Fecal Coliform TMDL
for
Crooked Brook, Rhode Island
(Waterbody ID Number RI0010044R-03)

Prepared By:

Office of Water Resources
Rhode Island Department of Environmental Management
235 Promenade St.
Providence, RI 02908
October 2002

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

List of Acronyms and Terms

BMP = Best management practice, the schedule of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the pollution of and impacts upon waters of the State. BMPs also include treatment requirements, operating procedures, and practices to control runoff, spillage or leaks, sludge or waste disposal, or drainage from raw material storage.

Clean Water Act = the Federal Water Pollution Act (33 U.S.C. § 1251) et seq. and all amendments thereto.

Designated uses = those uses specified in water quality standards for each water body whether or not they are being attained. In no case shall assimilation or transport of pollutants be considered a designated use.

EPA = the United States Environmental Protection Agency

Fecal coliform = bacteria found in the intestinal tracts of warm blooded animals. Their presence in water or sludge is an indicator of pollution and possible contamination by pathogens, which are disease causing organisms.

LA = Load allocation, the portion of a receiving water's loading capacity that is allocated either to nonpoint sources of pollution or to natural background sources.

Loading capacity = means the maximum pollutant loading that a surface water can receive without violating water quality standards.

MOS = Margin of safety. Because bacteria levels are variable, it is possible that the specified reductions may not be adequate to allow water quality to meet standards. To account for this uncertainty, an additional reduction in bacteria levels beyond the required numeric bacteria concentration is specified. This can be achieved by using conservative assumptions, an explicitly allocated reduction, such as a level 10% below the standard, or a combination of both techniques.

MPN = Most probable number. An estimate of microbial density per unit volume of water sample, based on probability theory.

Natural Background = all prevailing dynamic environmental conditions in a waterbody or segment, other than those human-made or human-induced. Natural background bacteria concentrations include contributions from wildlife and/or waterfowl.

Nonpoint source = any discharge of pollutants that does not meet the definition of point source in section 502.(14). of the Clean Water Act. Such sources are diffuse, and often associated with land use practices that carry pollutants to the waters of the state. They

include but are not limited to, non-channelized land runoff, drainage, or snowmelt; atmospheric deposition; precipitation; and seepage.
Point source = any discernible, confined, and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation or vessel, or other floating craft, from which pollutants are or may be discharged. This term does not include return flows from irrigated agriculture.

RIDEM = Rhode Island Department of Environmental Management

Runoff = water that drains from an area as surface flow.

TMDL = Total maximum daily load, the amount of a pollutant that may be discharged into a waterbody without violating water quality standards. The TMDL is the sum of wasteload allocations for point sources, load allocations for nonpoint sources, and natural background. Also included is a margin of safety.

Water quality standard = provisions of state or federal law which consist of designated use and water quality criteria for the waters of the state. Water quality standards also consist of an antidegradation policy. Rhode Island's water quality regulations may be found at http://www.state.ri.us/dem/pubs/regs/REGS/WATER/h20qlty.pdf

WLA = Waste load allocation, the portion of a receiving water's loading capacity that is allocated to point sources of pollution.

Abstract

Crooked Brook (waterbody ID number RI0010044R-03) is located in the southern portion of the State of Rhode Island within the Town of Narragansett. The surrounding watershed is entirely sewered and predominantly forested. Land use consists of some low to medium density residential development and a small amount of industrial/commercial use. Crooked Brook is designated a Class A waterbody, suitable for primary and secondary recreation and fish and wildlife habitat. The brook consistently exceeds Class A standards for fecal coliform concentrations. As a result it is listed as a Group 1 waterbody, the highest priority for TMDL development, on Rhode Island's 303(d) List of Impaired Waters.

The goals of this TMDL are to characterize fecal coliform concentrations throughout the Crooked Brook watershed, to identify sources of fecal coliform and to recommend mitigation measures to restore all designated uses to the brook. The monitoring program revealed elevated fecal coliform levels throughout the watershed. In the eastern "upper Crooked Brook" branch, instream fecal coliform concentrations require reductions of up to 99+% to meet state water quality standards. In the western "Sprague Brook" branch, fecal coliform concentrations require reductions of up to 70% to meet state water quality standards.

Identified nonpoint sources to the brook include wildlife, a small horse boarding operation, and overland stormwater runoff. The only point sources in the watershed are storm sewer outfalls along South Pier Road, Kingstown Road, and adjacent to Narragansett High school.

Recommended mitigation measures vary according to source. Wildlife sources encountered in the Crooked Brook watershed are generally uncontrollable. A combination of structural and nonstructural manure management practices may be required to minimize the water quality impacts of the horse boarding operation. A combination of structural and nonstructural BMPs must be employed throughout the developed portions of the Crooked Brook watershed to minimize fecal coliform loadings from stormwater runoff.

