	1449	7.0	23,000
SCa-12	9/30/99	1709	9.5	6,100
SCa-24	10/1/99	1111	27.5	410
SCb-02	9/30/99	1020	3.0	52,000
SCb-03	9/30/99	1126	4.0	38,000
SCb-04	9/30/99	1229	5.0	69,000
SCb-06	9/30/99	1453	7.0	24,000
SCb-12	9/30/99	1712	9.5	4,400
SCb-24	10/1/99	1114	27.5	440
SCc-03	9/30/99	1107	4.0	27,000
SCc-04	9/30/99	1212	5.0	11,000
SCc-06	9/30/99	1435	7.0	630
SCc-12	9/30/99	1734	9.5	200
SCd-0	9/30/99	0744	0.0	110 [b]
SCd-03	9/30/99	1110	4.0	7,600
SCd-04	9/30/99	1215	5.0	24,000
SCd-06	9/30/99	1440	7.0	7,200
SCd-12	9/30/99	1737	9.5	1,300
SCd-24	10/1/99	1101	27.5	1,500
SCe-0	9/30/99	0803	0.0	37[b]
SCe-03	9/30/99	1120	3.0	30,000
SCe-04	9/30/99	1231	4.0	50,000
SCe-06	9/30/99	1455	6.5	14,000
SCe-12	9/30/99	1714	9.5	6,600
SCe-24	10/1/99	1117	27.5	350
SCh-03	9/30/99	1130	4.0	65,000
SCh-04	9/30/99	1234	5.0	27,000
SCh-06	9/30/99	1456	7.0	5,400
SCh-12	9/30/99	1700	9.5	8,700
SCh-24	10/1/99	1119	27.5	780
SC01-0	9/30/99	0810	0.0	690[b]
SC01-02	9/30/99	1020	3.0	11,000
SC01-03	9/30/99	1133	4.0	45,000
SC01-04	9/30/99	1238	5.0	51,000
SC01-06	9/30/99	1500	7.0	27,000
SC01-12	9/30/99	1705	9.5	8,800
SC01-24	10/1/99	1123	27.5	1,400

[a] *All data are in units of fc/100ml.*

[b] *Indicates pre-storm value. For TMDL analysis, the pre-storm value was considered part of the dry-weather data set.*

Table 3.5 RIDEM 1999 Data for Wet Weather Event #2[a].

Sample	Collection Date	Collection Time	No. of Hours After Pre-Storm Sample	Concentration (fc/100ml)
SCa-0	10/17/99	2024	0	25[b]
SCa-02	10/18/99	0055	4	450
SCa-04	10/18/99	0712	10	1,500
SCa-06	10/18/99	1035	14	630
SCa-12	10/18/99	1436	18	280
SCa-24	10/19/99	1315	41	110
SCb-0	10/17/99	2026	0	23[b]
SCb-02	10/18/99	0058	4	340
SCb-04	10/18/99	0715	10	1,600
SCb-06	10/18/99	1035	14	580
SCb-12	10/18/99	1439	18	170
SCb-24	10/19/99	1317	41	120
SCc-0	10/17/99	2012	0	25[b]
SCc-02	10/18/99	0040	4	7,000
SCc-02upstream	10/18/99	0039	4	14,000
SCc-06	10/18/99	1046	14	1,200
SCc-12	10/18/99	1420	18	470
SCc-24	10/19/99	1323	41	31
SCd-0	10/17/99	2016	0	24[b]
SCd-02	10/18/99	0043	4	110
SCd-02upstream	10/18/99	0044	4	140
SCd-04	10/18/99	0700	10	570
SCd-06	10/18/99	1044	14	2,300
SCd-12	10/18/99	1424	18	1,800
SCd-24	10/19/99	1321	41	230
SCh-0	10/17/99	2020	0	1,200[b]
SCh-02	10/18/99	0100	4	5,300
SCh-04	10/18/99	0717	10	3,200
SCh-06	10/18/99	1031	14	2,000
SCh-12	10/18/99	1440	18	710
SCh-24	10/19/99	1309	41	62
SC01-0	10/17/99	2033	0	140[b]
SC01-02	10/18/99	0103	4	2,200
SC01-04	10/18/99	0719	10	2,100
SC01-06	10/18/99	1033	14	760
SC01-12	10/18/99	1442	18	400
SC01-24	10/19/99	1312	41	160

[a] *All data are in units of fc/100ml.*

[b] *Indicates pre-storm value. For TMDL analysis, the pre-storm value was considered part of the dry-weather data set.*

4.0 WATER QUALITY CHARACTERIZATION

Both dry and wet weather data were used to characterize water quality conditions in the Scrabbletown Brook watershed. Dry weather data was used to assess steady state conditions when the waters are most likely to be utilized for the designated uses of primary and secondary recreational activities. Wet weather data was used primarily to assess worst case conditions and to help locate nonpoint source pollution hot spots in the watershed.

Given that the conditions were so different during the monitoring periods (i.e., there was a severe drought in 1999 when RIDEM conducted water quality investigatins), the dry and wet weather data collected from the URI and RIDEM studies are evaluated independently below. The data sets are then combined to assess compliance with the water quality standards, as described below.

In order to assess compliance with water quality standards, the monitoring data must be compared to both parts of the Class A standard. In order to determine compliance with the geometric mean portion of the criteria, a "weighted average" geometric mean was established for each station. To assess compliance with the percent exceedence part of the criteria, a 90th percentile value was calculated for each station. Both of these approaches are described below.

4.1 Dry Weather Characterization

URI Water Quality Study (1996-1997)

University of Rhode Island (URI) researchers, under contract to RIDEM, completed six dry-weather surveys in the Hunt River watershed during 1996-1997. The only location sampled in the Scrabbletown Brook sub-watershed was SC01. During the six surveys, researchers collected 28 samples at SC01 (Table 3.1). The minimum value was 25 fc/100ml, and the maximum value was 1000 fc/100ml. The geometric mean of the URI dry weather data set was 258 fc/100ml.

RIDEM Supplementary Monitoring (1999)

The most recent assessment of the Scrabbletown Brook watershed (RIDEM 1999) included ambient monitoring for fecal coliform bacteria at a total of 7 stations located in the watershed (Figure 3.1). Each station was sampled from three to eight times during the summer and fall of 1999. Table 4.1 shows the minimum, maximum, and geometric mean values for each station.

Table 4.1 Summary of RIDEM 1999 Dry Weather Data*.

Station	Location	No. of Samples	Minimum Value	Maximum Value	Geometric Mean
SCa	Pleasant Valley Rd.	8	14	270	66*
SCb	Pleasant Valley Rd.	7	22	120	65*
SCc	South Road	3	2	100	15
SCd	South Road	5	10	260	71*
SCe	Scrabbletown Rd.	6	59	1900	320*
SCh	Route 2	4	330	680	526*
SC01	Stony Lane	11	130	5300	917*

** Indicates violation of criteria for fecal coliform bacteria at that station.*

4.2 Wet Weather Characterization

URI Water Quality Study (1996-1997)

Four wet weather events were monitored: April 12-13, 1997 (WWS#1), August 13-15, 1997 (WWS#2), November 7-10, 1997 (WWS#3), and November 7-10, 1997 (WWS#4). The total rainfall and duration for each storm was1.02 inches/12 hrs, 0.60 inches/4 hrs, 1.56 inches/28 hrs, and 2.02 inches/24 hrs, respectively. A total of 36 samples were collected at SC01 during the four wet weather events (Table 3.2). The URI wet weather data show elevated levels of fecal coliform occurring at SC01. The minimum value was 61 fc/100ml, and the maximum value was 20000 fc/100ml. The geometric mean of this wet weather data set was 1406 fc/100ml.

RIDEM Supplementary Monitoring (1999)

Wet weather samples were collected from 2 separate storms: Sept 30- Oct 1, 1999 and Oct 17th-18th, 1999. The first storm was a high-intensity short duration event (0.56 inches/3 hours, average intensity = 0.19 in/hr), and the second storm was a medium-intensity longer duration event (1.68 inches/10 hours, average intensity = 0.16 in/hr). The RIDEM study found that most of Scrabbletown Brook and its tributaries do not fully support the designated uses for Class A waterbodies during wet weather conditions. All six stations had significant increases in fecal coliform geometric mean concentrations compared to dry weather conditions. Data are summarized below in Table 4.2 for the Scrabbletown Brook stations.

Table 4.2 Summary of RIDEM 1999 Wet Weather Data.

Station	Location	No. of Samples	Minimum Value	Maximum Value	Geometric Mean
SCa	Pleasant Valley Rd.	11	110	200000	3032*
SCb	Pleasant Valley Rd.	11	120	69000	2625*
SCc	South Road	9	31	27000	1588*
SCd	South Road	11	110	24000	1321*
SCe	Scrabbletown Road	6	350	50000	8023*
SCh	Route 2	10	62	65000	3149*
SC01	Stony Lane	11	160	51000	1765*

* *Indicates violation of criteria for fecal coliform bacteria at that station.*

4.3 Weighted Average Approach

In order to develop an overall assessment of water quality conditions in the watershed, the dry and wet weather data sets from both the URI and RIDEM studies had to be combined. RIDEM developed an innovative approach to doing this by combining the data in the form of a "weighted average" based on the number of wet and dry days that occur, on average, in the watershed. The approach also incorporates the time needed for the stream to return to steady state conditions after a rain event.

The weighted average calculation incorporates the probability of occurrence of both dry and wet weather conditions to calculate a weighted average geometric mean value representative of the frequency of occurrence of wet and dry weather conditions in the watershed. The weighted average is compared to the water quality standard to determine if water quality standards are violated. Thus, percent reductions for each water quality station were based on the weighted average value, calculated from the following equation:

Weighted Avg. Geomean (for each WQ station) = (% of dry weather days) x (Dry weather geomean) + (% of wet weather days) x (Wet weather geomean)

Initially, the amount of precipitation needed to produce runoff in the watershed was determined. Any precipitation event in the watershed that produces runoff was considered to be a "wet" weather condition. Based on data collected from five stations in the Hunt River watershed, runoff from a 0.20-inch precipitation event can be expected. This number was calculated by comparing in-stream fecal coliform concentrations, hourly precipitation data, and discharges from 4 wet weather events (2 RIDEM events and 2 URI events) monitored in the watershed. Five stations from both the URI and RIDEM studies were used to calculate an average value for precipitation-producing runoff. These five stations all had similar land uses upstream in their respective watersheds, therefore it was felt that these stations would be representative of hydrologic processes in Scrabbletown Brook.

For all 4 wet weather events, cumulative precipitation was plotted against fecal coliform concentrations and in-stream flows. In all cases, for precipitation amounts of approximately 0.20 inches of rainfall, flows have risen (based on stage readings) and fecal coliform concentrations have increased at least an order of magnitude (sometimes 2 orders of magnitude). The data for both wet weather events sampled by RIDEM in 1999 are given in Table 4.3. The URI wet weather data are shown at the end of this document in Appendix A. Although runoff was observed to occur from precipitation events of less than 0.20 inches, the amount of runoff was considered insignificant and thus, impacts to water quality in the system are unlikely.

