Fecal Coliform TMDL Development

For

Fry Brook, Rhode Island

FINAL REPORT

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1. Description of Waterbody, Priority Ranking, Pollutant of Concern, and Pollutant Sources

Description of Waterbody

Fry Brook is a third-order stream located entirely within the town of East Greenwich, Rhode Island. The watershed is approximately 1,986 acres in size and drains several wetland areas. Several smaller tributaries join the stream as it flows southeast, approximately 6.2 miles, towards its confluence with the Hunt River. Based on the most recent land use information (Wright et al. 1999), land use in watershed is 23% residential, 5% commercial-industrial, 6% agriculture, 36% forest, 18% wetland, and 12% other (transitional, barren, transportation, etc.)

Fry Brook is located in the Hunt River watershed and has been determined to impact water quality in the Hunt River. As a result, the Fry Brook TMDL is an integral part of the overall Hunt River TMDL for fecal coliform.

Priority Ranking

Fry Brook is listed as a Group 1 waterbody (highest priority) on the State of Rhode Island's 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 Fry Brook as being impaired by pathogens for its entire length of approximately 6.2 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 Fry Brook. For the purposes of this TMDL, the storm sewer discharges were considered as nonpoint sources due to a lack of site specific data.

RIDEM has identified 3 major sources of fecal coliform bacteria in the Fry Brook watershed. These include: 1) stormwater runoff from Routes 2, 4 and residential/commercial areas, 2) a dairy farm, and 3) resident waterfowl (geese) and other wildlife in the watershed. All sources are summarized in Table 1. The largest dry weather source of bacteria comes from the dairy farm. The farm includes confined animal operations in which large quantities of manure are produced. Manure found in barnyards, pastures, feedlots, and uncontrolled manure storage areas is a significant source of bacteria to Fry Brook. In addition, cows are allowed access to all portions of Fry Brook on the dairy farm. Elevated levels of bacteria during dry weather are a direct result of this.

The two largest wet weather sources of bacteria to the watershed are stormwater runoff from roads and commercial areas, and the dairy farm. A detailed description of individual sources is presented by stream segment in the Water Quality Impairment Section of this report.

A significant agricultural nonpoint source in the Fry Brook watershed is a dairy farm. Other sources of bacteria were domestic pets and wildlife, especially waterfowl. There is a large resident population of Canada geese in the Fry Brook watershed.

As indicated in Table 1, both dry and wet weather nonpoint sources were identified. Dry weather sources include contributions from waterfowl, agricultural practices, and wildlife. Wet weather sources include contributions from waterfowl, agricultural practices, and stormwater runoff from roadways.

Table 1. Sources of fecal coliform contamination in the Fry Brook watershed.

Station	Location	Dry Weather Sources	Wet Weather Sources
FRY01	Downstream of golf course	Resident population of geese at golf course.	Resident population of geese at golf course.
FRY02	Upstream of Dairy Farm	Background levels (i.e. wildlife)	Runoff from Route 2 near Fry Corner
FRY03	Route 4 near confluence with Hunt River	Dairy Farm- Barnyard operations	Dairy Farm- Barnyard operations, upstream sources-Route 2 runoff
FRY04	North Stream tributary- Route 2	Dairy Farm- Grazing pasture	Dairy Farm- Grazing pasture, Route 2 runoff
FRY05	South Stream tributary-Route 2	Dairy Farm- Grazing pasture	Dairy Farm- Grazing pasture, Route 2 runoff

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). Designated and existing uses for Fry Brook include fish and wildlife habitat and primary and secondary recreational activities. In addition, the waters of Fry 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 Fry 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, especially geese, and other sources are thought to make up a significant portion of the total fecal coliform load in the Fry 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

Fry Brook is designated as a Class B water in the state water quality regulations. Designated uses for Fry Brook are fish and wildlife habitat and primary and secondary recreational activities. Class B 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 B waters, is as follows: "*not to exceed a geometric mean value of 200 MPN/100ml and not more than 20% of the samples shall exceed a value of 500 MPN/100ml.*"

In Fry Brook, the Class B fecal coliform standard was used as the applicable endpoint. This standard states that fecal coliform concentrations in Class B waters shall not exceed a geometric mean value of 200 fc/100ml and not more than 20% of the samples shall exceed a value of 500 fc/100ml.

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 dependant upon flow conditions.

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

Based on the Class B Standard, the loading capacity is set at a geometric mean not to exceed 200 fc/100ml and less than 20% of the samples exceeding a concentration of 500 fc/100ml.

Linking Water Quality and Pollutant Sources
Knowledge of potential pollutant sources in the Fry 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. 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.

Strengths/Weaknesses in the Overall Analytical Process
The Fry Brook TMDL was developed using existing water quality and hydrologic data, collected through extensive wet and dry weather field surveys and land use investigations, and utilizing past meteorological records. Observations made during numerous site visits to the East Greenwich Golf Course and the dairy farm helped to establish the link between these fecal coliform sources and the high instream concentrations identified by RIDEM field monitoring.

Strengths:
- Approach utilized first-hand knowledge of agricultural practices and other land uses 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 and were 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 conducted throughout the state 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 Fry Brook as well.

In addition, past monitoring has shown that fecal coliform levels increase 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

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 pipe-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) by comparing 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 Fry 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 following sections of this TMDL report.

Comparison of the Sample Dataset's 80th Percentile Value to the Percent Exceedence Standard
In order to address the second portion of fecal coliform standard, which states that "*not more than 20% of the samples shall exceed a value of 500 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 80th percentile value calculated. This value was then compared to 500 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 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 2.

Table 2. Weighted Average, 80th Percentile Values, and Load Reductions Required for Fry Brook.

Station	Weighted Average (fc/100ml)	80th percentile of Combined Dataset (fc/100ml)	Reduction Needed to Meet Standards
FRY01	251	1524	67%
FRY02	779	2420	79%
FRY03	6408	17000	97% [a]
FRY04	2784	12800	96%
FRY05	799	2100	76%

a. Reductions achieved at FRY-01, 02, 04, and 05 should contribute to the needed reductions at FRY03.

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 80th 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 Fry 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 Fry 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 Fry 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 3 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 3. BMP recommendations for Fry Brook TMDL.

Recommended BMP	Location	Responsible Entity	Station or River Segment Impacted
Agricultural BMPs, including a waste storage structure, a roofed concrete pad, streambank fencing, and stabilized stream crossings.	Dairy Farm	Property owner	From the farm downstream to Fry Brook's confluence with the Hunt River. Also, two unnamed tributaries to Fry Brook (stations FRY04 and FRY05).
Structural Stormwater Management BMP(s) to treat highway runoff	Fry Brook at Fry Corner-Route 2.	RIDOT	Downstream of FRY02 and FRY03.
Structural Stormwater Management BMP(s) to treat highway runoff	Fry Brook at Fry Corner-Middle Road.	Town of East Greenwich	Downstream of FRY02 and FRY03.
Remove or reduce populations of resident waterfowl.	East Greenwich Golf Course, Dairy Farm, commercial areas near Route 2.	Commercial areas, Industrial areas, residents, and property owners, Town of East Greenwich	FRY01, FRY03
Structural Stormwater Management BMP(s)	Fry Brook tributary intersection with Route 2.	RIDOT	Downstream of FRY04
Structural Stormwater Management BMP(s)	Fry Brook tributary intersection with Route 2.	RIDOT	Downstream of FRY05

In addition to the recommended BMPs in Table 3, 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 Town of East Greenwich would be responsible for carrying out this program.

The public outreach program in the Fry 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 and around ponds, impoundments, and lawns. Additionally, educational information concerning the importance of ISDS maintenance and cleaning up after 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 town of East Greenwich 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 Fry Brook watershed. However, it is very difficult to assign a load reduction to these programs.

Since Fry 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, and where appropriate recommends, structural BMPs to reduce pollutant loads. Actions to achieve the required reductions can be taken voluntarily by the Town and RIDOT prior to the issuance of Phase II Stormwater Permits, or will be required by the Phase II permits.

Plans are already in place to reduce fecal coliform concentrations in the Fry Brook watershed. The areas in which progress is already underway are described below.

East Greenwich Golf Course BMPs

The East Greenwich Golf Course is a significant contributor of fecal coliform bacteria to Fry Brook. BMPs will be proposed for the golf course to reduce goose populations. The geese contribute significant amount of fecal coliforms to this section of Fry Brook. RIDEM will work closely with the golf course over the next year to provide technical assistance to, and identify and implement practical BMPs that are compatible with the normal operations of the course.

Dairy Farm BMPs
The dairy farm was identified as the largest dry and wet weather contributor of fecal coliform bacteria to Fry Brook. Plans are already underway to implement BMPs and improve water quality at the Dairy Farm in the Fry Brook watershed. We anticipate that RIDEM will be able to provide Section 319 Nonpoint Source Program grant funds to supplement NRCS funding sources to pay for the design and construction of BMPs on the farm. It is hoped that construction of these BMPs will begin within the next year. The proposed BMPs will focus on the heavy-use areas where most of the day-to-day farming operations occur. Future BMPs should focus on the outlying areas of the farm, including the FRY04 and FRY05 sub-watersheds.

9. Monitoring Plan for TMDLs Developed Under the Phased Approach

A phased approach to implementation is appropriate for fecal coliform TMDLs, considering the highly variable nature of nonpoint source bacterial 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 Fry Brook watershed in order to assess BMP effectiveness. This monitoring plan is discussed later 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 FRY BROOK TMDL FOR FECAL COLIFORM

1.0 INTRODUCTION

The State of Rhode Island's 1998 303 (d) List of Impaired Waters identified Fry Brook as being impaired by pathogens, as evidenced by the presence of elevated fecal coliform concentrations. The purpose of this report is to establish a fecal coliform TMDL for Fry Brook and its tributaries that are not meeting state fecal coliform standards. This TMDL outlines an implementation strategy 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 states' waters.

The TMDL analysis examines point and non-point sources of pollution, such as industrial and wastewater treatment facility discharges, runoff from agricultural areas and stormwater discharges from municipal separate storm sewer 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, since 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 Fry Brook as being impaired by pathogens for a length of approximately 6.2 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 Fry Brook is Class B, which are waters designated for such uses as fish and wildlife habitat and primary and secondary recreational activities. In addition, Class B 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 B waters, is as follows: "*not to exceed a geometric mean value of 200 MPN/100ml and not more than 20% of the samples shall exceed a value of 500 MPN/100ml.*" (RIDEM 1997).

2.0 DESCRIPTION OF THE FRY BROOK WATERSHED

Fry Brook is a third-order stream located entirely within the Town of East Greenwich, Rhode Island (Figure 2.1). The watershed is approximately 1,986 acres in size and drains several wetland areas. Fry Brook originates in a small pond south of Route 95 approximately 1 mile east of Exit 8. Several smaller tributaries join the stream as it flows southeast, approximately 6.2 miles, towards its confluence with the Hunt River.

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

Stream flow in Fry 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

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 Fry Brook watershed were formed.