1.0 Introduction

1.1 Study Area

The Crooked Brook watershed is located in Narragansett, RI which is situated in the southern portion of the state (see Figure 1.1). Crooked Brook is the third largest tributary to Narrow River discharging to Pettaquamscutt Cove at the southern end of the Narrow River estuary.

1.2 Pollutant of Concern

The pollutant of concern is fecal coliform, a parameter used by Rhode Island as an indicator of pathogen contamination.

1.3 Priority Ranking

Crooked Brook is listed as a Group 1 waterbody and therefore has the highest priority for TMDL development.

1.4 Applicable Water Quality Standards

Designated Uses

Crooked Brook is designated a Class A waterbody by the State of Rhode Island. Class A waters are designated for primary and secondary contact recreation and fish and wildlife habitat. Class A waters should have good aesthetic value.

Numeric Water Quality Criteria

The fecal coliform water quality standard for Crooked Brook is a geometric mean MPN value of 20 fc/100 ml with not more than 10% of the samples exceeding an MPN value of 200 fc/100 ml. These are the numeric targets for the reaches above the mouth of Crooked Brook.

At the point where Crooked Brook discharges to Pettaquamscutt Cove, it must meet the more stringent Class SA water quality standards. The fecal coliform water quality criteria for a Class SA waterbody is not to exceed a geometric mean MPN value of 14 fc/100ml and not more than 10% of the samples shall exceed an MPN value of 49 fc/100ml.

Antidegradation Policy

Rhode Island's antidegradation policy requires that, at a minimum, the water quality necessary to support existing uses be maintained (see Rule 18, Tier 1 in the State of Rhode Island's Water Quality Regulations). If water quality for a particular parameter is of a higher level than necessary to support an existing use (i.e. bacterial levels are below Class A standards), that improved level of quality should be maintained and protected (see Rule 18, Tier 2 in the State of Rhode Island's Water Quality Regulations).

Numeric Water Quality Target

The numeric water quality target is therefore the Class A standard geometric mean of 20 fc/100 ml with a 90th percentile value of 200 fc/100 ml for the upstream areas of Crooked Brook and the Class SA standard geometric mean of 14 fc/100 ml with a 90th percentile value of 49 fc/100 ml. for the point of discharge. Because bacteria levels are presently