The frequency of occurrence of precipitation events on an annual basis was determined using 15 years of rainfall data from T.F. Green Airport (Warwick, RI). The frequency of occurrence was determined for rainfall events greater than or equal to 0.10, 0.15, 0.20, 0.25, and 0.3 inches of rainfall in a 24-hr period (Figure 4.1). Upon examination of meteorological data recorded at T.F. Green Airport over the past 15 years, it was determined that wet weather days, as determined above, occur 17.8% percent of the time, and dry weather days occur 82.2% percent of the time.

The overall percentage of wet weather days was adjusted to include recovery time (time required for the in-stream fecal coliform concentrations to return to either pre-storm levels or the Class A criteria of 20 fc/100ml). Data collected from stations SC01 and SCh were used to calculate recovery times from the first wet weather event, while station SC01 was used for the second event. Station SC01 is located at the mouth of Scrabbletown Brook, while SCh is located at the mouth of the largest tributary. Fecal coliform concentrations were plotted against time, and the falling limb of the plots was fitted to an exponential decay equation. Extrapolation from the decay equations was used to estimate the amount of time needed for fecal coliform concentrations at each station to drop to either the pre-storm values or the Class A standard of 20 fc/100ml for fecal coliform. It was not necessary to compute decay equations for station SCh or SC01during the second wet weather event because the sampling program captured the reduction in fecal coliform concentrations to acceptable levels.

Analysis of wet weather data for stations SC01 and SCh show that an additional day is required for in-stream fecal coliform concentrations to drop to either pre-storm levels or the Class A criteria of 20 fc/100ml (Table 4.4). The data for both wet weather events sampled by RIDEM in 1999 are presented in Appendix B.

Table 4.3. RIDEM 1999 hydrologic, bacteria, and rainfall data.

RIDEM 1999 1st Wet Weather Event

HRe

hour	stage	FC/100ml	hour	rainfall (in)
0	0.76	160	0	0
3	1.07	12000	0.5	0.21
4	1.13	40000	1	0.31
5	1.03	260000	1.5	0.31
7	0.9	27000	2	0.32
9.5	0.86	9500	2.5	0.42
27.5	0.81	27	3	0.56

FRY03

hour	stage	FC/100ml	hour	rainfall (in)
0	0.6	1100	0	0
3	0.68	4900	0.5	0.21
5	1.1	240000	1	0.31
7	1.08	66000	1.5	0.31
9.5	0.96	39000	2	0.32
27.5	0.74	3400	2.5	0.42
			3	0.56

HR02

hour	stage	FC/100ml	hour	rainfall (in)
0	7.5	40	0	0
3	7.55	100	0.5	0.21
5	7.66	210	1	0.31
7	7.68	110	1.5	0.31
9.5	7.68	120	2	0.32
27.5	7.68	710	2.5	0.42
			3	0.56

SC01

hour	stage	FC/100ml	hour	rainfall (in)
0	0.81	690	0	0
3	1.32	11000	0.5	0.21
4	1.09	45000	1	0.31
5	1.01	51000	1.5	0.31
7	0.89	27000	2	0.32
9.5	0.94	8800	2.5	0.42
27.5	0.86	1400	3	0.56

FB01

hour	stage	FC/100ml	hour	rainfall (in)
0	7.7	60	1	0.31
3	7.88	8900	2	0.32
5	8.06	8900	3	0.56
7	7.92	2500		
9.5	7.92	3300		
27.5	7.9	1500		

RIDEM 1999 2nd Wet Weather Event

HRe

hour	stage	FC/100ml	hour	rainfall (in)
0	0.98	32	0	0
4	1	225	0.5	0.12
10	1.22	2400	1	0.15
14	1.23	630	1.5	0.16
18	1.15	240	2	0.31
41	1.08	180	2.5	0.41
			3	0.42
			3.5	0.45
			4	0.52
			4.5	0.59
			5	0.69
			5.5	0.79
			6	0.84
			6.5	0.87
			7	0.94
			7.5	1.03
			8	1.16
			8.5	1.32
			9	1.51
			9.5	1.62
			10	1.68

FRY03

hour	stage	FC/100ml	hour	rainfall (in)
0	0.84	2400	0	0
4	0.88	8600	0.5	0.12
10	1.4	33000	1	0.15
14	1.24	13000	1.5	0.16
18	1.2	12000	2	0.31
41	0.94	1600	2.5	0.41
			3	0.42
			3.5	0.45
			4	0.52
			4.5	0.59
			5	0.69
			5.5	0.79
			6	0.84
			6.5	0.87
			7	0.94
			7.5	1.03
			8	1.16
			8.5	1.32
			9	1.51
			9.5	1.62
			10	1.68

HR02

hour	stage	FC/100ml	hour	rainfall (in)
0		14	0	0.15
4		7	1	0.31
10		19	2	0.42
14		30	3	0.52
18		80	4	0.69
41		150	5	0.84
			6	0.94
			7	1.16
			8	1.51
			9	1.68
			10	

SC01

hour	stage	FC/100ml	hour	rainfall (in)
0	0.81	140	0	0
4	1.06	2200	0.5	0.12
10	1.26	2100	1	0.15
14	1.24	760	1.5	0.16
18	1.24	400	2	0.31
41	0.91	160	2.5	0.41
			3	0.42
			3.5	0.45
			4	0.52
			4.5	0.59
			5	0.69
			5.5	0.79
			6	0.84
			6.5	0.87
			7	0.94

FB01

hour	stage	FC/100ml	hour	rainfall (in)
0	0.779	24	1	0.15
4	0.79	130	2	0.31
10	0.835	1500	3	0.42
14	0.828	610	4	0.52
18	0.828	380	5	0.69
41	0.81	130	6	0.84
			7	0.94
			8	1.16
			9	1.51
			10	1.68

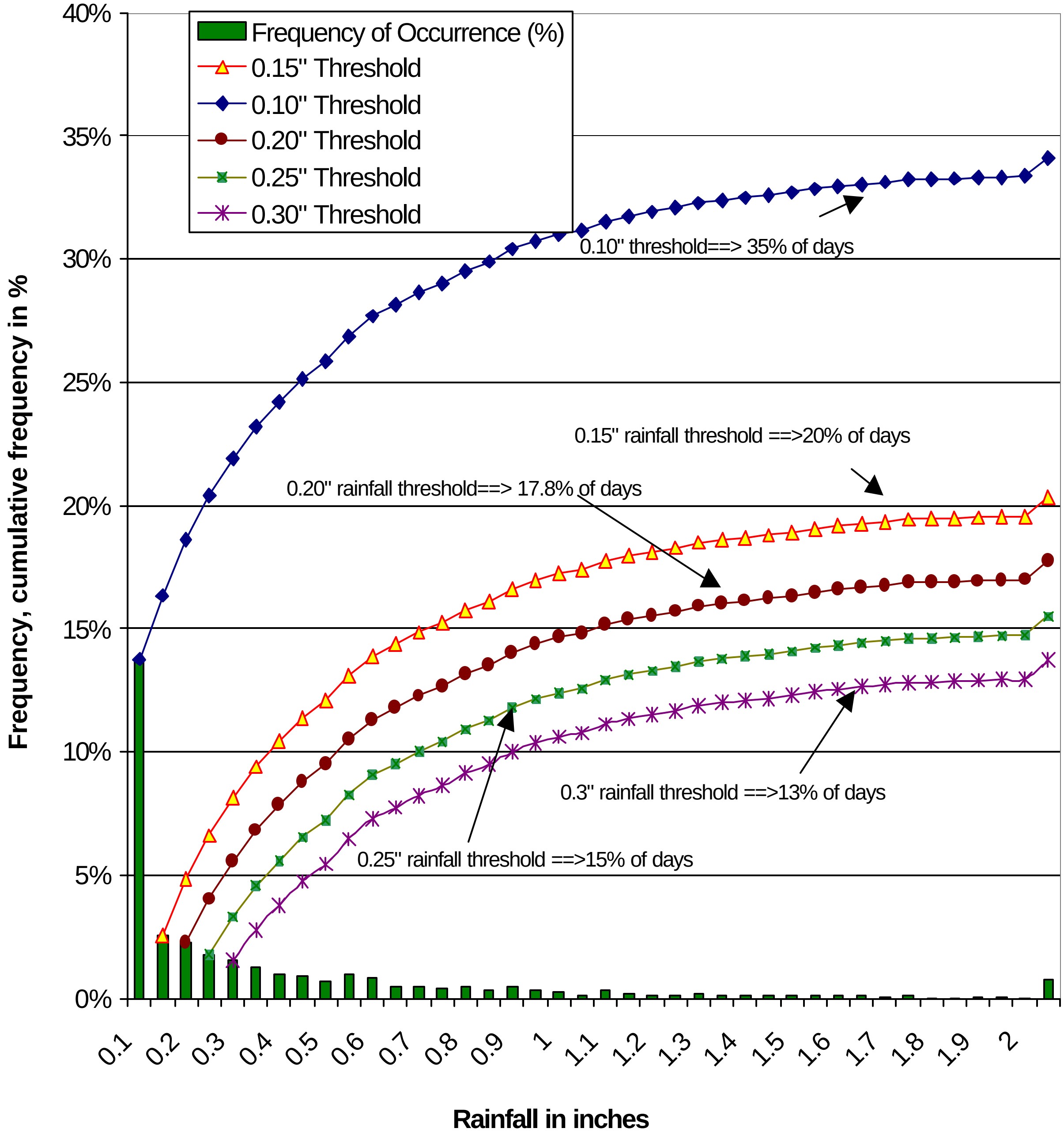


Figure 4.1 Frequency of occurrence of rainfall events for the Scrabbletown Brook watershed.

Table 4.4. Summary of calculated decay equations and approximate time to recovery for Scrabbletown Brook wet weather events.

Station	Class	WW1-calculated decay equation	WW1-approximate time to recovery in days	WW2- calculated decay equation	WW1-approximate time to recovery in days
SC01	A	$Y=45727e^{(-0.1207x)}$	2	Recovery w/out extrapolation	2
SCh	A	recovery	2	Recovery w/out extrapolation	2

For an additional day of recovery needed, the percentage was doubled, making the percent of wet weather days equal to 35.6% (17.8% X 2). This takes into consideration wet weather bacteria violations not only for the day of the storm but also for the additional day it takes for the system to recover. The percent of dry weather days is 64.4% (100% - 35.6%).

A weighted average calculation for Scrabbletown Brook, as determined from the information above, is shown below:

Weighted Avg. Geomean (for each WQ station) = (0.356) X (Wet weather geomean) + (0.644) X (Dry weather geomean)

The results of this calculation are shown in Table 4.5. Once computed, the weighted average geomean can be compared to the geometric mean portion of the fecal coliform standard to determine whether that portion of the water quality standard for fecal coliform bacteria is violated.

Table 4.5. Weighted Average Geometric Mean Calculations.