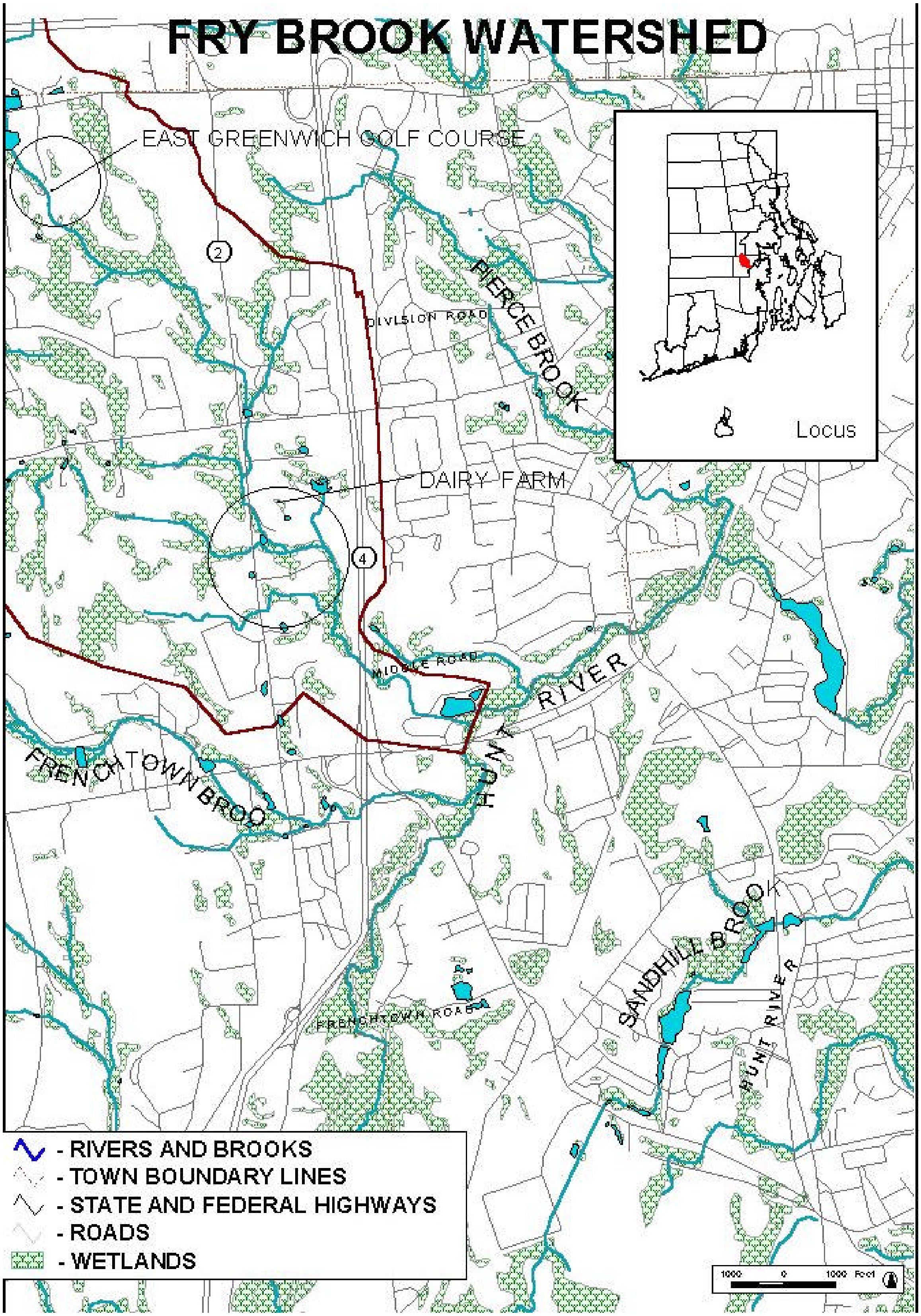
The principal parent materials of the Fry Brook watershed soils are glacial till and glacial outwash. A small percentage of soils have developed from organic deposits. Organic deposits form the parent materials for peat and muck soils. These organic deposits generally occur in small, very poorly drained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

2.2 Land Use

Based on the most recent land use information (Wright et al. 1999), land use in watershed is 23% residential, 5% commercial-industrial, 6% agriculture, 36% forest, 18% wetland, and 12% other (transitional, barren, transportation, etc.).

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



FRY BROOK WATERSHED
EAST GREENWICH GOLF COURSE
DAIRY FARM
DIVISION ROAD
PIERCE BROOK
MIDDLE ROAD
HUNT RIVER
FRENCHTOWN BROOK
FRENCHTOWN ROAD
SANDHILL BROOK
HUNT RIVER
Locus
- RIVERS AND BROOKS
- TOWN BOUNDARY LINES
- STATE AND FEDERAL HIGHWAYS
- ROADS
- WETLANDS
1000 0 1000 Feet

Figure 2.1. Map showing Fry Brook watershed.

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. The study also concluded that residential streets were able to support the growth of fecal coliforms.

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 FRY BROOK WATERSHED

3.1 RIDEM Supplemental Water Quality Trend Monitoring (1988-1991)

Periodic low-flow monitoring for fecal coliform bacteria has been conducted over the years near the mouth of Fry Brook at FRY03 (See Figure 2.1). RIDEM Supplemental Water Quality Trend Monitoring data for Fry Brook (1988-1991) found elevated fecal coliform levels (Table 3.1) that exceed the state's Class B criteria for fecal coliform. Based on this data, and the knowledge of potential sources in the watershed, Fry Brook was placed on Rhode Island's 1998 303(d) list of impaired waterbodies.

Table 3.1 Summary of Fecal Coliform concentrations from RIDEM low-flow monitoring (1988-1991).

Station	No. of samples	Minimum value	Maximum value	Geometric Mean	Percent >500
FRY03	4	430	9300	1928	75

3.2 URI Study (1996-1997)

In 1996 and 1997, the University of Rhode Island Civil and Environmental Engineering Department, under contract to RIDEM, conducted a water quality assessment of the Hunt River. Many other Hunt River tributaries were monitored during that time, however, the Fry Brook watershed was not addressed in that study. However, the URI study did mention that future water quality investigations should focus on Fry Brook

3.3 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 fecal coliform monitoring at 34 sampling stations located along the mainstem of the Hunt River and many of its tributaries, including Fry Brook. 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 during and after two separate storms: Sept 30- Oct 1 and Oct 17-18, 1999.

Dry Weather Data

Dry weather fecal coliform data were collected at five locations in the Fry Brook basin. The locations of these stations are shown in Figure 1. Two out of the five stations had dry weather fecal coliform concentration geometric means below the Class B standard of 200 fc/100ml. The remaining three stations had dry weather geometric mean values which either exceeded the State standard of 200 fc/100ml or more than 20% of those samples exceeded 500 fc/100ml. All dry weather data, including two preliminary site visits, collected in the Fry Brook watershed are summarized below in Table 3.2.

Table 3.2. Summary of RIDEM 1999 Dry Weather[a] Data.[b]

Water Quality Station	Site Visit #1 (6/2/99)	Site Visit #2 (6/9/99)	DW # 1 6/17/99	DW # 2 7/19/99	DW # 3 8/17/99	DW # 4 9/14/99	WW #1 Pre-storm	WW #2 Pre-storm
FRY01			19	dry	dry	160	40	
FRY02		52	15	74	620	130	80	80
FRY03	4000	3300	5500	240	620	360	1100	2400
FRY04		210	500	13000	12000	2700	2200	300
FRY05		210	200	47	dry	280	1400	1600

[a] *Wet weather pre-storm samples were considered "dry weather data".*
[b] *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.

Five stations (FRY01-FRY05) were sampled for wet weather fecal coliform concentrations. The locations of these stations are shown in Figure 3.1. Fecal coliform samples were collected from two separate storms: a high-intensity short duration event (0.56 inches/3 hours, average intensity = 0.19 in/hr), and a medium-intensity longer duration event (1.68 inches/10 hours, average intensity = 0.16 in/hr). All five stations had significant increases in fecal coliform geometric mean concentrations compared to dry weather conditions. Data collected in the first storm (September 30 – October 1) is summarized in Table 3.3.

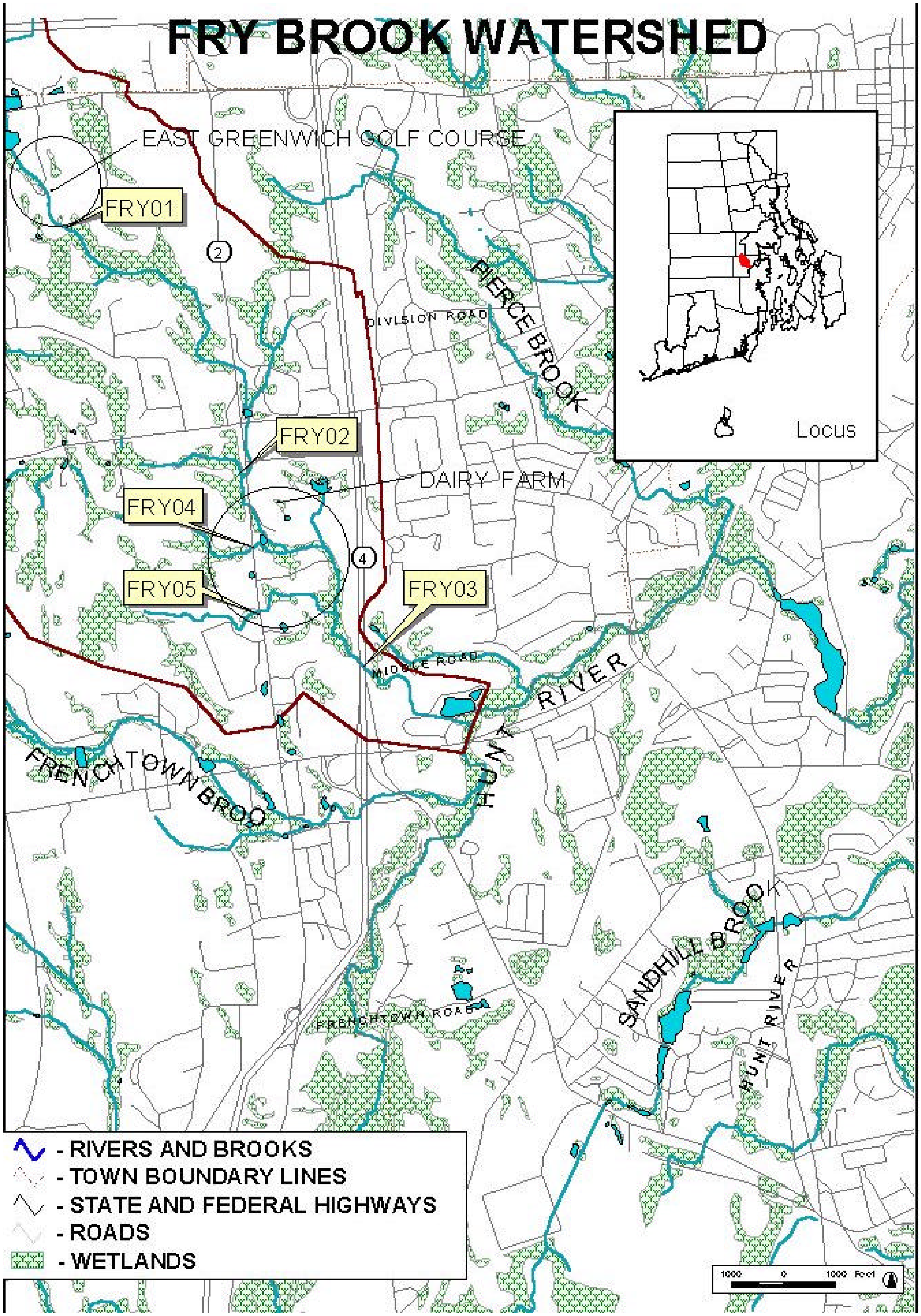


Figure 3.1. Location of RIDEM (1999) water quality sampling locations.