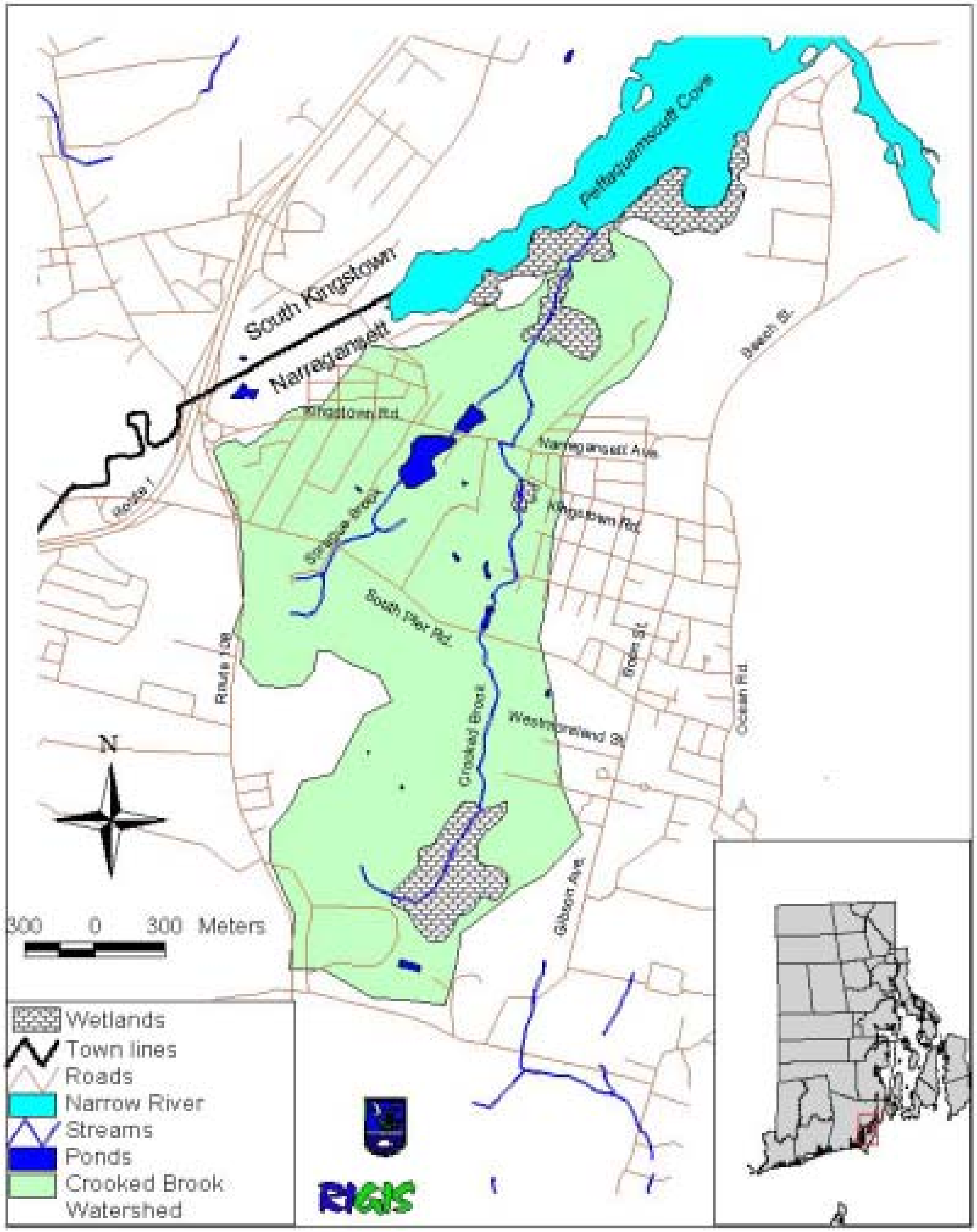

Figure 1.1 Crooked Brook Locus Map

well above the Class A standard, the Tier 2 protection of the antidegradation policy does not apply. These targets incorporate an implicit Margin of Safety (MOS) through conservative assumptions explained in section 4 to ensure that the Class A and SA standards are reached.

2.0 Description of the Study Area

The Crooked Brook watershed is located in the Town of Narragansett in the southern portion of the State of Rhode Island. Crooked Brook is a subwatershed of the Narrow River watershed. It is the second largest tributary to Pettaquamscutt Cove and the third largest tributary to Narrow River. The watershed is located on glacial till soils (Rector, 1977) with a water table generally close to the surface. Land use in this region falls into three categories: (a.) residential areas, including single and multi-family homes, condominiums, parks, and associated playing fields, which comprise 28% of the watershed, (b.) forest/wetlands, which comprise 68.4% of the watershed and, (c.) industrial/commercial areas, including restaurants, retail stores, auto shops, and a municipal garage, which comprise 3.6% of the watershed. The entire watershed is sewered and served by public water supplies.

Shown in Figure 1.1, Crooked Brook generally flows south to north. It originates as two distinct branches that merge and discharge to the Pettaquamscutt Cove section of Narrow River. The western branch, hereinafter referred to as Sprague Brook, originates in a wetland area, flows north, passing through two small ponds, then continues north into a hardwood swamp before joining the eastern branch. The eastern branch, hereafter referred to as upper Crooked Brook, is roughly 2.7 km long. Portions of the brook run dry during extended periods of drought. Upper Crooked Brook originates in a large forested wetland area remote from anthropogenic sources and flows northward passing by lightly to moderately developed residential neighborhoods. It eventually passes under Kingstown Road, and runs through a small park before entering the previously mentioned hardwood swamp. Sprague Brook and upper Crooked Brook join within the hardwood swamp then flow approximately 700 meters south to Pettaquamscutt Cove.

3.0 Present Condition of the Waterbody

3.1 Current Water Quality Conditions

Water quality has been a concern in the Narrow River watershed, which encompasses the Crooked Brook watershed, for many years. It has been documented that rapid land development within the Narrow River watershed has resulted in an increase of point and nonpoint sources. This concern motivated the accomplishment of two major studies to assess the impact of this development on Narrow River water quality. A component of each study incorporated the sampling of Narrow River tributaries, including Crooked Brook.

The first study was the Narrow River Stormwater Management Study Problem Assessment and Design Feasibility (ASA et al, 1995). The study was designed to characterize contamination from fecal coliform, TSS, and trace metals in Narrow River and to determine the magnitudes and locations of sources within the watershed. To evaluate contaminant loadings from Crooked Brook, one sampling station, D-8 shown in Figure 3.1, was chosen near the mouth where it discharges to Pettaquamscutt Cove. The data from the ASA et al. study is presented in Table 3.1.

The dry weather geometric mean for this data set is 96 fc/100 ml. Excluding the April and May data, the geometric mean was 482 fc/100 ml. These values are well above the 20 fc/100mL limit designated for Class A waters.

Table 3.1 ASA et al. study: dry weather fecal coliform results from station D-8

Date	fc/100 ml
4/21/93	9
5/15/93	8
6/28/93	660
8/6/93	500
9/25/93	340
Geometric mean of all data	96
Geometric mean of 6/93-9/93 data	482

Based on the data from ASA et al (1993), RIDEM conducted a supplemental monitoring program during the summer of 1999 in support of the Narrow River TMDL. The RIDEM study was designed to characterize fecal coliform contamination in Narrow River and to determine magnitudes and locations of sources within the watershed. To evaluate fecal coliform loadings from Crooked Brook and to initially bracket source areas, three locations (shown in Figure 3.2) were sampled. The data from RIDEM's study are presented in Table 3.2.