Station	DW Geometric mean (fc/100ml)	WW Geometric mean (fc/100ml)	Weighted Average Geometric Mean (fc/100ml)
SCa	66	3032	1122
SCb	65	2625	976
SCc	15	1588	575
SCd	71	1321	516
SCe	320	8023	3062
SCh	526	3149	1460
SC01	350	3720	854

4.4 Calculation of the Percent Exceedence Value

State water quality standards require that, for Class A waterbodies, not more than 10% of the samples shall exceed a value of 200 MPN/100ml. In order to determine compliance with this portion of the standard, the wet and dry weather data sets from both the URI and RIDEM studies were combined into one data set for each station. The 90th percentile value was then determined for each station from that combined data set. The results are presented in Table 4.6.

Table 4.6 Percent Exceedence Values by Station.

Station	Location	Calculated 90th Percentile Value of Combined Data Sets (fc/100ml)
SCa	Pleasant Valley Rd.	34400
SCb	Pleasant Valley Rd.	42200
SCc	South Road	13700
SCd	South Road	7400
SCe	Scrabbletown Rd.	26800
SCh	Route 2	21510
SC01	Stony Lane	7200

5.0 WATER QUALITY IMPAIRMENTS

The URI and RIDEM water quality investigations performed in the watershed document that the bacteria impairments in Scrabbletown Brook and its tributaries are primarily due to nonpoint sources of pollution and stormwater discharges from MS4's.

Both dry and wet weather data were used to characterize water quality conditions in the Scrabbletown Brook watershed. Dry weather data was used to assess steady state conditions when the waters are most likely to be utilized for the designated uses of primary and secondary recreational activities. Wet weather data were used primarily to assess worst case conditions and to help locate nonpoint source pollution hot spots in the watershed.

This TMDL addresses the different segments of the Scrabbletown Brook watershed as defined by the seven-water quality monitoring locations established as part of RIDEM's supplementary monitoring program. The water quality assessment conducted by RIDEM sought to characterize current conditions and identify pollution sources for each stream segment monitored. This information is provided below by station. Note that, since station SC01 is the most downstream station, it is listed last.

In seeking to identify sources of pathogen contamination, RIDEM staff reviewed aerial photos, topographic maps, GIS land use data, and other available sources. In addition, RIDEM staff conducted extensive wet and dry weather field reconnaissance and, where possible, talked to area residents regarding potential sources of bacteria pollution. DEM believes that the sources of bacteria in several sections of Scrabbletown Brook are from natural background. Follow-up field surveys will be conducted to confirm that this is truly the case.

5.1 Station SCa (Scrabbletown Brook at Pleasant Valley Road)

Water Quality Impairments

The geometric mean of the dry weather data collected at SCa is 66 fc/100ml. The geometric mean of the wet weather data collected at SCa is 3032 fc/100ml. The resulting weighted average geometric mean at SCa is 1122 fc/100ml, significantly higher than the Class A standard of 20 fc/100ml.

Pollution Source Identification

No anthropogenic dry weather sources of fecal coliform bacteria were identified in the sub-watershed draining to SCa. However, nearby residents noted that ducks frequent the small impoundment located upstream of SCa and that numerous deer frequent the area. The elevated levels of fecal coliform at this station have been determined to be due to wildlife in the area, and, thus, an uncontrollable load. RIDEM considers these levels to be background. Follow-up field surveys will be conducted to confirm that this is truly the case.

Similarly, no anthropogenic wet weather sources of fecal coliform were identified upstream of station SCa. There are no roads impacting this area and RIDEM staff observed no stormwater runoff impacting this section of the stream. Elevated wet weather loads are attributed to the build up and flushing of fecal matter from the ducks and other wildlife in the area.

5.2 Station SCb (Scrabbletown Brook at Pleasant Valley Road)

Water Quality Impairments

The dry weather fecal coliform geometric mean for SCb was calculated to be 65 fc/100ml. The wet weather fecal coliform geometric mean is 2625 fc/100ml. The resulting weighted average geometric mean at SCb is 976 fc/100ml, well over the Class A standard of 20 fc/100ml.

Pollution Source Identification

Stations SCa and SCb were located approximately 100 yards apart just upstream and downstream, respectively, of an older home situated very close to the stream. The intent was to bracket the home and determine if a failing septic system or any direct discharges from the house were impacting the stream. However, there were no differences between dry weather fecal coliform levels at the two stations (Table 4.1). The geometric mean of the dry weather data collected at SCb was 65 fc/100ml. This data indicates that the house is not a dry weather source of fecal coliform bacteria. In addition, during wet weather, stormwater runoff discharges from the nearby highway were not observed by DEM staff to impact the stream at this location. As discussed for station SCa, RIDEM believes that the fecal coliform concentrations measured at SCb are attributable to ducks and any other natural background sources (i.e. wildlife).

5.3 Station SCc (Scrabbletown Brook at South Road)

Water Quality Impairments

There is no dry weather impairment at station SCc, since the geometric mean is 15 fc/100ml. At this time, we believe that the levels of fecal coliform bacteria measured upstream of SCc are natural. However, fecal coliform concentrations measured during storm events confirm a wet weather impairment. The wet weather geometric mean value at SCc was 1588 fc/100ml. The resulting weighted average geometric mean at SCc is 575 fc/100ml, well above the Class A standard of 20 fc/100ml.

Pollution Source Identification

There appears to be a wet weather impairment at SCc. The land use in this area is low density residential with houses located along South Road. There is only one house in the sub-watershed upstream of SCc. After a review of land use information and extensive field reconnaissance by RIDEM staff, the only identified wet weather anthropogenic source was the stormwater runoff from South Road that flows, untreated, into the stream at SCc. RIDEM staff observed runoff from South Road entering the stream during several storm events.

Elevated bacteria concentrations in untreated stormwater runoff from roads have been documented by Burnhart (1991) and Thiem et al (1999). Fecal matter, deposited on roads and streets by domestic animals, wildlife and waterfowl, accumulate during dry periods, and are subsequently washed into street gutters during rain events. Burnhart (1991) showed that during storm events, roads and streets were the primary contributors of fecal coliform bacteria. Burnhart measured fecal coliform concentrations of 56,000 fc/100ml off mid-traffic roads (> 500 cars/day) in rural areas. Thiem et al. (1999) measured bacteria concentrations during wet weather events from direct discharges of stormwater runoff from selected stormdrains off I-95 in Rhode Island. Thiem measured maximum fecal coliform bacteria concentrations of 240,000 fc/100ml from selected culverts.

Several researchers have sampled small source-areas within the urban landscape to determine where the major nonhuman sources of fecal coliform bacteria are found. Two recent studies conducted in Madison, Wisconsin (Bannerman et al. 1993) and Marquette, Michigan (Steuer et al. 1997) indicated that commercial parking lots, streets, residential lawns, and residential driveways were major source areas for bacteria (Table 5.1). In addition, both studies reported end-of-pipe bacteria concentrations that were at least an order of magnitude higher than any source area in the contributing watershed, suggesting that the stormdrain system was the greatest bacteria source in the watershed.

Table 5.1. Fecal coliform concentrations (geometric mean colonies per 100 ml) in runoff from urban-suburban land uses.

Geographic Location	Marquette, Michigan	Madison, Wisconsin
No. of Storms Sampled	**12**	**9**
Commercial Parking Lot	4,200	1,758
Medium Traffic Street	2,400	56,554
Low Traffic Street	280	92,061
Residential Driveway	1,900	34,294
Residential Lawns	4,700	42,093

Source: Bannerman et al. 1993 and Steuer et al. 1997.

5.4 Station SCd (Scrabbletown Brook at South Road)

Water Quality Impairments

Water quality data collected at station SCd indicate both dry and wet weather impairments. The dry weather fecal coliform geometric mean was calculated to be 71 fc/100ml. The wet weather fecal coliform geometric mean is 1321 fc/100ml. The resulting weighted average geometric mean at SCd is 516 fc/100ml, well over the standard of 20 fc/100ml.

Pollution Source identification

The residential land use in this part of the watershed is low density and is clustered around South Road. There are no houses and no impervious areas located in that portion of the watershed upstream of SCd. After extensive field reconnaissance and review of maps and other land use information, no dry weather sources of fecal coliform bacteria upstream of SCd were identified. The violation of the Class A standard during dry weather appears to be due to natural sources that are considered to be uncontrollable by conventional means.

The wet weather geometric mean concentration is significantly above the Class A standard. However, the only apparent anthropogenic wet weather source of bacteria is stormwater runoff from South Road that flows, untreated, into the stream at SCd. RIDEM staff have observed runoff from South Road from several different storm events.

As discussed above in section 5.3, roads and highways have been found to serve as a conduit for fecal coliform bacteria into waterways. After a thorough review of land use information and extensive field reconnaissance, no other wet weather sources of bacteria were identified.

5.5 Stations SCe and SCh (Tributary to Scrabbletown Brook at Scrabbletown Road and Route 2, respectively)

Station SCe is located approximately 100 yards upstream of SCh. Both stations lie on the southernmost tributary to the Scrabbletown mainstem. Dry and wet weather water quality impairments are shared by both stations and therefore will be discussed in the same section.

Water Quality Impairments
Water quality data collected at station SCe indicate both dry and wet weather impairments. The dry weather fecal coliform geometric mean was calculated to be 320 fc/100ml. The wet weather fecal coliform geometric mean is 8023 fc/100ml. The resulting weighted average geometric mean at SCe is 516 fc/100ml, well over the standard of 20 fc/100ml.

The dry weather fecal coliform geometric mean for SCh was calculated to be 526 fc/100ml. The wet weather fecal coliform geometric mean is 3149 fc/100ml. The resulting weighted average geometric mean at SCh is 1460 fc/100ml, well over the Class A standard of 20 fc/100ml.

Pollution Source identification
Land use upstream of SCe and SCh is low density residential. The primary source of dry weather fecal coliform bacteria impacting the stream at SCe and SCh is due to the resident population of waterfowl found in the two ponds located approximately 200 yards upstream of SCe. Nearby residents have reported that approximately 25-30 ducks frequent both ponds year-round. In-pond deposition of fecal material by the ducks likely impacts both dry and wet weather water quality in this tributary.

Theoretical values for coliform inputs from waterfowl on a 24-hr basis were calculated by Hussong et al (1979) and Koppelman and Tanenbaum (1982). Ducks were reported to produce 10^9 coliforms per day. If approximately 25 ducks use both ponds, then estimated fecal coliform counts deposited in the pond could reach 2.5×10^{10}. Even if a relatively small percentage of coliform bacteria were introduced into the stream, it would still be sufficient to violate the state's Class A standards for fecal coliform. No other dry weather sources of fecal coliform bacteria were identified in this sub-watershed.

The primary wet weather pollution sources in the watershed upstream of SCh and SCe are inputs from the resident waterfowl and stormwater runoff from Route 2 and Scrabbletown Road. Runoff from areas adjacent to streams and ponds transports fecal matter, deposited by resident waterfowl directly into receiving waters.