Table 3.3 RIDEM 1999 Data for Wet Weather Event # 1. [a]

Sample	Collection Date	Collection Time	No. of Hours After Start of Rainfall	Concentration (fc/100ml)
FRY01-0	9/30/99	0750	0.0	40[b]
FRY01-3	9/30/99	1047	3.0	1,800
FRY01-6	9/30/99	1452	7.0	2,700
FRY01-12	9/30/99	1907	9.5	420
FRY01-24	10/1/99	1113	27.5	70
FRY02-0	9/30/99	0804	0.0	80 [b]
FRY02-3	9/30/99	1058	3.0	21,000
FRY02-6	9/30/99	1502	7.0	18,000
FRY02-12	9/30/99	1920	9.5	5,900
FRY02-24	10/1/99	1127	27.5	430
FRY03-0	9/30/99	0729	0.0	1,100[b]
FRY03-2	9/30/99	1003	2.5	4,900
FRY03-4	9/30/99	1200	4.5	240,000
FRY03-6	9/30/99	1436	7.0	66,000
FRY03-12	9/30/99	1853	9.5	39,000
FRY03-24	10/1/99	1100	27.5	3,400
FRY04-0	9/30/99	0810	0.0	2,200[b]
FRY04-3	9/30/99	1104	3.0	450,000
FRY04-6	9/30/99	1504	7.0	20,000
FRY04-12	9/30/99	1924	9.5	14,000
FRY04-24	10/1/99	1130	27.5	3,500
FRY05-0	9/30/99	0814	0.0	1,400[b]
FRY05-3	9/30/99	1115	3.0	13,000
FRY05-6	9/30/99	1508	7.0	2,100
FRY05-12	9/30/99	1927	9.5	920
FRY05-24	10/1/99	1132	27.5	670

[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.*

Data collected in the second storm (October 17-18) are summarized in Table 3.4.

Table 3.4 RIDEM 1999 Data for Wet Weather Event # 2. [a]

Sample	Collection Date	Collection Time	No. of Hours After Start of Rainfall	Concentration (fc/100ml)
FRY02-0	10/17/99	2055	0	80[b]
FRY02-2	10/18/99	0118	4	1000
FRY02-4	10/18/99	0724	10	2700
FRY02-6	10/18/99	1058	14	2000
FRY02-12	10/18/99	1443	18	940
FRY02-24	10/19/99	1345	41	78
FRY03-0	10/17/99	2041	0	2400[b]
FRY03-2	10/18/99	0103	4	8600
FRY03-4	10/18/99	0716	10	33000
FRY03-6	10/18/99	1048	14	13000
FRY03-12	10/18/99	1433	18	12000
FRY03-24	10/19/99	1335	41	1600
FRY04-0	10/17/99	2100	0	300[b]
FRY04-2	10/18/99	0121	4	4300
FRY04-4	10/18/99	0728	10	7200
FRY04-6	10/18/99	1100	14	1400
FRY04-12	10/18/99	1445	18	560
FRY04-24	10/19/99	1346	41	150
FRY05-0	10/17/99	2104	0	1600[b]
FRY05-2	10/18/99	0125	4	7300
FRY05-4	10/18/99	0731	10	5100
FRY05-6	10/18/99	1103	14	920
FRY05-12	10/18/99	1448	18	630
FRY05-24	10/19/99	1349	41	250

[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 Fry 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.

In order to assess compliance with water quality standards, the monitoring data must be compared to both parts of the applicable Class B standards. 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, an 80th percentile value was calculated at that station. Both of these approaches are described below.

4.1 Dry Weather Characterization

Five stations (FRY01-FRY05) were monitored during the RIDEM study. Two out of the five, FRY01 and FRY02, did not violate Class B standards during dry weather conditions. The remaining stations, FRY03-FRY05, had dry weather geometric mean values that either exceeded the state standard of 200 fc/100ml or more than 20% of those samples exceeded 500 fc/100ml (Table 4.1). Note that pre-storm values for each wet weather survey were added to the dry weather data set.

Table 4.1. Summary of RIDEM 1999 Dry Weather Data

Station	No. of samples	Minimum value	Maximum value	Geometric mean	Percent >500
FRY01	3	19	160	50	0
FRY02	9	15	2400	140	56
FRY03	10	80	5800	1462	60
FRY04	7	210	13000	1619	57
FRY05	6	47	1600	328	33

4.2 Wet Weather Characterization

The five stations (FRY01-FRY05) were also sampled during wet weather events. Fecal coliform samples were collected from two separate storms: a high-intensity short duration event, and a medium-intensity longer duration event. All five stations had significant increases in fecal coliform geometric mean concentrations that resulted in wet weather violations of the Class B standard (Table 4.2).

Table 4.2. Summary of RIDEM 1999 Wet Weather Data.

Station	No. of samples	Minimum value	Maximum value	Geometric mean	Percent >500
FRY01	4	70	2700	615	50
FRY02	8	78	21000	1935	13
FRY03	10	1600	240000	15356	100
FRY04	9	150	450000	4892	89
FRY05	9	250	13000	1650	89

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 RIDEM study had to be combined. RIDEM approaches 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 incorporated the time needed for the stream to return to steady state conditions after a rain event. Current bacterial conditions in Fry Brook were determined based on this "weighted average" approach.

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. The 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 is considered to be a "wet" weather condition. Based on data collected in the Hunt River basin, 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 the amount of precipitation needed to produce 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 Fry 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 collected from 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 B. 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

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

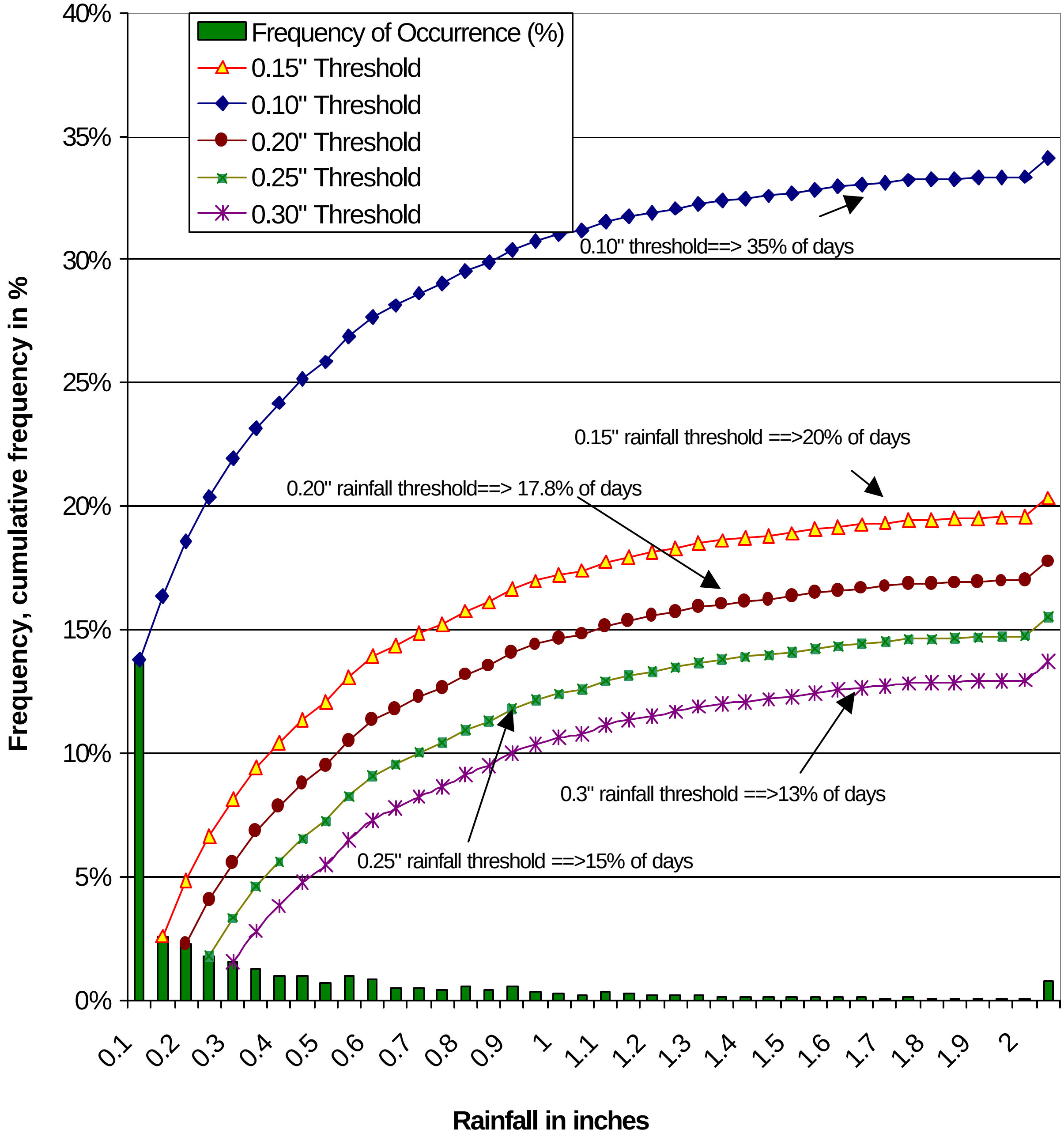


Figure 4.1. Frequency of occurrence of rainfall events for the Fry Brook watershed.

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 B criteria of 200 fc/100ml). Data collected from five stations in the watershed (FRY01-FRY05) were used to calculate recovery times from the first wet weather event while data from four stations (FRY02-FRY05) were used to calculate recovery times from the second event. 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 B standard of 200 fc/100ml for fecal coliform (Table 4.4). It was not necessary to compute decay equations for 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 the Fry Brook watershed show that an additional day is required for in-stream fecal coliform concentrations to drop to either pre-storm levels or the Class B criteria of 200 fc/100ml. Data collected from both wet weather events sampled by RIDEM in 1999 are presented in Appendix B.

Table 4.4 Summary of calculated decay equations and approximate times to recovery for Fry 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
FRY01	B	$y=1081.3e^{(-0.0995x)}$	1	Recovery w/out extrapolation	2
FRY02	B	$y=23504e^{(-0.1455x)}$	1.5	Recovery w/out extrapolation	2
FRY03	B	$y=5430.7e^{(-0.0493x)}$	3	Recovery w/out extrapolation	2
FRY04	B	$y=33089e^{(-0.082x)}$	1.5	Recovery w/out extrapolation	2
FRY05	B	recovery	1	Recovery w/out extrapolation	2

A weighted average calculation for Fry 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 (fc/100ml)
FRY01	50	615	251
FRY02	140	1935	779
FRY03	1462	15356	6408
FRY04	1619	4892	2784
FRY05	328	1650	799

4.4 Calculation of the Percent Exceedence Value

State water quality standards require that for Class B waters, not more than 20% of the samples shall exceed a value of 500 MPN/100ml. In order to determine compliance with this portion of the standard, the wet and dry weather data sets from the RIDEM 1999 study were combined into one data set for each station. The applicable percentile value was then determined for each station from that combined set of concentration values. The results are presented below in Table 4.6.

Table 4.6 Percent Exceedence Values by Station.

Station	Calculated 80^{th} Percentile Value of Combined Data Sets (fc/100ml)
FRY01	1524
FRY02	2420
FRY03	17000
FRY04	12800
FRY05	2100

5.0 WATER QUALITY IMPAIRMENTS

Water quality investigations in the watershed have found that bacteria impairments in Fry Brook and its tributaries are primarily due to nonpoint sources of pollution and discharges from MS4's.

Both dry and wet weather data were used to characterize water quality conditions in the Fry 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 bacteria concerns in the mainstem of Fry Brook as well as several tributaries, as defined by the five 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 tributary. This information is provided below by station. Please note that, since station FRY03 is the most downstream station, it is listed last.