The dry weather geometric mean of observed fecal coliform concentrations at SW-23 was 527 fc/100 ml, at SW-28 it was 369 fc/100 ml, and at SW-27 it was 16 fc/100 ml. Additionally, one wet weather sample was obtained at SW-23. The observed wet weather concentration was 7000 fc/100 ml. Again, observed concentrations at all but SW-27 were well above standards. Because observed fecal coliform concentrations in the developed

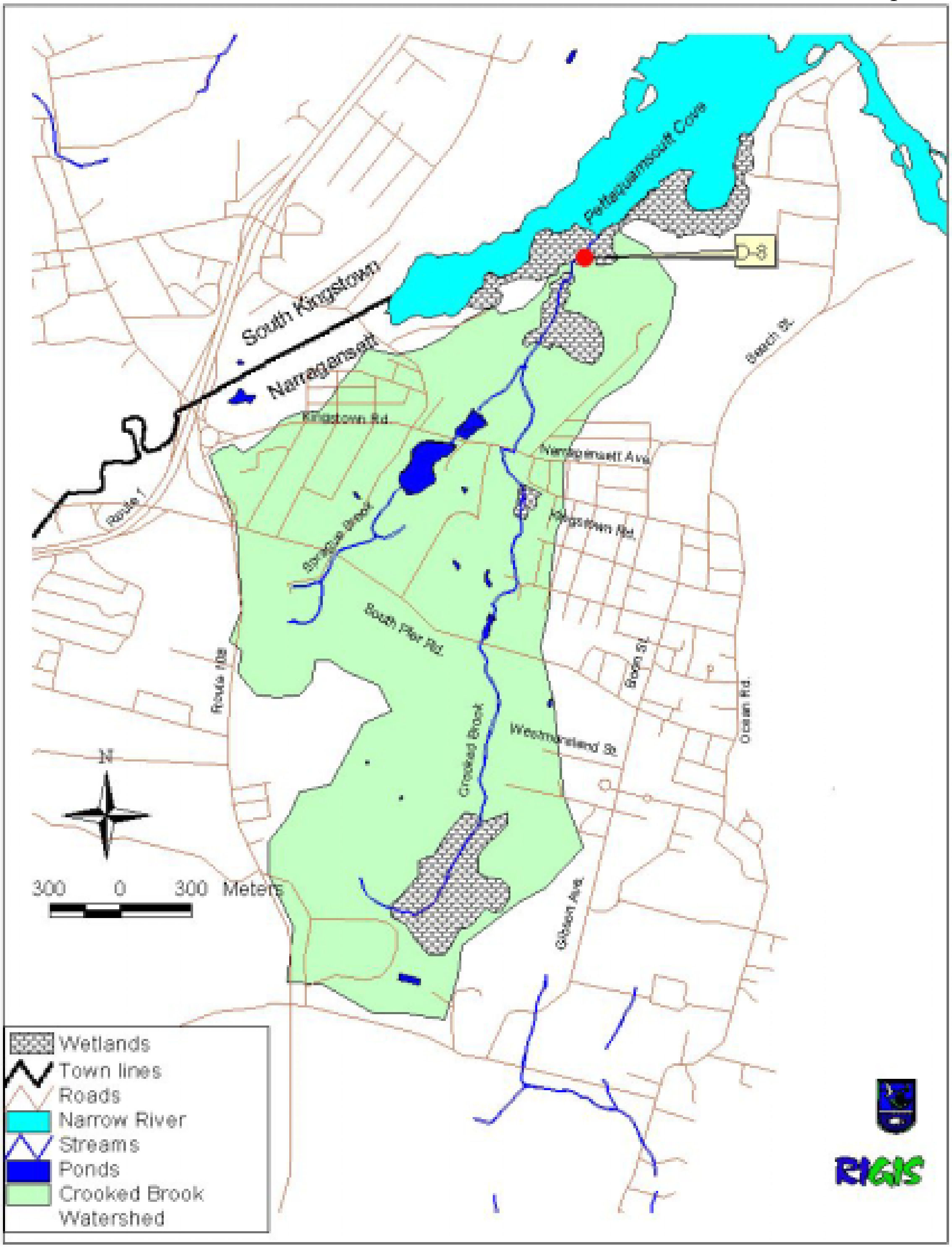

Figure 3.1 Sampling Station for the ASA et al. Study

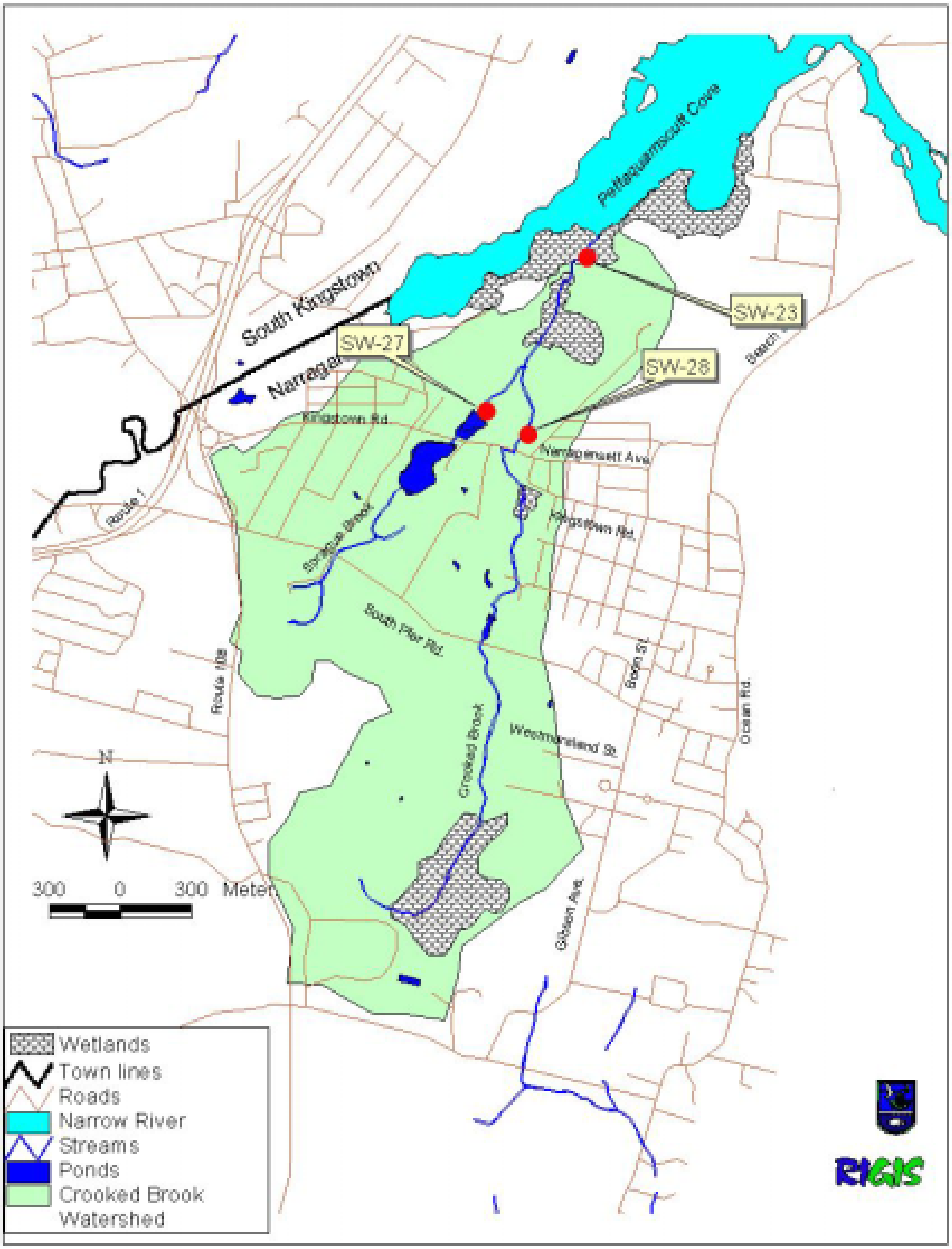

Figure 3.2 Sampling Stations for the 1999 RIDEM Narrow River Study

portion of the watershed (measured at SW-27 and SW-28) were consistently lower than observed concentrations immediately downstream of a remote hardwood swamp, it was considered likely that principal fecal coliform sources to the brook in the sampled reach were not anthropogenic.

Table 3.2 1999 RIDEM TMDL study: dry weather fecal coliform results by date and station

Date	fc/100ml by Station		
	SW-23	SW-27	SW-28
6/23/99	630	10	440
7/9/99	3700	10	600
7/22/99	1100	100	700
8/20/99	200	6	100
8/25/99	300	*	*
9/15/99	140	*	*
Geometric mean	527	16	369

* These stations not sampled on these dates

As a result of previous studies, Crooked Brook was listed in the 1998 and draft 2000 303(d) List of Impaired Waters. In 2001, RIDEM conducted additional monitoring in the brook to support the Crooked Brook TMDL. The study was designed to characterize fecal coliform contamination in Crooked Brook and to determine magnitudes and locations of sources within the watershed. To determine fecal coliform concentrations in the brook and to bracket source areas, thirteen locations (shown in Figure 3.3) were sampled. A brief description of the stations and their locations is given in Table 3.3. The data from RIDEM's study is presented in Table 4.1. The monitoring program consisted of three dry and one wet weather survey during the summer of 2001. The study methods and results are more fully explained in the TMDL data report (Appendix A).