Untreated runoff from road surfaces flows into this tributary of Scrabbletown Brook at two locations. Runoff from Scrabbletown Road flows into the stream at SCe, and runoff from Route 4 flows into the stream at SCh. As discussed above in section 5.3, roads and highways have been found to serve as a conduit for fecal coliform bacteria into waterways. After a thorough review of land use information and extensive field reconnaissance, no other wet weather sources of bacteria were identified.

5.6 Station SC01 (Scrabbletown Brook at Stony Lane)
Water Quality Impairments
Dry weather fecal coliform geometric mean values increased from 65 fc/100ml at SCb, located just upstream off Stony Lane, to 917 fc/100ml approximately 50 yards downstream

at SC01. Wet weather fecal coliform geometric mean values increased from 2625 fc/100ml at SCb to 3720 fc/100ml approximately at SC01. The weighted average geometric mean at SC01 is 854 fc/100ml.

Pollution Source Identification
RIDEM has identified the major dry weather source of fecal coliform bacteria impacting water quality at SC01 as the large population of pigeons roosting under the Route 4 overpass. The overpass is approximately 50 yards upstream of SC01. Excessive amounts of fecal matter were observed both in, and directly adjacent to, the channel. Fecal matter is deposited directly into the stream and dry weather fecal coliform concentrations reflect these loadings. No other dry weather sources of fecal coliform bacteria other than those described above to impact dry weather bacteria concentrations at SCa and SCb, were identified upstream of SC01.

During wet weather events, increased flows wash pigeon droppings off the rocks and into the stream. In addition to the bacterial inputs from the pigeons, runoff from Stony Lane, Routes 4 and 2 enters Scrabbletown Brook upstream of SC01. Typical bacteria loads from roads and highways are discussed in section 5.3. These wet weather sources are sufficient to increase bacteria concentrations to levels that violate the state's Class A water quality standards for fecal coliform.

5.7 Summary of known and potential sources of fecal coliform bacteria

Pollution sources in Scrabbletown Brook include stormwater runoff from roads and other impervious areas, and loadings from pigeons, waterfowl, and wildlife. A summary of known and potential sources of fecal coliform bacteria is provided below in Table 5.2.

Table 5.2 Summary of known and potential sources of fecal coliform bacteria in Scrabbletown Brook.

Station	Location	Known sources	Potential sources
SCa	Pleasant Valley Rd.	None identified	Natural sources of bacteria (i.e. wildlife)
SCb	Pleasant Valley Rd.	None identified	Natural sources of bacteria (i.e. wildlife)
SCc	South Road	Stormwater runoff	Natural sources of bacteria (i.e. wildlife)
SCd	South Road	Stormwater runoff	Natural sources of bacteria (i.e. wildlife)
SCe	Scrabbletown Road	Stormwater runoff	Natural sources of bacteria (i.e. wildlife)
SCh	Route 2	Stormwater runoff	Natural sources of bacteria (i.e. wildlife)
SC01	Stony Lane	Stormwater runoff, fecal inputs from pigeons	Natural sources of bacteria (i.e. wildlife)

6.0 TOTAL MAXIMUM DAILY LOAD ALLOCATIONS

6.1 TMDL Overview

The TMDL represents the greatest amount of pollutant loading that a waterbody can receive without violating water quality standards. For most pollutants, TMDLs are expressed as mass loading (e.g. pounds per day). For bacteria, however, TMDLs can be expressed in terms of organism counts or concentrations. The TMDL establishes a level of pollutant loading not to be exceeded by the sum of all sources (point and nonpoint) plus a suitable Margin of Safety.

The TMDL is often expressed as:

TMDL= WLA + LA + MOS

Where:

> WLA = Waste Load Allocation which is the portion of the receiving water's loading capacity that is allocated to each existing and future point source of pollution.
>
> LA = Load Allocation which is the portion of the receiving water's loading capacity that isallocated to each existing and future nonpoint source of pollution.
>
> MOS = Margin of Safety which accounts for the uncertainty about the relationship between pollutant loads and the quality of the receiving water.

The Scrabbletown Brook TMDL is directly based on the state's fecal coliform standard and is expressed in terms of the geometric mean of sample concentrations and percent exceedence over a certain concentration. Therefore, the above equation does not directly apply. In such cases, the TMDL is simply set equal to the standard and may be expressed as follows:

[TMDL] = [fecal coliform standard] = [WLA] + [LA] + [MOS]

6.2 Targeted Water Quality Goal

One of the major components of a TMDL is the establishment of instream water quality targets used to evaluate the attainment of acceptable water quality. These water quality goals are usually based on either narrative or numeric criteria required by state water quality standards.

In Scrabbletown Brook, the Class A fecal coliform standard was used as the applicable endpoint. This standard states that fecal coliform concentrations in Class A waters shall not exceed a geometric mean value of 20 fc/100ml and not more than 10% of the samples shall exceed a value of 200 fc/100ml.

6.3 Point Sources

The only point sources in the Scrabbletown Brook watershed are municipal stormwater sewer pipes. For purposes of this TMDL, these pipes were included in the Load Allocation due to a lack of detailed site-specific information. Therefore, the wasteload allocation for all existing and future point sources is zero.

6.4 Nonpoint Sources

The load allocations for nonpoint sources were determined for each water quality station (i.e. stream segment or tributary) by comparing current conditions (i.e. the weighted average geometric mean) to the water quality standard and then calculating the percent reduction needed to meet the standard. Since there are two parts to the fecal coliform standard, two calculations must be made at each station to determine the reductions necessary to meet each part of the fecal coliform standard. The more conservative (i.e. the greater) of those two values will be the one which the TMDL will be based. The values for each are presented below in Tables 6.1 and 6.2.

Table 6.1 Weighted Average Geometric Means and Percent Reductions Needed to Reach 20 fc/100ml.

Station	Weighted Average Geomean (fc/100ml)	% Reduction Needed to Reach Geomean of 20 fc/100ml
SCa	1122	98
SCb	976	98
SCc	575	97
SCd	516	96
SCe	3062	99
SCh	1460	99
SC01	854	98

The 90th percentile values of the combined dataset of wet and dry weather samples for each water quality station in the Scrabbletown Brook watershed are presented below in Table 6. 2. The accompanying reductions necessary to meet this part of the standard were derived by comparing the 90th percentile values to the second part of the criteria for Class A waterbodies (i.e. 200 fc/100ml).

Table 6.2. 90th Percentile Values and Percent Reductions Needed to Reach 200 fc/100ml

Station	90th percentile of Combined Dataset (fc/100ml)	% Reduction Needed to Reach 200 fc/100ml
SCa	34400	99
SCb	42200	99
SCc	13700	96
SCd	7400	93
SCe	26800	99
SCh	21510	98
SC01	7200	97

<u>Required Load Reductions</u>

The more conservative (i.e. the greater) of those two reduction values were used to base the TMDL upon. The load reductions determined for each stream segment are presented below in Table 6.3. These values represent the TMDL pollutant load reduction goals for Scrabbletown Brook.

Table 6.3 Load Reductions Required for Scrabbletown Brook.

Station	% Reduction Needed to Meet Standards
SCa	99
SCb	99
SCc	97
SCd	96
SCe	99
SCh	99
SC01	98

6.5 Margin of Safety

For this analysis, an implicit MOS is provided. In other words, a separate value is not added to the TMDL "equation" to account for a MOS. Instead, the MOS is incorporated "implicitly" into estimates of current pollutant loadings, the targeted water quality goal (i.e., the instream numeric endpoint), and the load allocation. This is done by making conservative assumptions throughout the TMDL development process. Some of the key conservative assumptions are described below.

- Conservative estimates of both the amount of rainfall needed to produce runoff and recovery time were used in the weighted average geomean calculations.

- For some of the wet weather events included in the weighted average geomean calculation, enough time may not have elapsed since the preceding storm event for pollutant levels to return to the elevated levels represented by the wet weather data. Similarly, other wet weather events may not be large enough, or long enough in duration, to generate the kind of loads represented by the wet weather data.

- The data used to calculate the 90th percentile values was conservatively biased, since a disproportionate percentage of the data for each station were collected during wet weather conditions.

- RIDEM 1999 Dry weather data was collected during drought conditions.

6.6 Seasonal Variation

The Scrabbletown Brook TMDL is protective of all seasons, as all fecal coliform data were collected during the summer months when instream fecal coliform concentrations are typically the highest.

6.7 Natural Background

Based on extensive field observations and review of available land use information, it is concluded that uncontrollable background concentrations of bacteria resulting from wildlife and other natural sources make up a significant portion of the total fecal coliform load in Scrabbletown Brook. However, due to the limited amount of data regarding fecal coliform contributions from wildlife, natural background loads were not separated from the overall water quality calculations. Without detailed site-specific information on fecal coliform contributions from wildlife, it is difficult to meaningfully separate natural background from the total nonpoint source load.

7.0 IMPLEMENTATION

This TMDL addresses the different segments of the Scrabbletown Brook watershed as defined by the water quality monitoring locations established as part of RIDEM's supplementary monitoring program. Water quality was assessed, and load allocations set, for each of the segments. Similarly, RIDEM has developed recommendations for BMP implementation for each of those sub-watersheds.

This TMDL relies upon phased implementation to reach its water quality goals. As BMPs are installed, the corresponding response in fecal coliform bacteria concentrations will be measured. If standards are not met after the BMPs recommended herein are implemented, then additional measures will be set forth. It should be noted that, with regards to the effectiveness of stormwater practices, BMPs must be extremely efficient if they are to produce storm outflows that meet the 20 fc/100ml standard for fecal coliform bacteria from a site. To date, performance monitoring studies research has indicated that no structural stormwater BMP can reliably achieve a 99 percent removal rate of any urban pollutant on a consistent basis. Therefore, structural BMPs must be used in conjunction with non-structural BMPs such as public education and street sweeping. Significant reductions can be expected if the following recommendations are implemented.

The BMPs that RIDEM currently recommends are provided below by station. Please note that since station SC01 is the most downstream station, it is listed last.

7.1 Stations SCa and SCb (Scrabbletown Brook upstream of Pleasant Valley Road)

Required Reduction
A reduction of 99% is required in the fecal coliform concentrations at stations SCa and SCb.

Proposed BMPs
RIDEM was unable to identify any controllable anthropogenic sources of fecal coliform bacteria impacting water quality at stations SCa or SCb. At this point, RIDEM does not believe it to be cost-effective to implement a structural BMP at this location. However, public outreach efforts in this part of the watershed should target residential homeowners and focus on the importance of ISDS maintenance and proper disposal of pet waste.

7.2 Station SCc (Scrabbletown Brook at South Road)

Required Reduction
A required reduction of 97% is required in the fecal coliform concentrations at station SCc.

Proposed BMPs
Since there is no dry weather impairment at SCc, any BMPs targeted for this portion of the Scrabbletown Brook watershed would need to address wet weather loadings. However, the only known wet weather source of bacteria is runoff from South Road, which is a low-traffic residential street in a heavily wooded area.

RIDEM recommends that the Town of East Greenwich delineate the catchment area draining to Scrabbletown Brook at South Road, especially that portion of the road that drains to the stream. Further, the Town should seek to attenuate stormwater runoff from

South Road to the maximum extent practicable, through the use of structural BMPs that promote the detention and infiltration of runoff.