In seeking to identify sources of pathogen contamination in Fry Brook, 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.

5.1 Station FRY01 (Fry Brook south of East Greenwich Golf Course)

Water Quality Impairments

The geometric mean of the dry weather data collected at FRY01 is 50 fc/100ml. The geometric mean of the wet weather data is 615 fc/100ml. The resulting weighted average geometric mean at FRY01 is 251 fc/100ml, slightly higher than the Class B standard of 200 fc/100ml.

Pollution Source Identification

Dry weather sources upstream of station FRY01 include the East Greenwich Golf Course as well as the source of Fry Brook itself, the pond located just south of Route 95. The source pond supports resident populations of ducks, although accurate numbers could not be assessed. Fry Brook runs the length of the golf course and drains a large pond (approximately 0.40 acres) located on the course. A second, smaller pond (approximately 0.18 acres), located near the southern end of the course augments the flow. The manager of the golf course estimates a resident population of approximately 75-125 geese. The manager of the golf course has reported that the geese are a nuisance and that large amounts of fecal material can be found on the fairways, greens, and especially around the ponds, including the larger source pond. This material is washed into both the ponds and Fry Brook during wet weather events.

Theoretical values for coliform inputs from waterfowl on a 24-hr basis were calculated by Hussong et al (1979) and Koppelman and Tanenbaum (1982). Geese were reported to produce 10^7 coliforms per day. Based on this information, the pathogen loads from the geese on the golf course could be significant.

5.2 Station FRY02 (Fry Brook approximately 600 yards south of Fry's Corner)

Water Quality Impairments

The dry weather geometric mean value of 140 fc/100ml is well within the Class B criteria for fecal coliform bacteria. Wet weather fecal coliform concentrations at this station were elevated, with a peak concentration of 240,000 fc/100ml and a geometric mean of 1935 fc/100ml.

Pollution Source Identification

Land use upstream of FRY02 consists of forested wetlands with some low density residential areas. There are several road-stream crossings in this sub-basin, the largest being the Route 2 stream-crossing and the Middle Road stream-crossing. No anthropogenic dry weather sources of fecal coliform bacteria upstream of FRY02 have been identified. The measured levels of fecal coliform at this station have been determined to be due to wildlife in the area, and RIDEM considers these levels to be background in this particular sub-watershed.

Untreated stormwater runoff from Route 2, and the intersection of Route 2 and Middle Road impacts Fry Brook upstream of FRY02. The majority of stormwater runoff comes from Frys Corner, at the intersection of Route 2 and Middle Road. Elevated bacteria concentrations in untreated stormwater runoff 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
High Traffic Street	1,900	9,627
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.

5.3 Station FRY04 (Tributary of Fry Brook, known as North Stream, located off Route 2)

Water Quality Impairments

Dry weather fecal coliform concentrations downstream of FRY04 ranged from 210 fc/100ml to 13,000 fc/100ml, with a geometric mean value of 1,619 fc/100ml. Wet weather fecal coliform concentrations at FRY04 reached 450,000 fc/100ml, with a geometric mean of 4892 fc/100ml.

Pollution Source Identification

Elevated dry and wet weather fecal coliform concentrations upstream of station FRY04 are the direct result of agricultural practices in this sub-basin. The dominant land use in this area, as well as the areas upstream of FRY05 is agriculture, namely a pasture used for grazing dairy cows. The dairy cows graze upstream of FRY04 and have unlimited access to the stream. Cows were observed standing in the channel. Manure was also observed in and around the channel. Fecal coliform sampling was performed approximately 40 yards downstream from this area and elevated dry and wet weather fecal coliform concentrations reflect the observed land use in this area.

5.4 Station FRY05 (Tributary of Fry Brook, known as South Stream, located off Route 2)

Water Quality Impairments

Dry weather fecal coliform concentrations at FRY05 ranged from 47 to 1,600 fc/100ml, with a geometric mean value of 328 fc/100ml. Wet weather fecal coliform concentrations at FRY05 reached 13,000 fc/100ml with a geometric mean value of 1650 fc/100ml.

Pollution Source Identification

Elevated dry and wet weather fecal coliform counts upstream of station FRY05 are the direct result of agricultural practices in this sub-basin. The dominant land use in this area is also agriculture. Cattle graze in a pasture in the FRY05 sub-watershed and have unlimited access to the stream. The water quality station is located approximately 20 yards downstream of the pasture.

5.5 Station FRY03 (Fry Brook at downstream side of Route 4)

Water Quality Impairments

Dry weather fecal coliform geometric means at FRY03 ranged from 80 to 5800 fc/100ml, with a geometric mean of 1462 fc/100ml. Wet weather concentrations ranged from 1600 to 240,000 fc/100ml, with a geometric mean of 15,356 fc/100ml.

Pollution Source Identification

Elevated fecal coliform concentrations at FRY03 likely reflect inputs from all upstream tributaries. However, the major impacts on water quality are thought to come from agricultural practices in this sub-basin. A 77-acre dairy farm, with approximately 70 cows, is situated in the sub-basin. The cows have unlimited access to the channel and associated wetlands. There is no roof on the manure storage area and it was evident that runoff from this area impacts Fry Brook. DEM staff observed rills in the unvegetated soil leading from the manure pile directly to the stream channel. On the property, the streambanks along the channel are unvegetated and trampled, with manure in and around the channel.

Stormwater runoff from Routes 2 and 4, as well as the parking lots of 2 commercial-industrial facilities also contributes to the elevated wet weather bacteria concentrations measured at FRY03.

Highway runoff from Route 4 flows overland and becomes channelized before draining to a small pond approximately one mile upstream of FRY03. Runoff from the parking lot of American Die Casting Corporation flows into a large pond surrounded by cattails before joining the flow from Route 4 approximately 1000 feet south of the pond. Stormwater runoff from Cherry Semiconductor flows into a detention basin before flowing south and joining the flow from American Die Casting Corporation and Route 4. Station FRY03 is located approximately one mile downstream of the confluence of all three stormwater discharges.

There is a large, resident population of Canada geese in the FRY03 sub-watershed. The geese feed and rest at the golf course, dairy farm, large lawns located adjacent to industrial areas, and near the detention basins designed for attenuating stormwater runoff. The elevated concentrations of bacteria present in the stormwater runoff are augmented by dry weather loadings from the geese. During wet weather, accumulated fecal matter, which has been deposited in and adjacent to the natural drainageways, and detention basins, washes off and mixes with stormwater runoff before being transported to the receiving waters. RIDEM staff have observed this first-hand during wet weather events.

5.6 Summary of known and potential sources of fecal coliform bacteria

Pollution sources in Fry Brook include a dairy farm, untreated stormwater runoff from roads and other impervious areas, loadings from waterfowl (especially geese), and loadings from other 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
FRY01	East Greenwich Golf Course	Resident population of Canada geese	Natural sources of bacteria (i.e. wildlife)
FRY02	Off Route 2	Untreated stormwater runoff	Natural sources of bacteria (i.e. wildlife)
FRY03	South Road	Dairy farm, untreated stormwater runoff, inputs from Canada geese	Natural sources of bacteria (i.e. wildlife)
FRY04	South Road	Dairy farm, untreated stormwater runoff	Natural sources of bacteria (i.e. wildlife)
FRY05	Scrabbletown Road	Dairy farm, untreated stormwater runoff	Natural sources of bacteria (i.e. wildlife)

6.0 TOTAL MAXIMUM DAILY LOAD ALLOCATIONS

6.1 TMDL Overview

A 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 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 is allocated 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 Fry 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]

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 the narrative or numeric criteria required by state water quality standards.

In Fry Brook, the Class B fecal coliform standard was used as the applicable endpoint. This standard states that fecal coliform concentrations in Class B waters shall not exceed a geometric mean value of 200 fc/100ml and not more than 20% of the samples shall exceed a value of 500 fc/100ml.

6.2 Point Sources

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

6.3 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 upon which the TMDL will be based. The values for each are presented below in Tables 6.1 and 6.2.

Weighted average geometric means and the resulting percent reductions are presented in Table 6.1 for all water quality stations in the Fry Brook watershed.

Table 6.1. Weighted Average Geometric Means and Percent Reductions Needed to Reach 200 fc/100ml.

Station	Weighted Average Geomean (fc/100ml)	% Reduction Needed to Reach Geomean of 200 fc/100ml
FRY01	251	20
FRY02	779	74
FRY03	6408	97
FRY04	2784	93
FRY05	799	75

The 80th percentile values of the combined dataset of wet and dry weather samples for each water quality station in the Fry 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 80th percentile values to 500 fc/100ml.

Table 6.2. 80th Percentile Values and Percent Reductions Needed to Reach 500 fc/100ml

Station	80th percentile of Combined Dataset (fc/100ml)	% Reduction Needed to Reach 500 fc/100ml
FRY01	1524	67
FRY02	2420	79
FRY03	17000	97
FRY04	12800	96
FRY05	2100	76

Required Load Reductions
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 Fry Brook.

Table 6.3. TMDL Load Reductions Required for Fry Brook.

Station	% Reduction Needed to Meet Standards
FRY01	67
FRY02	79
FRY03	97[a]
FRY04	96
FRY05	76

[a] *Reductions achieved at FRY-01, 02, 04, and 05 should contribute to the needed reductions at FRY03.*

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 80th 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 Fry 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 loads in Fry 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 Fry 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 200 fc/100ml standard for fecal coliform bacteria from a site. Given existing stormwater fecal coliform levels equivalent to the national mean of 15,000 fc/100ml (CWP 1999), watershed practices may need to achieve nearly a 99 percent removal rate to meet standards. To date, performance monitoring studies research has indicated that no stormwater practice 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 FRY03 is the most downstream station, it is listed last.

7.1 Station FRY01 (Fry Brook south of East Greenwich Golf Course)

Required Reduction

A reduction of 67% is required in the fecal coliform concentrations at station FRY01.

Proposed BMPs

Several methods exist to rid golf courses of nuisance geese. RIDEM will propose the following BMPs, as alternatives to be considered by the managers of the golf course.

1. **G-Grid -** G-grid discourages geese from landing near a waterbody. G-Grid consists of a polypropylene netting placed to a height of 2 feet around 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.

Estimated Pollution Reduction for Recommended BMPs

If approximately 75 geese frequent the golf course daily (Michael Kroian, President-East Greenwich Golf and Country Club, personal communication), then estimated fecal coliform counts deposited in and around the waterways would reach 7.5 X 10^8. Even if a relatively small percentage of coliform bacteria were introduced during wet weather into the ponds and stream, it would still be sufficient to violate the states Class B standards for fecal coliform bacteria. Turf Shield reports a removal efficiency of approximately 95%.

We believe that a significant reduction in the geese population at the golf course will result in a corresponding decrease in the fecal coliform loadings to the receiving ponds and stream. To achieve a 20% reduction in fecal coliform concentrations, we recommend a 50% reduction in the number of geese on the course. Furthermore, we believe that application of one or more of the BMPs described above could result in attainment of this goal.

7.2 Station FRY02 (Fry Brook approximately 600 yards south of Fry's Corner)

Required Reduction

A reduction of 79% is required in the fecal coliform concentrations at station FRY02.

Proposed BMPs

Stormwater runoff from both Route 2 and Middle Road (Fry Corner) was identified as a wet weather source of pollution. RIDEM recommends that RIDOT and the Town of East Greenwich delineate the catchment area draining to Fry Brook at Route 2 and Middle Road, especially those portions of the roadways that drain to the stream. RIDEM recommends one or more structural BMPs to attenuate stormwater runoff from the Route 2-Middle Road intersection to the maximum extent practicable. Structural BMPs for this area should be designed to promote the detention and infiltration of runoff.