To simplify the water quality characterization, the Crooked Brook watershed was divided into four segments (Figure 3.4). Segment delineations were chosen to group similar land uses and/or sources. Segment 1 comprises the upper Crooked Brook watershed south of South Pier Road. The area is predominantly forested with a small amount of low to medium density residential development. The segment includes stations CB-09 and CB-10 and has a weighted geometric mean of 1192 fc/100 ml. Segment 2 comprises the upper Crooked Brook watershed between South Pier Road and Kingstown Road. The segment is partially forested with some low to medium density residential development. A town park is located just north of Kingstown Road. The segment includes stations CB-03 through CB-08 and has a weighted geometric mean of 18587 fc/100 ml. Segment 3 comprises the Sprague Brook watershed. This area is located to the south of Kingstown Road. The segment is predominately low to medium density residential development along with a town baseball field and municipal garage. Two small ponds are located along this segment. Segment 3 includes stations CB-11 through CB-14 and has a weighted geometric mean of 45 fc/100 ml. Segment 4 is completely forested to near the mouth of the brook, running through a field of *Spartina sp*. before discharging to

Pettaquamscutt Cove. The segment includes stations CB-01 and CB-02 and has a weighted geometric mean of 1522 fc/100 ml.

Table 3.3 Crooked Brook bacteriological sampling locations.

ID	Name	Location	3.1.1.1.1.1.1.1.1 Rationale
CB-01	Power Lines	Discharge point to Pettaquamscutt Cove.	Establish total loading
CB-02	Swamp	Along nature path in hardwood swamp.	Establish loading within hardwood swamp
CB-03	Sprague Park	At culvert headwall in Sprague Park.	Establish loading coming from the southern branch of the brook
CB-04	Pier Ice Plant	Along the path near the bend in Kingstown road at the culvert headwall.	Possible input from road
CB-05	**Pre-Storm Drain**	**Along the path (see above) before the storm swale.**	Possible input from storm drain
CB-06	**Storm Swale**	**Sample within the storm swale.**	Determine fecal coliform concentrations within storm swale
CB-07	**Wooden Bridge**	**Past the storm swale at the wooden bridge.**	Establish loading upstream of storm drain
CB-08	**Rodman+Watson**	**The downstream side of the dirt driveway at culvert headwall.**	Possible input from horse boarding operation
CB-09	South Pier Rd.	At culvert headwall on upstream side of the road.	Possible input from road
CB-10	Westmoreland Rd.	Along the path at the end of Westmoreland Street at the downstream culvert headwall.	Determine "background" concentrations
CB-11	Sprague Pond	At headwall below Sprague Pond. Former station SW-28.	Determine effect of ponds on water quality
CB-12	Kingstown Rd.	At culvert discharge point at the top of Sprague Pond.	Ascertain differences in fecal coliform concentrations between two ponds including potential input from road
CB-14	South Pier +Lakewood	At culvert headwall on downstream side of South Pier Road.	Establish loading upstream of ponds including possible input from road