Public outreach efforts in this part of the watershed should target residential homeowners and focus on the importance of ISDS maintenance and proper disposal of pet waste.

7.3 Station SCd (Scrabbletown Brook at South Road)

Required Reduction
A required reduction of 96% is required in the fecal coliform load contributing to concentrations at station SCd.

Proposed BMPs
Since the dry weather fecal coliform concentrations found at SCd are likely the result of natural background loads and the majority of violations occur during wet weather, any BMPs targeted for this portion of the Scrabbletown Brook watershed should address wet weather loadings. The only known wet weather source is runoff from South Road, a low-traffic residential street in a heavily wooded area.

RIDEM recommends that the Town of East Greenwich delineate the catchment area draining to Scrabbletown Brook at South Road, especially that portion of the road that drains to the stream. Further, the Town should seek to attenuate stormwater runoff from South Road to the maximum extent practicable, through the use of structural BMPs that promote the detention and infiltration of runoff.

Public outreach efforts in this part of the watershed should target residential homeowners and focus on the importance of ISDS maintenance and proper disposal of pet waste.

7.4 Stations SCe and SCh (Tributary to Scrabbletown Brook at Scrabbletown Road and Route 2, respectively)

Required Reduction
A required reduction of 99% is required in the fecal coliform concentrations at both SCe and SCh.

Proposed BMPs
It is evident from RIDEM investigations that waterfowl concentrations in the ponds negatively impact the water quality in this tributary to Scrabbletown Brook. Public outreach efforts should be targeted at reducing the resident population of waterfowl by discouraging the practice of feeding waterfowl and promoting the use of BMPs designed to make these areas less desirable to waterfowl. This would have the effect of decreasing both dry and wet weather bacteria contributions from the ponds to the stream.

Several habitat modification methods have been shown to be effective in ridding ponds of waterfowl. RIDEM proposes the following BMPs to be considered by the Town and private property owners.

1. **G-Grid-** G-grid discourages ducks from landing near a waterbody. G-Grid consists of a polypropylene netting placed to a height of 2 feet immediately on the edge of a pond. . The pond needs to be completely surrounded, and the netting needs to be placed to the waters edge.

2. **Turf Shield-** Turf Shield is a formulation of two U.S. FDA Generally Recognized as Safe (GRAS) compounds that have been approved by the U.S. EPA as a biological chemical. The active ingredient is methyl anthranilate. Turf Shield has been shown to significantly reduce geese and ducks from feeding on turf for prolonged periods of time when applied according to label directions. Reported removal efficiency of approximately 95% of birds.

3. **Habitat Alterations-** Habitat alterations include reducing grassy areas by planting large borders of ground cover, planting trees and shrubs around the waterbody, increase the rough wherever possible.

4. **Installation of Mechanical Barriers-** Fences, hedgerows, and other physical barriers are effective tools to restrict movement. A low fence or other barrier around ponds, which prevents access, may be sufficient to restrict movement.

As discussed above, there are several methods to reduce the Canada goose population. RIDEM recommends that affected landowners and the Town of East Greenwich work with the RIDEM Division of Fish and Wildlife to implement comprehensive management programs that include a variety of techniques. Control measures will be most effective if coordinated among nearby sites in a community.

In addition to resident waterfowl, stormwater runoff from Scrabbletown Road and Routes 2 and 4 was identified as a wet weather source of pollution. RIDEM recommends that RIDOT implement one or more structural BMPs to reduce fecal coliform loads from Routes 2 and 4 to the maximum extent practicable.

RIDEM recommends that the Town of East Greenwich delineate the catchment area draining to Scrabbletown Brook at Scrabbletown Road, especially that portion of the road that drains to the stream. Further, the Town should seek to attenuate stormwater runoff from Scrabbletown Road to the maximum extent practicable, through the use of structural BMPs that promote the detention and infiltration of runoff.

Public outreach efforts in this part of the watershed should target residential homeowners and focus on the importance of discouraging waterfowl (e.g., do not feed the ducks), ISDS maintenance and proper disposal of pet waste.

Estimated Pollution Reduction for Recommended BMPs

Not much information is available to estimate the efficiency of the nuisance waterfowl BMPs. Turf Shield reports a removal efficiency of approximately 95%. If approximately 25 ducks use both ponds, then estimated fecal coliform counts would reach $2.5 X 10^{10}$. Even if a relatively small percentage of coliform bacteria were introduced during wet weather into the ponds and stream, it would be enough to violate the state's Class A standards for fecal coliform bacteria. We believe that a significant reduction in the duck population in and around the two ponds would result in a corresponding decrease in the fecal coliform loadings. Furthermore, we believe that application of one or more of the BMPs described above could result in attainment of this goal.

There are several options to investigate prior to determining the appropriate BMP to treat the runoff from Scrabbletown Road and Routes 2 and 4. RIDEM has reviewed current stormwater BMP technologies, and many appear to be effective at removing total suspended solids (TSS). Although fecal coliform abundance has been correlated with high levels of TSS, bacteria may still exist in runoff low in TSS.

A review of several conventional BMPs is provided in Table 7.1.

Table 7.1 Effectiveness of Conventional Stormwater BMPs in Reducing Bacteria Concentrations in Runoff.

BMP	Reduction in fecal Coliform	Reduction in fecal Streptococci	Reduction in E-Coli
Ponds	65% (n=10)	73% (n=4)	51% (n=2)
Sand filters	51% (n=9)	58% (n=7)	No data
Vegetated Swales	-58% (n=5)	No data	No data

Source: Watershed Protection Techniques. Vol 3. No. 1, 1999.

Similar information for manufactured BMPs and agricultural BMPs designed by NRCS (Natural Resources Conservation Service) is provided below in Table 7.2.

Table 7.2 Effectiveness of Manufactured and Agricultural Stormwater BMPs in Reducing Bacteria Concentrations in Runoff[a].

System	Manufacturer/ Designer	Description	Applications	Performance
Stormfilter	Stormwater Management	Passive, flow-through filtration system utilizing rechargeable filter cartridges. Media removes TSS by mechanical filtration, ion exchange, and adsorption.	Parking lots for urban environments. Residential to arterial roadways.	High level of performance for the removal of TSS[b] and approximately 50% removal of fecal coliform
NRCS Nutrient & Sediment Control System	Robert Wengrzynek	Living biological filter or treatment system. Combines marsh/pond components of constructed wetlands with other sediment management elements to use physical, chemical, and biological processes for the removal of sediment and nutrients.	Livestock and pasture runoff as well as urban stormwater runoff	Removes 90-100% of TSS[b].
Vortechs	Vortechnics Inc.	Stormwater introduced into system in a vortex-like flow path. Swirling action directs sediment into the center of the chamber.	Parking lots, roadways	Net TSS removal[b] efficiency rate over the course of storm events of over 80%.
Stormtreat	Stormtreat Systems Inc.	Captures and treats first-flush. System consists of 6 sedimentation chambers and a constructed wetland contained in a 9.5 foot diameter tank. The number of tanks depends on the level of treatment required, in-line detention capacity, and use of the optional infiltration feature.	Parking lots, residential subdivisions, roadways	315 analysis on 33 samples over 8 independent storm events during both winter and summer. 97% removal of fecal coliform and 99% removal of TSS.

a. *Source: Innovative Stormwater Treatment-Products and Services Guide, Stormwater Technologies Trade Show, May 25, 1999. Providence, RI.*
b. *Fecal coliform abundance has been correlated with high levels of TSS.*

7.5 Station SC01 (Scrabbletown Brook at Stony Lane)

Required Reduction
A required reduction of 98% is required in the fecal coliform concentrations at station SC01.

Proposed BMPs
It is evident from RIDEM investigations that the pigeons roosting under the Route 4 overpass negatively impact the water quality in this section of Scrabbletown Brook. Therefore, any efforts to reduce or eliminate the numbers of roosting pigeons would appear to be justified. This would have the effect of decreasing both dry and wet weather bacteria contributions to the stream. Therefore, RIDEM recommends that RIDOT construct a pigeon deterrent BMP for the overpass.

The second source of fecal coliform bacteria identified at SC01 is untreated stormwater runoff from Stony Lane and Route 2. RIDEM recommends that RIDOT implement one or more structural BMPs to reduce fecal coliform loads from Route 2 to the maximum extent practicable.

RIDEM recommends that the Town of East Greenwich delineate the catchment area draining to Scrabbletown Brook at Stony Lane, especially that portion of the road that drains to the stream. Further, the Town should seek to attenuate stormwater runoff from Stony Lane to the maximum extent practicable, through the use of structural BMPs that promote the detention and infiltration of runoff.

Public outreach efforts in this part of the watershed should target residential homeowners and focus on the importance of ISDS maintenance and proper disposal of pet waste.

A brief review of stormwater BMPs used to reduce bacteria concentrations in stormwater runoff was provided in Section 7.5 and summarized in Tables 7.1 and 7.2.

Estimated Pollution Reduction for Recommended BMPs
The proposed pigeon deterrent BMP should remove all roosting pigeons, effectively reducing the bacteria source by 100%.

A brief review of stormwater BMPs used to reduce bacteria concentrations in runoff was provided in Section 7.5 and summarized in Tables 7.1 and 7.2.

7.7 Watershed-Wide Stormwater Management Issues

Urban stormwater runoff from roads and residential/commercial land uses impacts water quality in several portions of the Scrabbletown Brook watershed. Therefore, it is important to address these issues on a watershed basis. RIDEM believes that the best way to accomplish this is by working with RIDOT and the Towns of East Greenwich and North Kingstown to highlight these concerns and support their stormwater management planning, including the construction of BMPs where needed.

Stormwater Phase II Permit Program
Over the next several years, RIDOT and the Towns of East Greenwich and North Kingstown will be required to meet Phase II Stormwater Program requirements. Federal program regulations recently adopted by EPA require that permitted municipalities develop

stormwater management programs, control runoff from small construction sites, investigate and eliminate illicit discharges, utilize pollution prevention/good housekeeping practices, and educate and involve the public in stormwater related issues. These aspects of the Phase II program should have a positive impact on water quality in the Scrabbletown Brook watershed. However, it is very difficult to assign a load reduction to these programs.

Since Scrabbletown Brook is an impaired waterbody, RIDEM anticipates that special emphasis will be placed on addressing stormwater impacts to this stream from municipal separate storm sewer systems (MS4s). This TMDL identifies those highway crossings and storm sewer outfalls associated with elevated in-stream bacteria levels. Where appropriate, we recommend investigation and/or implementation of stormwater BMPs to reduce pollutant loads through detention and infiltration. Opportunities for stormwater attenuation in the upland portions of the catchment areas should be evaluated.

Actions to achieve the required reductions can be taken voluntarily by the Towns and RIDOT prior to the issuance of Phase II Stormwater Permits, or will be required by the Phase II permits.

Road Runoff BMPs

Table 7.3 highlights possible locations in the watershed where stormwater BMPs may be the most effectively applied to address road runoff.