Estimated Pollution Reduction for Recommended BMPs

Coupled with reductions made upstream at the golf course, we believe that the application of BMPs to treat stormwater runoff in this sub-watershed would result in the attainment of water quality standards at FRY02. There are several options to investigate prior to determining the appropriate BMP to treat the runoff from Route 2 and Middle Road. 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 below 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 in Table 7.2.

Table 7.2. Effectiveness of Manufactured and Agricultural BMPs in Reducing Bacteria Concentrations in Runoff.

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- prepared for the Stormwater Technologies Trade Show Providence, Rhode Island. May 25, 1999.

b. Fecal coliform abundance has been correlated with high levels of TSS.

7.3 Station FRY04 (Tributary of Fry Brook, known as North Stream, located off Route 2)

<u>*Required Reduction*</u>

A reduction of 97% is required in the fecal coliform concentrations at station FRY04.

<u>*Proposed BMPs*</u>

Plans are currently underway to install BMPs in an area of the dairy farm downstream of FRY04. These BMPs will focus on the heavy-use areas where most of the day-to-day farming operations occur. Subsequent BMPs should focus on the outlying areas of the farm, including the FRY04 sub-watershed. The BMPs proposed upstream of FRY04 will address the pathogen contributions to Fry Brook from the pasture area and will reduce both dry and wet weather impacts. Proposed BMPs for the pasture, as well as a general description of their effectiveness taken from EPA (1993), are as follows:

1. **Fencing of Stream and Wetland Areas** - Livestock will by denied access or have "limited access" to stream and wetland areas adjacent to the farm. Permanent fencing will be installed along stream corridors and wetlands. *Protection should result in substantial improvement of water quality, as manure will be removed from the surface water (EPA 1993).*

2. **Livestock Stream Crossing** - BMP includes a stabilized area to provide access across a stream for livestock. *The purpose is to provide a controlled crossing or watering access point for livestock along with access for farm equipment (EPA 1993).*

In addition to impacts from the dairy farm, stormwater runoff from Route 2 was identified as a wet weather source of pollution. RIDEM recommends that RIDOT implement a structural BMP to reduce fecal coliform loads from Route 2 to the maximum extent practicable. Structural BMPs for this area should be designed to promote the detention and infiltration of runoff.

<u>*Estimated Pollution Reduction for Recommended BMPs*</u>

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

RIDEM was unable to identify references in the literature for load reductions from stream bank fencing and stabilized crossings. However, we believe that implementation of these BMPs in the pasture upstream of FRY04, as well as a structural BMP, will address all controllable loads related to in this sub-watershed and should result in the attainment of water quality standards at FRY04.

7.4 Station FRY05 (Tributary of Fry Brook, known as South Stream, located off Route 2)

Required Reduction

A reduction of 76% is required in the fecal coliform concentrations at station FRY05.

Proposed BMPs

Plans are currently underway to install BMPs in an area of the dairy farm downstream of FRY05. These BMPs will focus on the heavy-use areas where most of the day-to-day farming operations occur. Subsequent BMPs should focus on the outlying areas of the farm, including the FRY05 sub-watershed. The BMPs proposed upstream of FRY05 will address the pathogen contributions to Fry Brook from the pasture area and will reduce both dry and wet weather impacts. Proposed BMPs for the pasture, as well as a general description of their effectiveness taken from EPA (1993), are as follows:

1. **Fencing of Stream and Wetland Areas** - Livestock will be denied access or have "limited access" to stream and wetland areas adjacent to the farm. Permanent fencing will be installed along stream corridors and wetlands. *Protection should result in substantial improvement of water quality, as manure will be removed from the surface water (EPA 1993).*

2. **Livestock Stream Crossing** - BMP includes a stabilized area to provide access across a stream for livestock. *The purpose is to provide a controlled crossing or watering access point for livestock along with access for farm equipment (EPA 1993).*

In addition to impacts from the dairy farm, stormwater runoff from Route 2 was identified as a wet weather source of pollution. RIDEM recommends that RIDOT implement a structural BMP to reduce fecal coliform loads from Route 2 to the maximum extent practicable. Structural BMPs for this area should be designed to promote the detention and infiltration of runoff.

Estimated Pollution Reduction for Recommended BMPs

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

RIDEM was unable to identify references in the literature for bacteria load reductions from stream bank fencing and stabilized crossings. However, we believe that implementation of these BMPs in the pasture upstream of FRY05 will address all controllable loads in this sub-watershed and should result in the attainment of water quality standards at FRY05.

7.5 Station FRY03 (Fry Brook at downstream side of Route 4)

Required Reduction:

A reduction of 97% is required in the fecal coliform concentrations at station FRY03.

Proposed BMPs

Not all of the 97% reduction in concentration that is required at FRY03 has to come from this sub-watershed. Reductions made in other sub-watersheds should help in attaining water quality standards at FRY03. The following BMPs in the FRY03 sub-watershed will address the elevated bacteria levels measured at FRY03.

Based on work already done by NRCS, we can recommend five agricultural BMPs for the dairy farm: waste storage area, heavy use area protection, fencing of stream and wetland areas, livestock stream crossing, and roof runoff management. Plans are currently underway to install these BMPs at the dairy farm. The proposed BMPs will address the pathogen contributions to Fry Brook from the Dairy Farm and will reduce both dry and wet weather impacts.

Table 7.3 reports gross effectiveness levels generated by researchers at Pennsylvania State University (1992).

Table 7.3. Estimated Pollution Reduction Effectiveness of Selected Agricultural BMPs (PSU, 1992).

Practice Category	Total Phosphorus (%)	Total Nitrogen (%)	Sediment (%)	Fecal Coliform (%)
Animal Waste Systems	90	80	60	85
Diversion Systems	70	45	NA	NA
Filter Strips	85	NA	60	55
Terrace System	85	55	80	NA
Containment Structures	60	65	70	90

The gross effectiveness estimates reported in Table 7.3 simply indicate summary literature values. For specific cases, including the dairy farm, a wide range of effectiveness can be expected depending on the value and interaction of the site-specific variables described above. The effectiveness of BMPs to control contaminant losses from confined livestock facilities depends on several factors including:

- The containment(s) to be controlled and their likely pathways in surface, subsurface, and ground-water flows;
- The types of practices and how these practices control surface, subsurface, and groundwater contaminant pathways; and
- Site specific variables such as soil type, topography, precipitation characteristics, type of animal housing and waste storage facilities, method of waste collection, handling and disposal, and seasonal variations. The site-specific conditions must be considered in system design, thus having a large effect on practice effectiveness levels.

A description of the BMPs recommended for the dairy farm, as well as a general discussion of their effectiveness taken from EPA (1993), is provided below:

1. **Waste Storage Structure** - A roofed structure for temporary storage of animal wastes or other agricultural wastes is proposed for the dairy farm. *This practice may reduce the nutrient, pathogen, and organic loading to the surface waters. This is accomplished by intercepting and storing the polluted runoff from manure stacking areas, barnyards, and feedlots. (EPA, 1993).*

2. **Heavy Use Area Protection** - Heavy-use areas will be protected with a roof and surfaced with concrete. *Protection may result in a general improvement of surface water quality through the reduction of erosion and the resulting sedimentation. (EPA 1993).*

3. **Fencing of Stream and Wetland Areas** - Livestock will by denied access to stream and wetland areas with permanent fencing. *Protection should result in substantial improvement of water quality, as manure will be removed from the surface water (EPA 1993).*

4. **Livestock Stream Crossing** - BMP includes a stabilized area to provide access across a stream for livestock. *The purpose is to provide a controlled crossing or watering access point for livestock along with access for farm equipment (EPA 1993).*

5. **Roof Runoff Management -** BMP includes a facility for controlling and disposing of runoff water from roofs. *This practice may reduce erosion and the delivery of sediment and related substances to surface waters. It will reduce the amount of water polluted by animal wastes. Loadings of bacteria to surface waters are prevented from flowing down to and across concentrated waste areas and barnyards. Pollution and erosion will be reduced*

In addition to stormwater impacts upstream at FRY02, FRY04 and FRY05, stormwater runoff from Route 4, the parking lot of American Die Casting Corp., and Cherry Semiconductor was identified as contributing to the elevated bacteria loads measured at FRY03. BMP recommendations for FRY02, FRY04 and FRY05 were given in sections 7.2, 7.3, and 7.4.

RIDEM recommends that RIDOT implement one or more structural BMPs to reduce fecal coliform loads from Route 4 to the maximum extent practicable. Structural BMPs for this area should be designed to promote the detention and infiltration of runoff.

The removal efficiencies of conventional and structural BMPs were provided in Table 7.1 and 7.2 and provide estimates of pollutant reductions that can be expected if these types of BMPs were to implemented in the FRY03 sub-watershed.

Another source of high fecal coliform loadings, especially in wet weather, is the large, resident population of Canada geese in the FRY03 sub-watershed. RIDEM observations suggest that the local geese population spends a majority its time moving to and from the golf course, dairy farm fields, and adjacent industrial areas. The opinion among property owners in these areas is that the geese are a nuisance and steps should be taken to discourage their presence or reduce their numbers.

As discussed in section 7.1, there are several methods to reduce the Canada geese 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.

RIDEM recommends that American Die Casting Corporation and Cherry Semiconductor consider implementing one or more of the BMP recommendations discussed in section 7.1 to reduce the populations of geese.

Estimated Pollution Reduction for Recommended BMPs
If the BMPs that are recommended for the Fry Brook watershed are implemented, we believe that water quality standards can be met at FRY03. RIDEM believes that the best way to determine BMP effectiveness is to maintain existing water quality monitoring stations at key locations in the watershed. As the various BMPs are implemented, the resulting reductions can be tracked through monitoring data using a phased approach to implementation. Additional BMPs can then be recommended, as needed.

7.6 Watershed-Wide Stormwater Management Issues

Urban stormwater runoff from roads and residential/commercial land uses impacts water quality in several portions of the Fry 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 Town of East Greenwich 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 Town of East Greenwich 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 Fry Brook watershed. However, it is very difficult to assign a load reduction to these programs.

Since Fry 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 stormwater discharges 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. The Town and RIDOT should evaluate opportunities for stormwater attenuation in the upland portions of the watershed.

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 7.4 highlights possible locations in the Fry Brook watershed where stormwater BMPs may be the most effectively applied to address road runoff.

Table 7.4. Sites of stormwater discharge from roads and highways in the Fry Brook watershed.

Location	Responsible Entity	Station-River Segment Impacted	Wet Weather Geometric Mean (fc/100ml)
Fry's Corner- Route 2.	RIDOT	Downstream of FRY02	1935
Fry's Corner- Middle Road.	Town of East Greenwich	Downstream of FRY02	1935
West side of Route 4 near American Die Casting Corporation	RIDOT	Upstream of FRY03	n/a
Route 2	RIDOT	Downstream of FRY04	1650
Route 2	RIDOT	Downstream of FRY05	4892

Public Outreach
RIDEM recommends a public outreach program aimed at informing and educating residents as well as commercial-industrial interests about the sources of bacteria in streams and ways to eliminate or reduce these 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 geese and controlling their populations in areas of concern.

The Town of East Greenwich 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 threats from elevated pathogen levels in surface waters, they will be willing to take corrective actions that will result in improved water quality.

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.

Post-implementation monitoring is necessary to assess the effectiveness of applied controls, and whether or not standards are attained. RIDEM's Division of Agriculture (DOA) has made a commitment to conduct water quality monitoring to assess the effectiveness of BMPs implemented on the dairy farm. DOA will install water quality monitoring stations upstream and downstream of the dairy farm.