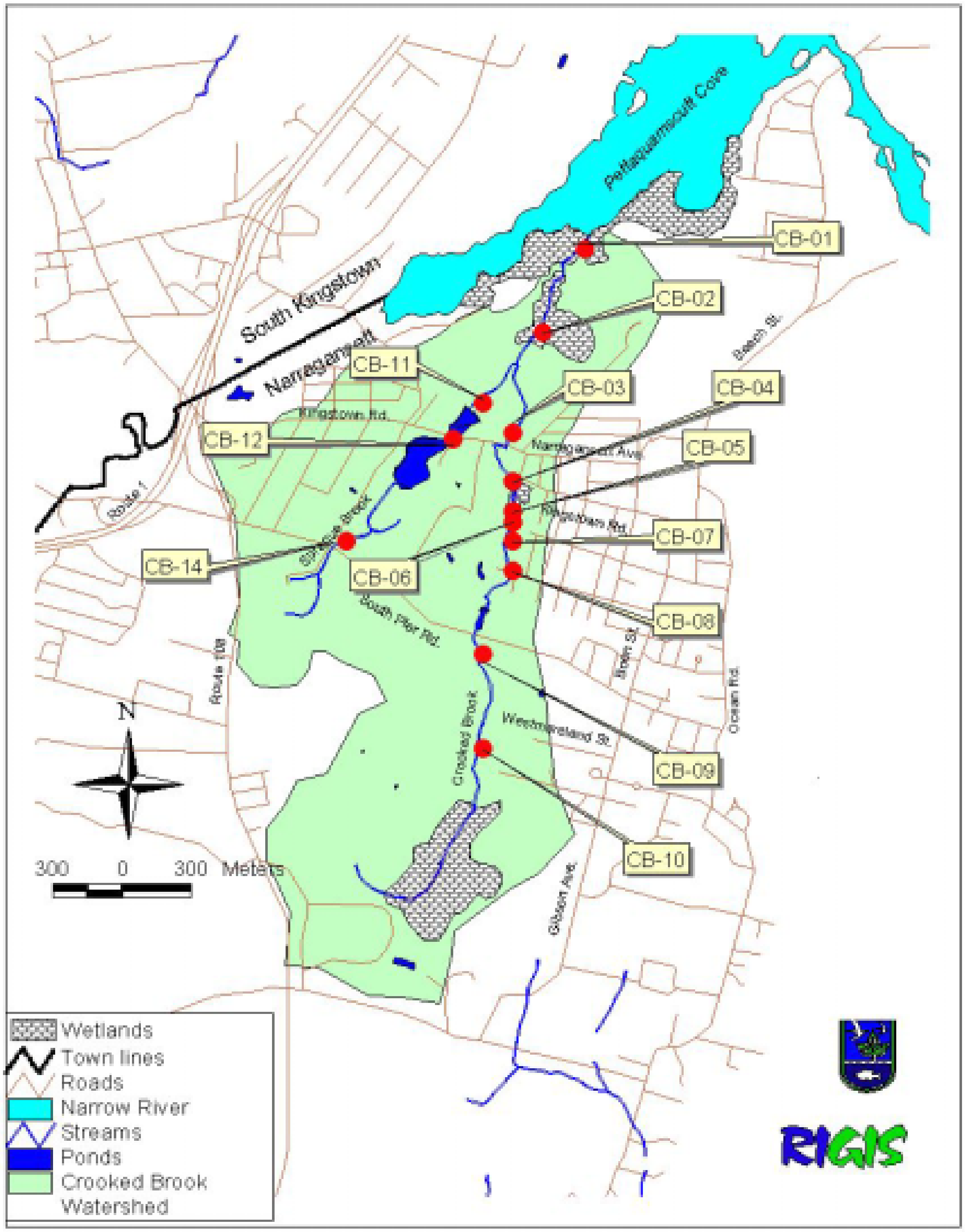

Figure 3.3 Station Locations Within the Crooked Brook Watershed

3.2 Pollution Sources

Identified sources vary by location. Segment 1 comprises the Crooked Brook watershed south of South Pier Road. No anthropogenic dry weather sources have been identified in this segment. In the absence of any identifiable human source, it has been concluded that dry weather fecal coliform loadings are wildlife related and therefore, uncontrollable. A storm sewer outfall at South Pier Road discharges substantial bacteria loads during wet weather.

Segment 2 comprises the Crooked Brook watershed between South Pier Road and Kingstown Road. Identified dry weather sources include a small horse boarding facility and wildlife. Wet weather inputs are dominated by stormwater runoff. This is especially evident in the area adjacent to the horse boarding facility where horse manure deposited and stored near the stream channel is washed into the brook during wet weather. Additionally, storm sewer outfalls located behind the Narragansett High School and along Kingstown Road contribute to the impairment.

Segment 3 encompasses the Sprague Brook branch of the watershed. This area is located to the south of Kingstown Road. The only identified dry weather sources are wildlife. Wet weather inputs are dominated by stormwater runoff entering the brook overland as sheet flow or through storm sewer outfalls located along Kingstown Road. This segment of the watershed has the lowest fecal coliform concentrations of the entire watershed. This is likely due to the influence of the two ponds where fecal coliform bacteria can settle out of the water column or die off from ultra violet radiation exposure from sunlight.

All station locations, bacteria concentrations, and sources are shown in Figure 3.4. Segment 4 includes the watershed area north of the park adjacent to Kingstown Road. This area is completely forested with the mouth of the brook running through a field of *Spartina sp*. before discharging to Pettaquamscutt Cove. No anthropogenic sources have been identified in close enough proximity to the brook to cause a significant impact to water quality. However, there is a dry and wet weather fecal coliform increase. Identified sources to the segment include wildlife and contributions from upstream segments. Additionally, the downstream fringe of the watershed is tidally influenced. Through the tidally driven water movement, bacteria may be washed off surrounding wetland plants and substrates and resuspended from bottom sediments leading to the increase in fecal coliform bacteria in this area.