Table 7.3. Sites of stormwater discharge from roads and highways in the Scrabbletown Brook watershed.

Location	Responsible Entity	Station-River Segment Impacted	Wet Weather Geometric Mean (fc/100ml)
Scrabbletown Brook intersection with South Road	Town of East Greenwich	Downstream of SCc	1588
Scrabbletown Brook intersection with South Road	Town of East Greenwich	Downstream of SCd	1321
Scrabbletown Brook intersection with Stony Lane.	Town of North Kingstown	Downstream of SC01	1765
Scrabbletown Brook intersection with Routes 2 and 4.	RIDOT	Downstream of SC01	1765
Scrabbletown Brook tributary intersection with Scrabbletown Road	Town of East Greenwich	Downstream of SCe	8023
Scrabbletown Brook tributary intersection with Routes 2 and 4	RIDOT	Downstream of SCh	3149

Other BMPs proposed for the Scrabbletown Brook watershed include the following:

Pigeon deterrent BMP
Implementation of the pigeon deterrent BMP should result in a complete removal of roosting pigeons from the Route 4 overpass, effectively eliminating this source of fecal coliform bacteria to Scrabbletown Brook

Public Outreach
RIDEM recommends that the Towns develop and implement public outreach programs aimed at informing and educating citizens about the sources of pathogens in streams and ways to eliminate or reduce those sources.

The public outreach program should be geared towards specific water quality issues identified as impacting each segment of the stream. Specifically, outreach efforts should include information on the importance of ISDS maintenance, proper disposal of pet waste, and discouraging the presence of resident waterfowl in impoundments and controlling their population.

The Towns will have to make a concerted effort for the public outreach and education program to be effective at reducing nonpoint sources of pollution in the watershed. Even though it is difficult to assign reductions to these types of programs, RIDEM believes that once the public is aware of the potential health threats from elevated pathogen levels in surface waters, they will be willing to take corrective actions that will result in improved water quality.

Microbial Source Tracking
RIDEM recommends that microbial source tracking (MST) techniques be utilized to collect more detailed information on the sources of pathogenic contamination in the watershed. This approach is an innovative technique for identifying sources of contaminants through DNA fingerprinting. The MST technique should provide information about whether or not sources of bacteria are of human, or non-human, origin.

Determining the origin of pathogens in the watershed will aid in pollution source identification and mitigation. RIDEM recommends that MST techniques be used in specific areas of the watershed where there remains uncertainty regarding the pollution source. RIDEM is seeking funds to support this monitoring effort and will look to partner with outside researchers to accomplish these goals.

8.0 MONITORING PLAN

EPA's 1991 document, *Guidance for Water Quality-Based Decisions: The TMDL Process* (EPA 440/4-91-001) recommends a monitoring plan when a TMDL is developed under the phased approach. The phased approach is appropriate when a TMDL is based on limited information and when there is considerable uncertainty associated with the analysis. EPA's guidance provides that a TMDL developed under the phased approach should include a monitoring plan that describes the additional data necessary to determine if the load reductions required by the TMDL will lead to attainment of water quality standards.

To monitor the effect that implementation activities throughout the watershed have on Scrabbletown Brook's water quality, RIDEM will conduct baseline monitoring at SC01 and SCh. Since almost all of the pollution sources in the watershed impact water quality at these downstream stations, they are conservative locations from which to gage the recovery of the stream. Grab samples will be collected bi-monthly (every two months) during warm weather months (from May to September). Once significant improvements in water quality are observed and the dry weather concentrations meet standards, then the decision can be made whether to conduct more intensive monitoring to determine if the waterbody is no longer impaired. If the trend is negative or if there is no improvement in water quality over time, then a follow-up assessment will be made and additional BMPs recommended.

RIDEM believes that, in several areas of the watershed, bacteria sources are naturally occurring and thus considered background. DEM plans to conduct follow-up field surveys to confirm that this is truly the case. Additional field investigations will include walking up the streams and collecting samples, as well as soliciting additional information from local residents as to possible pollution sources to the stream.

9.0 PUBLIC PARTICIPATION

The public participation associated with this TMDL has two components: open meetings and opportunity for public review and comment. An initial meeting was held prior to TMDL development on December 13, 1999. All interested public, private, and government entities were invited to attend. The meeting was held to disseminate information regarding the TMDL issues in the watershed as well as to solicit input regarding pollution sources and/or other concerns.

A second public meeting was held on September 27, 2000 to initiate a 30-day public comment period. RIDEM staff presented the draft TMDL and solicited input, however, no comments were received by the end of the comment period.

10.0 REFERENCES

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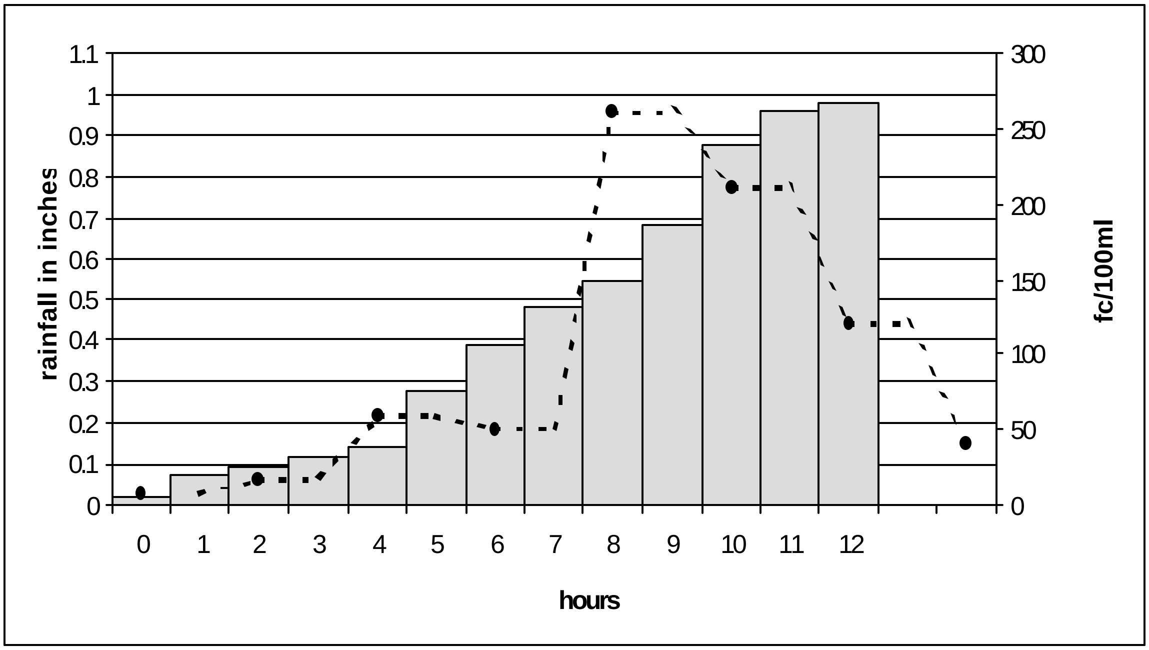
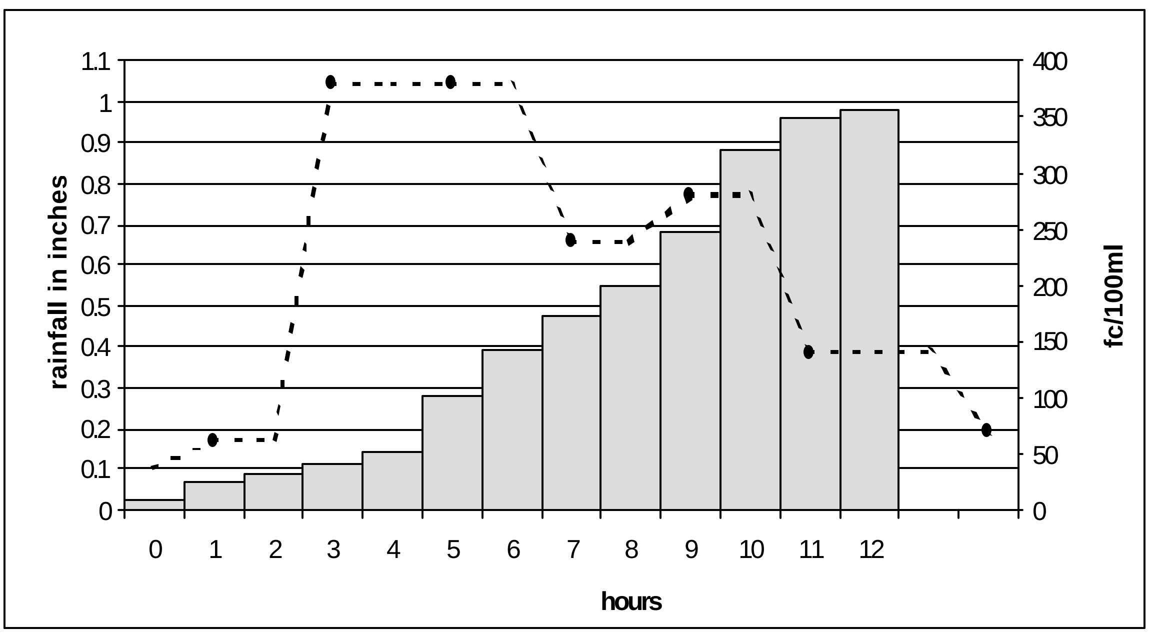
Appendix A. URI wet weather data plots of time, cumulative rainfall amounts, and fecal coliform concentrations for selected water quality stations.