To monitor the effect that implementation activities throughout the watershed have on Fry Brook's water quality, RIDEM will conduct baseline monitoring at FRY03. Since almost all of the pollution sources in the watershed impact water quality at this downstream point, this is a conservative location from which to gage the effectiveness of BMPs placed in the watershed. 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.

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.

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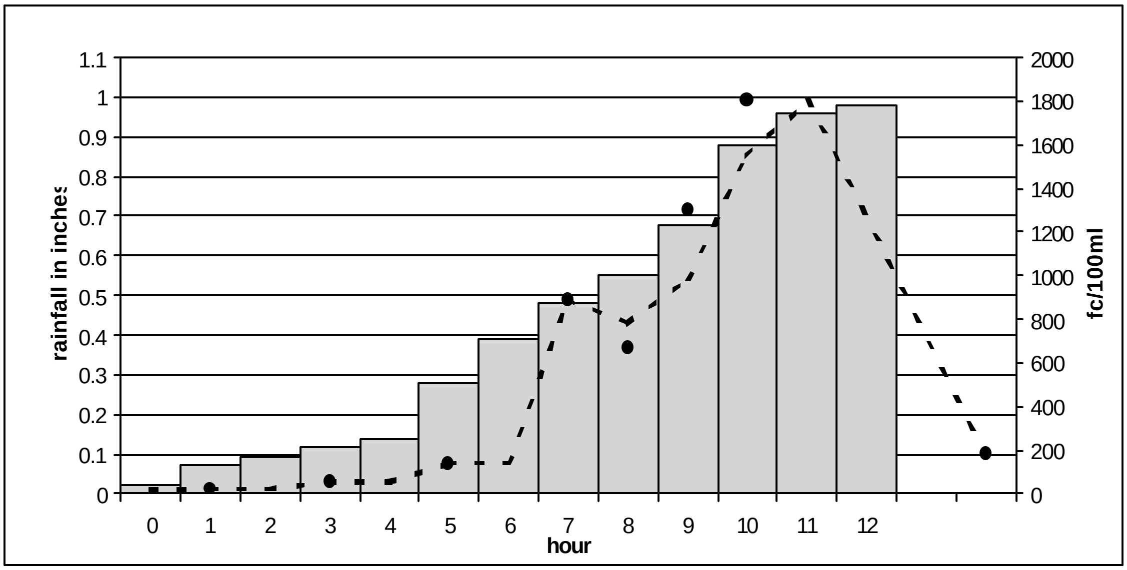
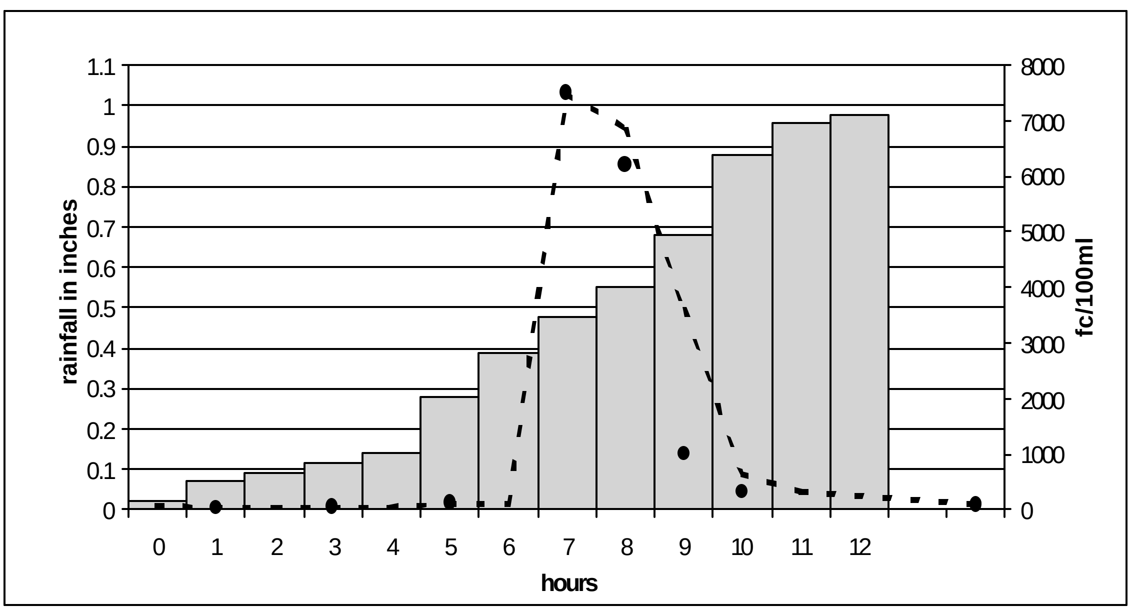
APPENDIX A. URI wet weather data plots of time, cumulative rainfall amounts, and fecal coliform concentrations for selected water quality stations. Rainfall plotted as a hyetograph.

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

Station SB01

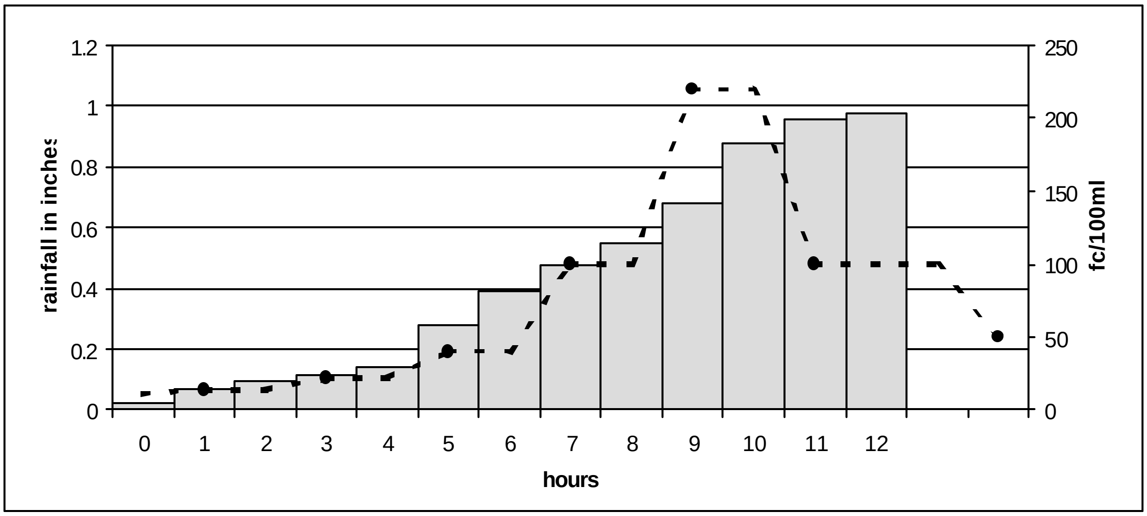


Station HR04



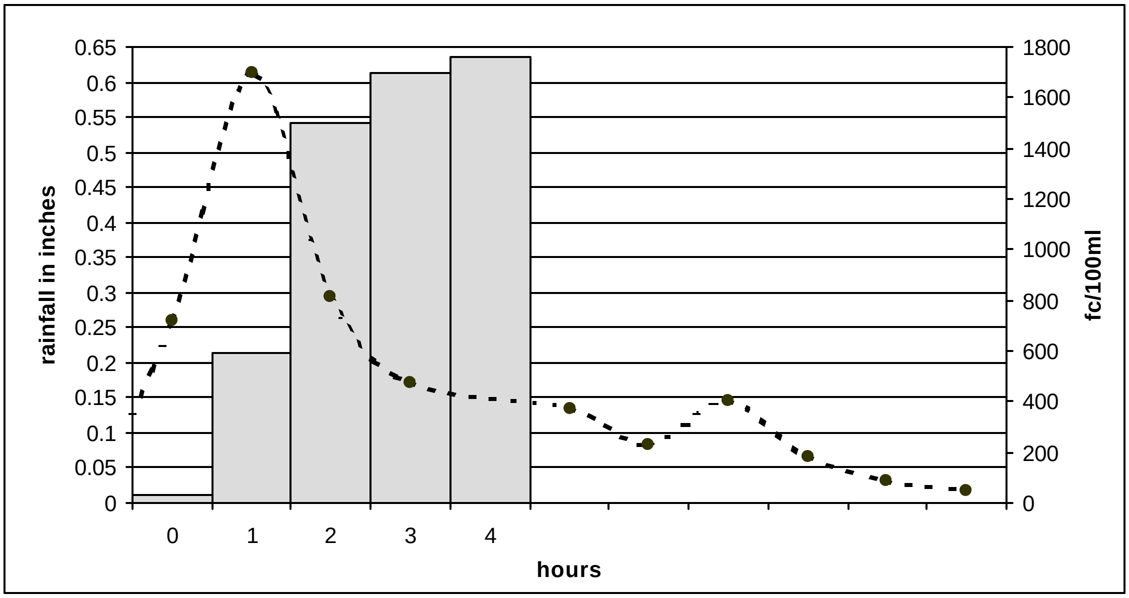
URI 1996 1st Wet Weather (0.98 inches/12 hrs)

Station HR03

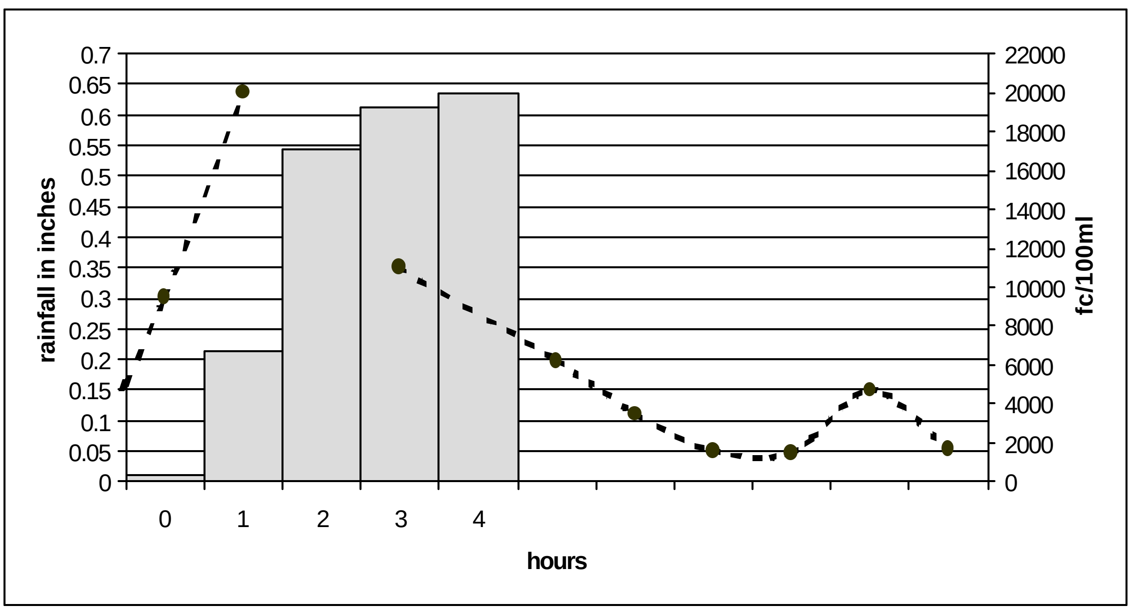


URI 1996 2nd Wet Weather (0.64 inches/4 hrs)

Station FB01

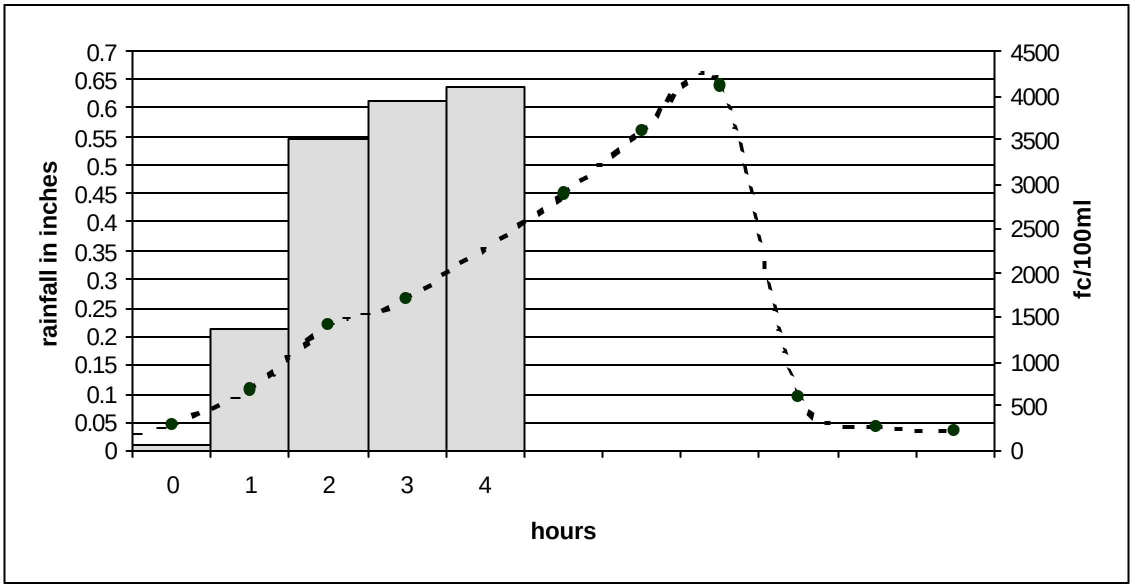


Station SC01

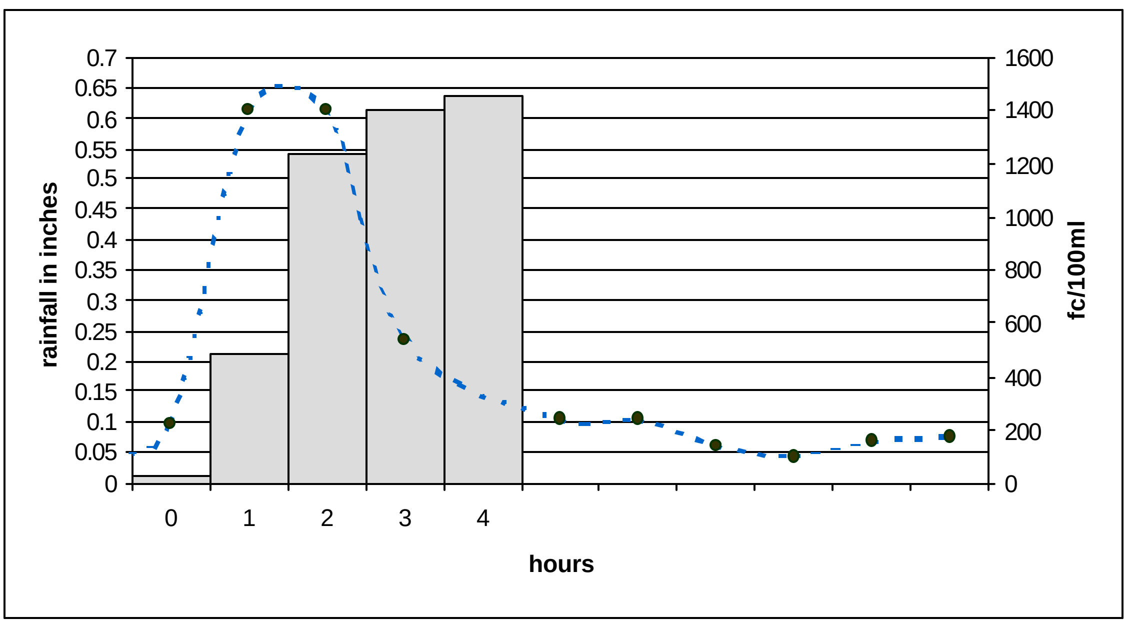


URI 1996 2nd Wet Weather (0.64 inches/4 hrs)

Station SB01

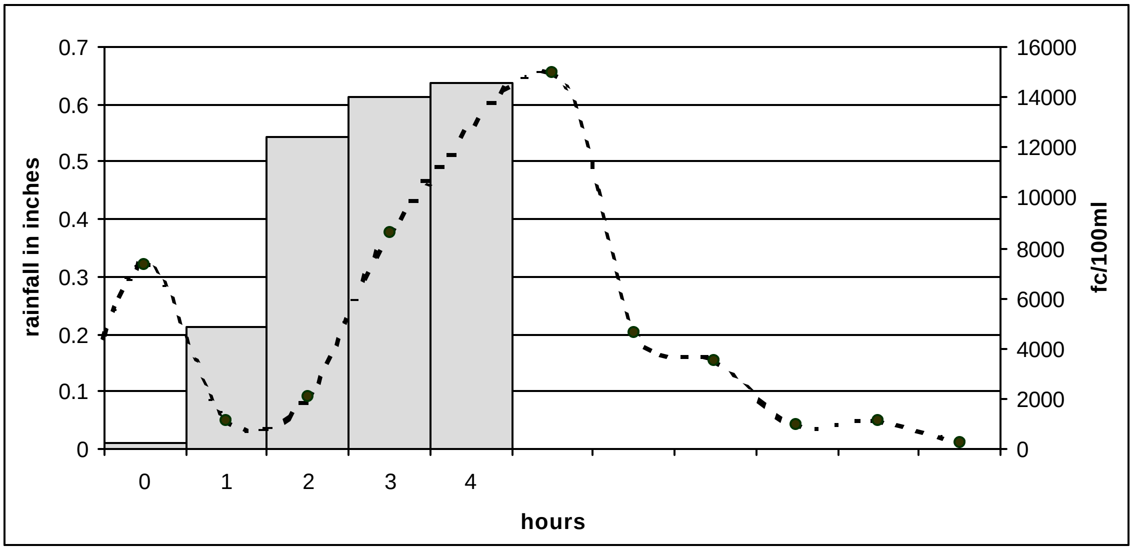


Station HR03



URI 1996 2nd Wet Weather (0.64 inches/4 hrs)

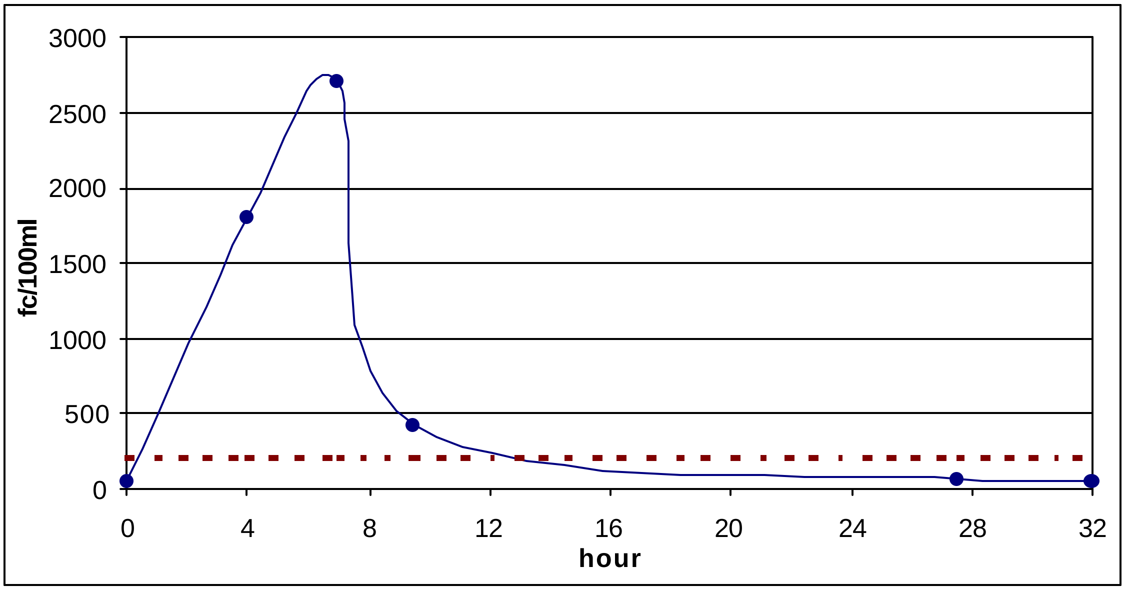
Station HR04



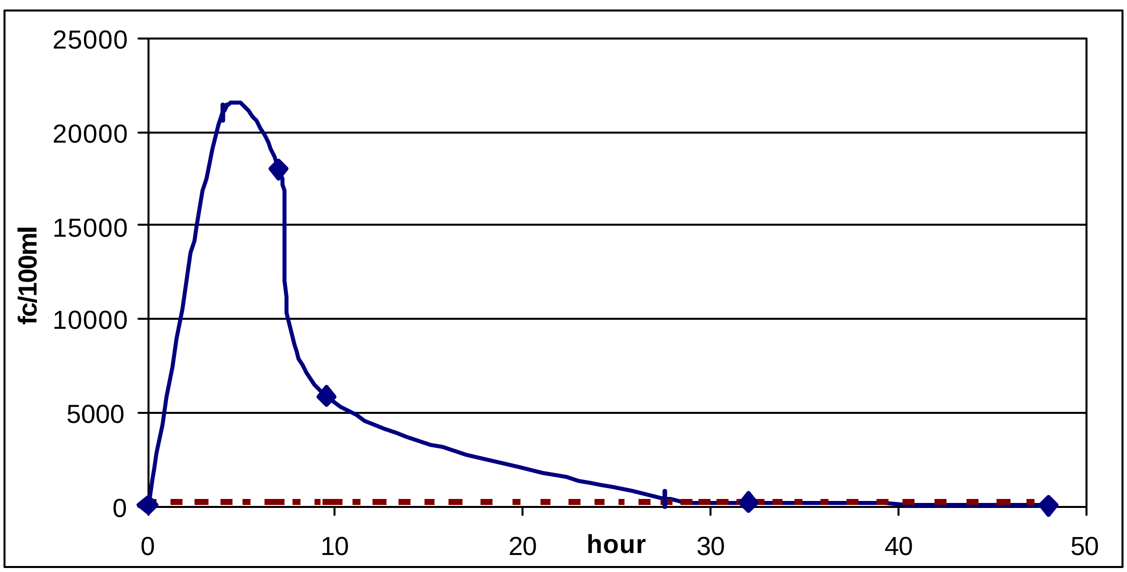
Appendix B. RIDEM wet weather plots of recovery time for selected stations. Dashed line represents Class B standard for fecal coliform bacteria (200 fc/100ml).