(URI 1996) 1st Wet Weather Event (0.98 inches/ 12hrs)

Station FB01

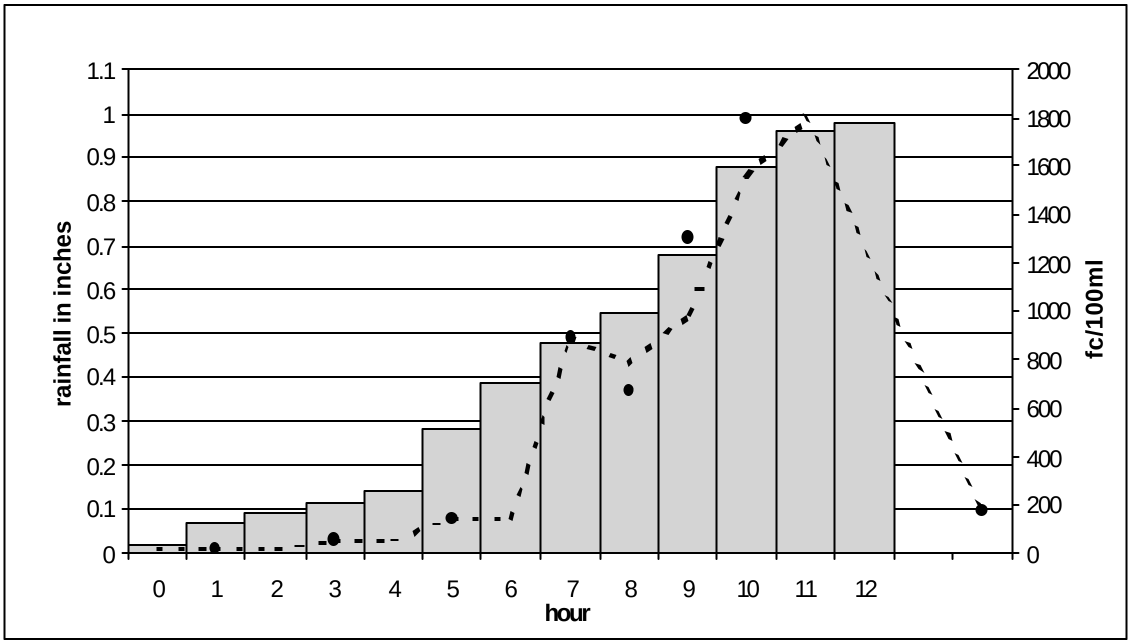


Station SC01

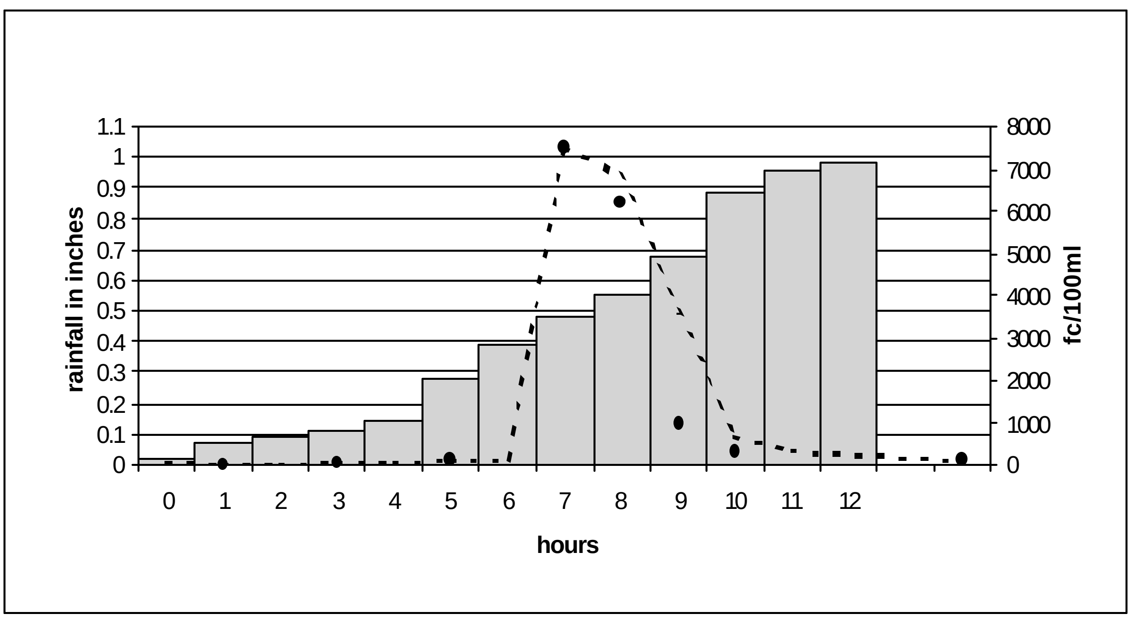


(URI 1996) 1st Wet Weather Event (0.98 inches/ 12hrs)

Station SB01

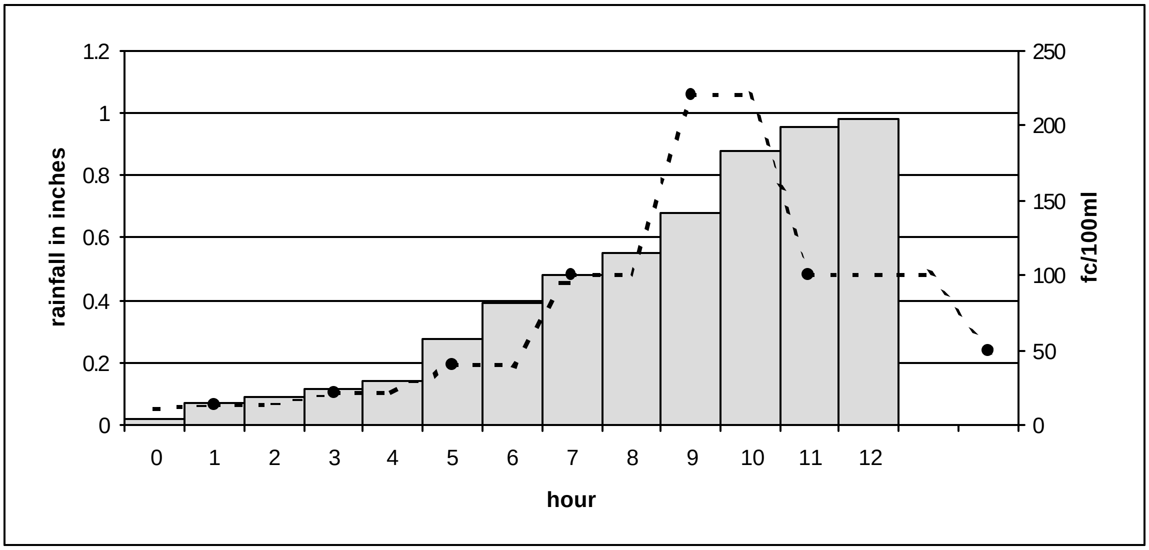


Station HR04



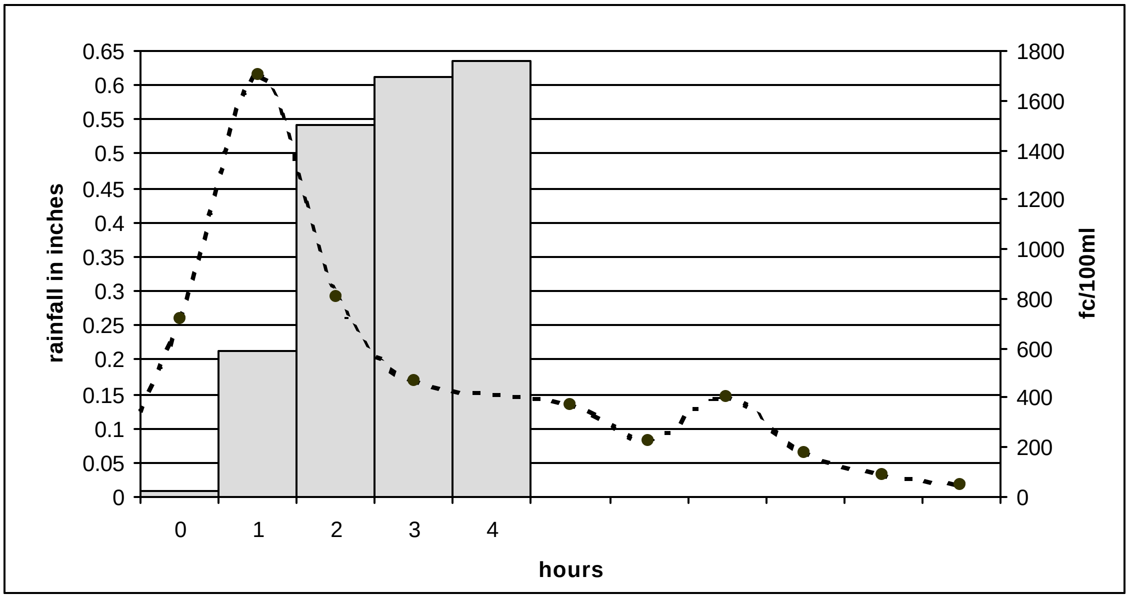
(URI 1996) 1st Wet Weather Event (0.98 inches/ 12hrs)

Station HR03

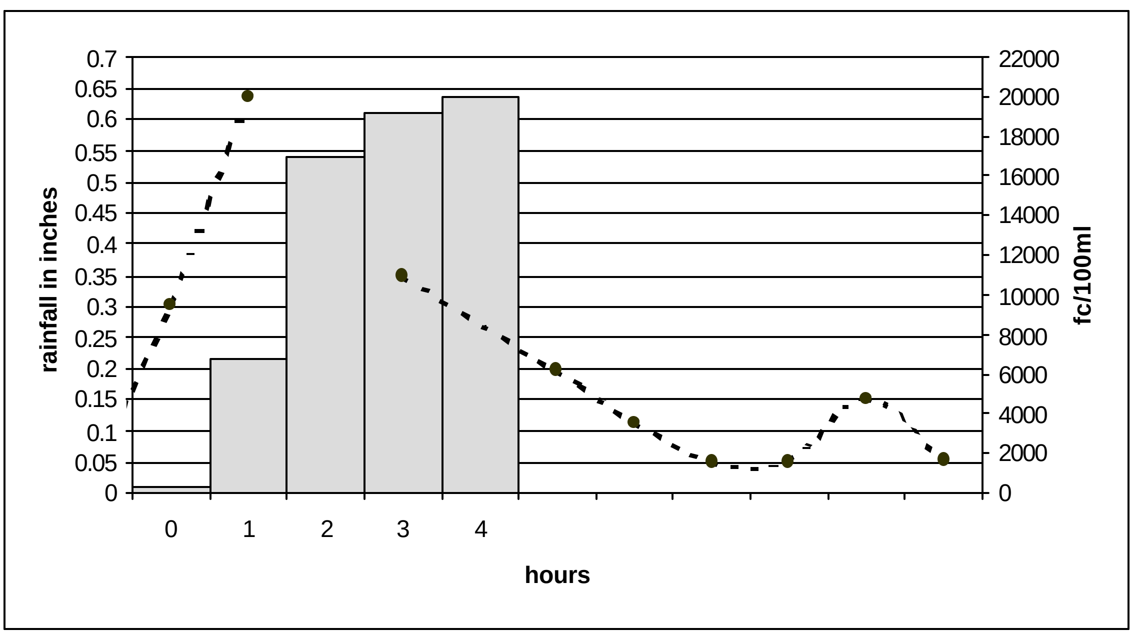


(URI 1996) 2nd Wet Weather Event (0.63 inches/ 4hrs)