Wet Weather Event #1 (0.56 inches/1.5 hrs)

Station FRY01

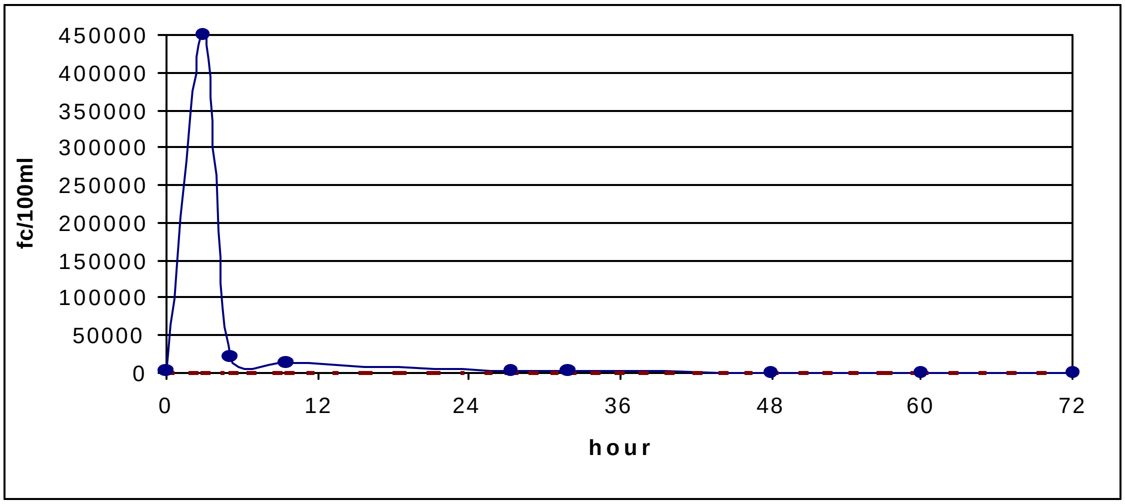


Station FRY02

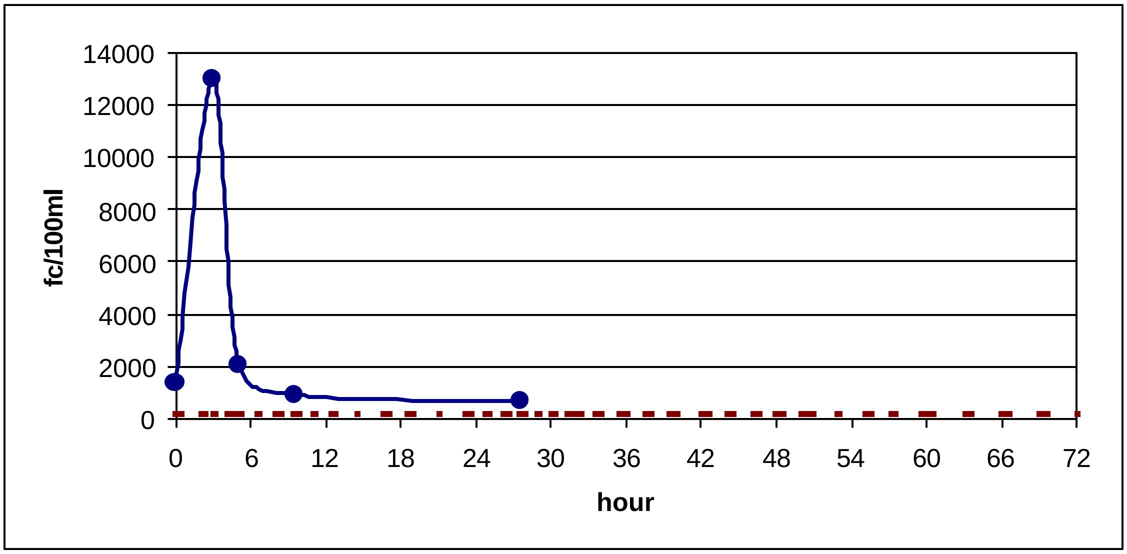


Wet Weather Event #1 (0.56 inches/1.5 hrs)

Station FRY04

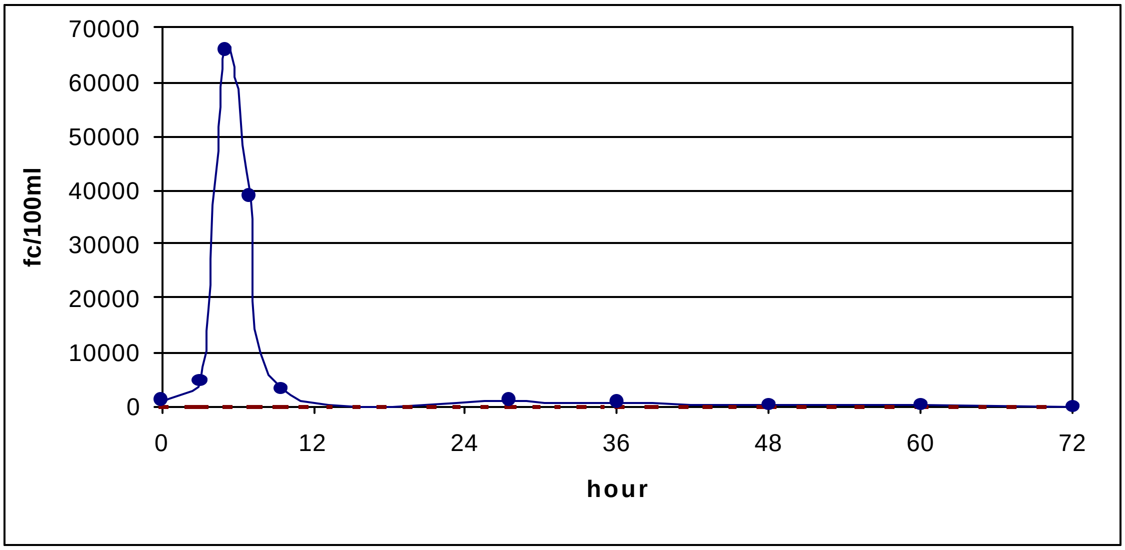


Station FRY05



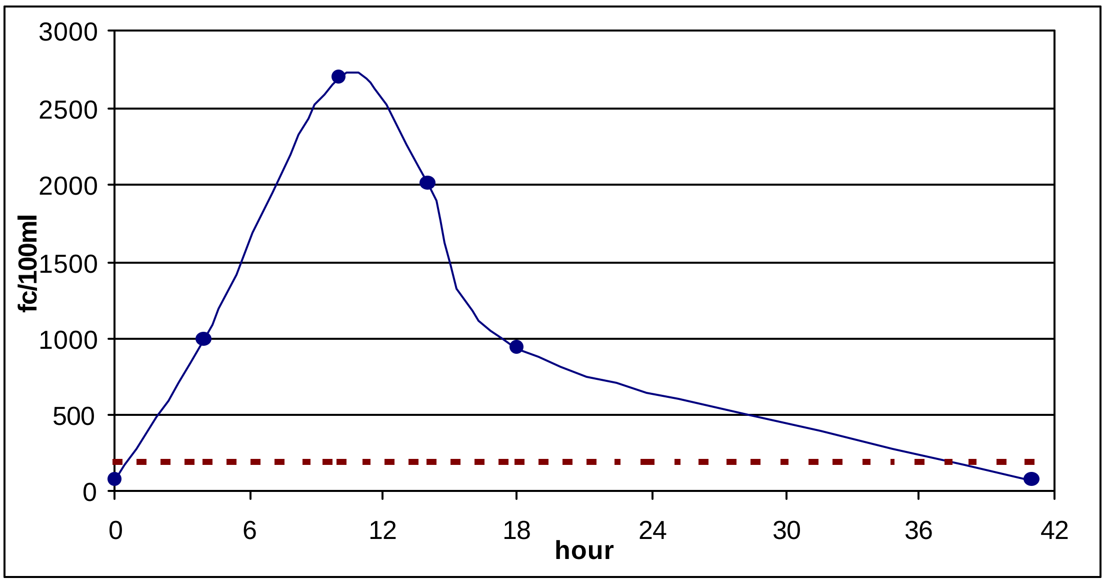
Wet Weather Event #1 (0.56 inches/1.5 hrs)

Station FRY03



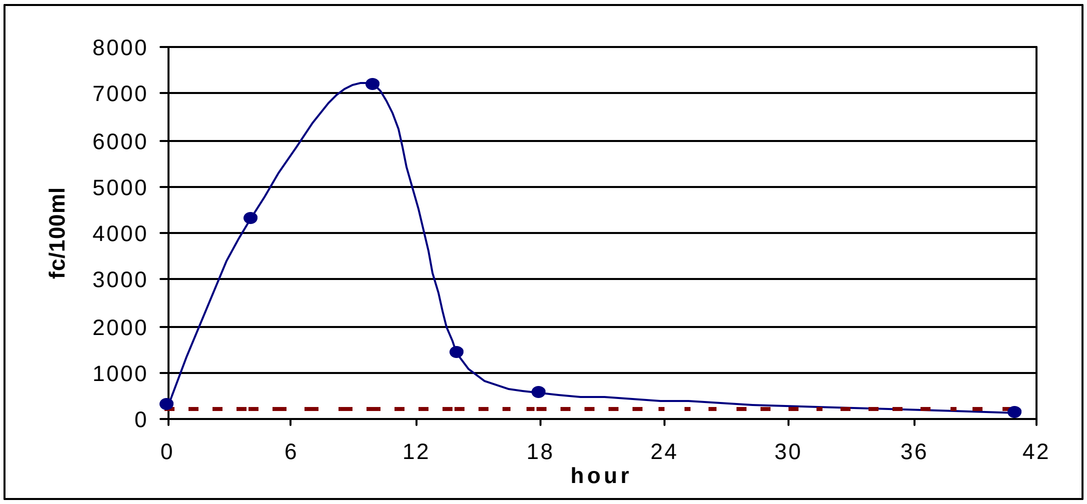
Wet Weather Event #2 (1.74 inches/10 hrs)

Station FRY02

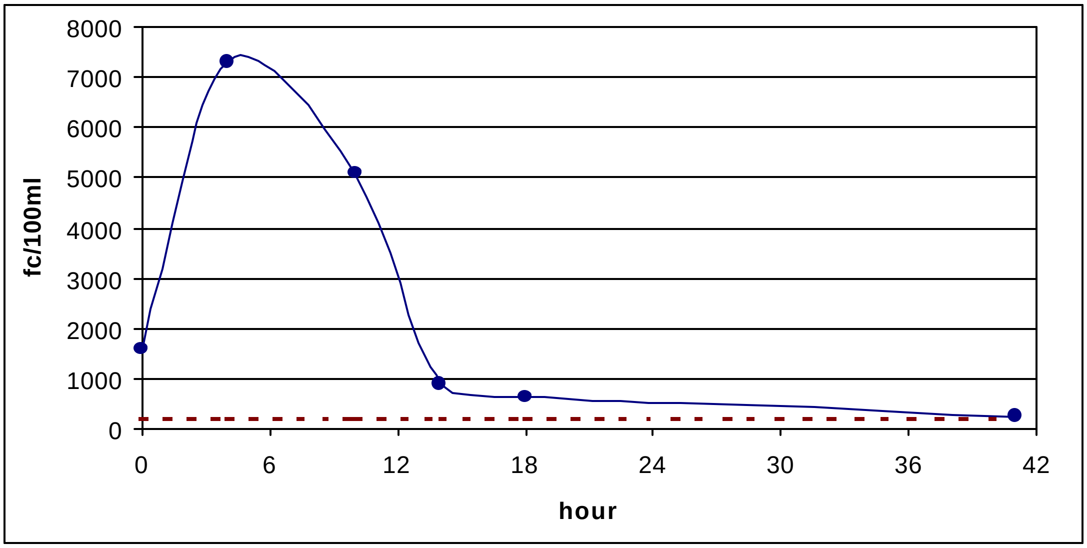


Wet Weather Event #2 (1.74 inches/10 hrs)

Station FRY04



Station FRY05



Wet Weather Event #2 (1.74 inches/10 hrs)

Station FRY03