Station FB01

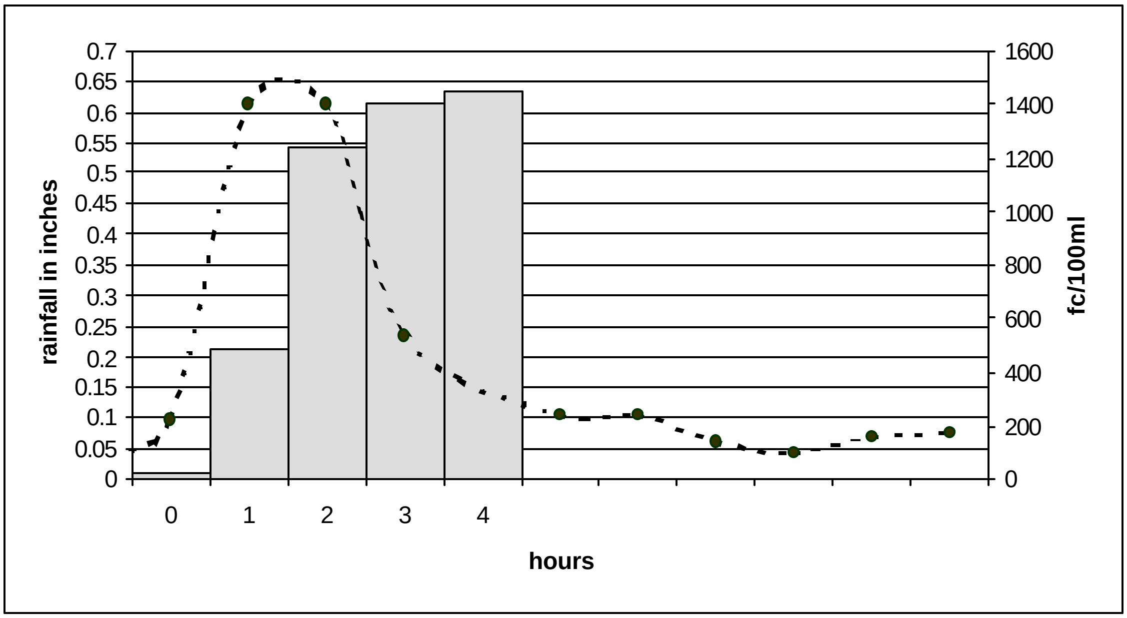


Station SC01

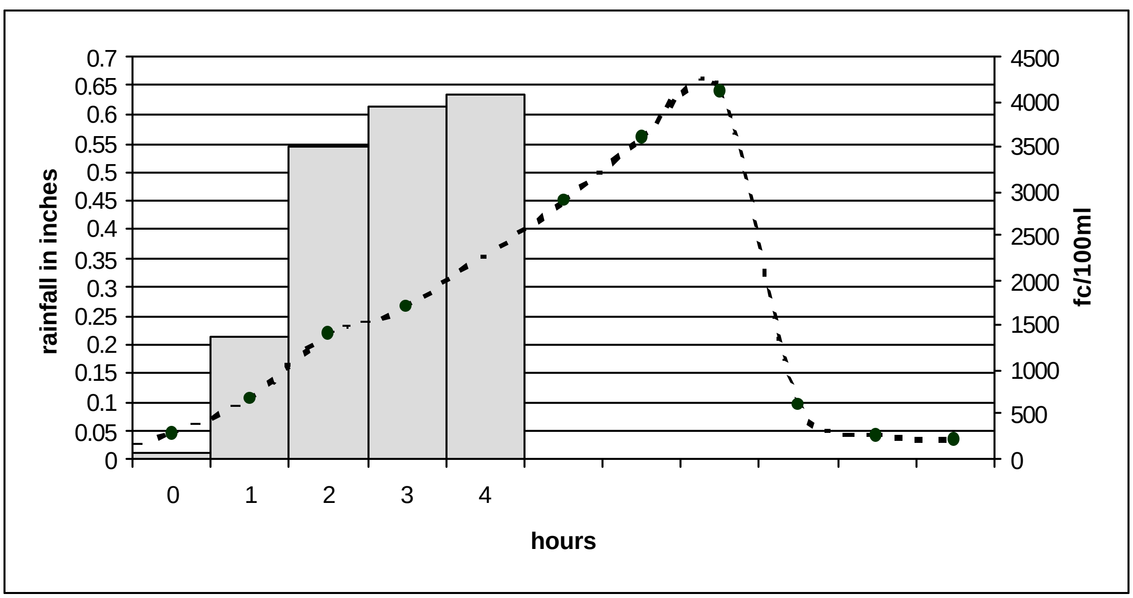


(URI 1996) 2nd Wet Weather Event (0.63 inches/ 4hrs)

Station HR03

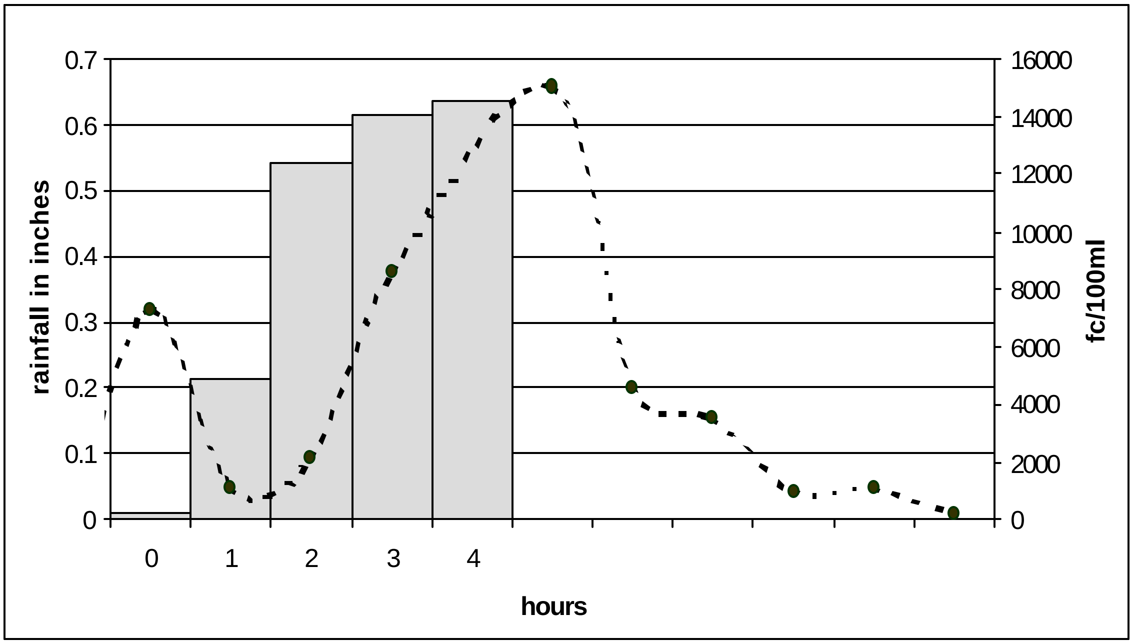


Station SB01



(URI 1996) 2nd Wet Weather Event (0.63 inches/ 4hrs)

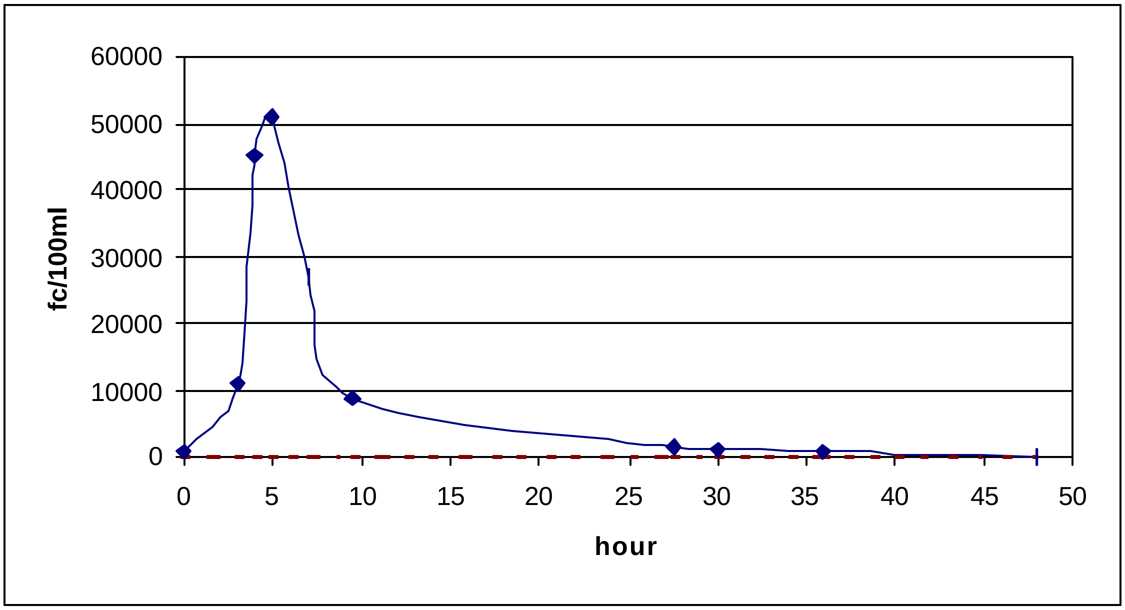
Station HR04



Appendix B. RIDEM wet weather plots of recovery time for selected stations.

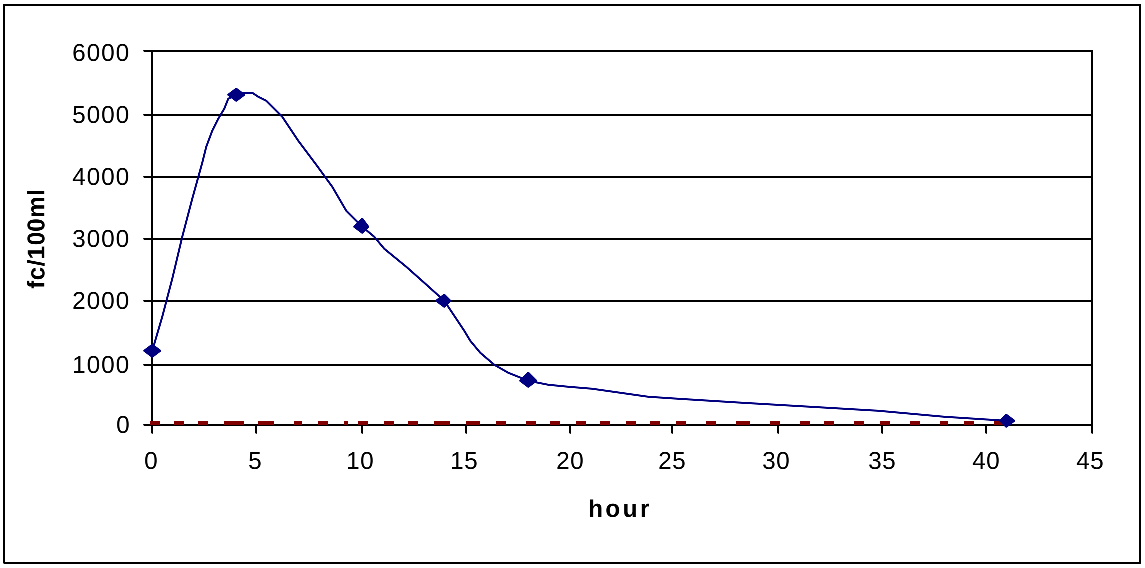
Wet Weather Event #1 (0.56 inches/ 1.5 hrs) dashed line is fecal coliform criteria of 20 fc/100ml for Class A waters.

Station SC01



Wet Weather Event #2 (1.74 inches/ 10 hrs) dashed line is fecal coliform criteria of 20 fc/100ml for Class A waters.

Station SCh



Station SC01