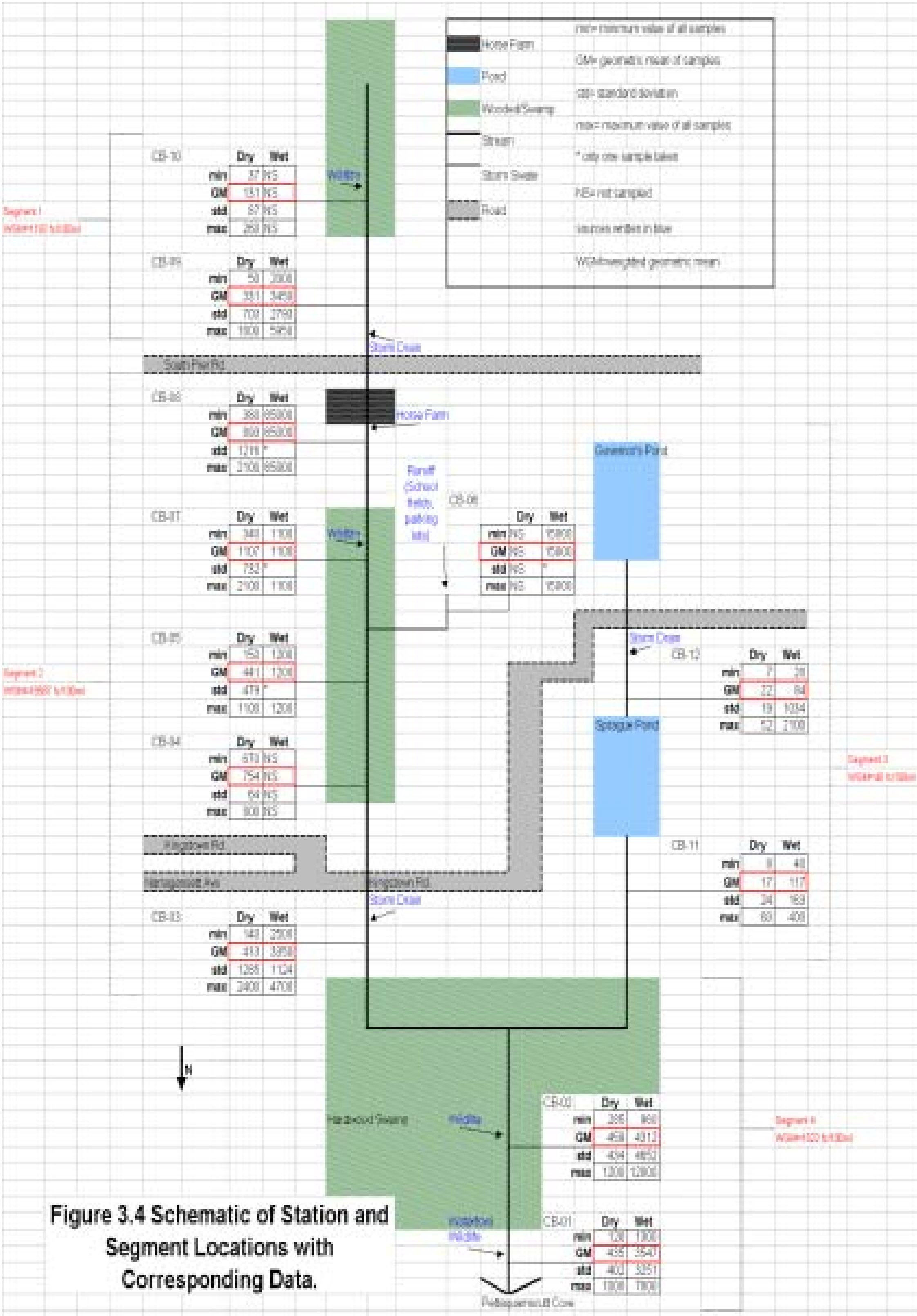

Figure 3.4 Schematic of Station and Segment Locations with Corresponding Data

3.3 Natural Background Conditions

Natural background concentrations are those that would exist in the area in the absence of human-induced sources. It was not possible to separate natural background from the total nonpoint source load due to a lack of site specific data on fecal coliform contributions from wildlife in the watershed. Observed concentrations in remote areas of the Crooked Brook Watershed indicated that background concentrations during dry weather are between 17 and 435 fc/100 ml and between 117 and 3547 fc/100 ml during wet weather. These conditions are above those allowed for a Class A waterbody.

3.4 Water Quality Impairments

Based on data gathered during the 2001 TMDL study, every segment of Crooked Brook violates the Class A fecal coliform standard.

4.0 TMDL Analysis

4.1 *Establishing a numeric water quality target*

MOS (Margin of Safety)

The MOS may be incorporated into the TMDL in two ways. One can implicitly incorporate the MOS using conservative assumptions to develop the allocations or explicitly allocate a portion of the TMDL as the MOS. This TMDL uses the former approach of conservative assumptions to ensure an adequate MOS. The primary sources of fecal coliform in the Crooked Brook watershed are nonpoint in nature. Because nonpoint source loadings, especially bacteria loadings, are inherently difficult to quantify with any certainty, this TMDL uses the following assumptions:

- The watershed was evaluated during the critical summer conditions when bacteria pollution contamination is most problematic.
- No allowances were made for bacterial decay.
- Conservative estimates of both the amount of rainfall needed to produce runoff and recovery of the watershed were used in the weighted geometric mean calculations.

Seasonal Variation/Critical Conditions

The required reductions were determined for the summer conditions when fecal coliform concentrations are typically the highest. The allocations and reductions, therefore protect designated uses during all seasons.

Numeric Water Quality Target

The water quality target for Crooked Brook is set at the state's Class A fecal coliform standard, which is a geometric mean of 20 fc/100 ml with a 90^{th} percentile concentration no greater than 200 fc/100 ml. It is assumed that the conservative assumptions mentioned previously will provide an adequate implicit MOS. Additionally, Crooked Brook must meet the more stringent Class SA fecal coliform standard, which is a geometric mean of 14 fc/100 ml with a 90^{th} percentile concentration of 49 fc/100 ml at the discharge point to Narrow River.

4.2 Establishing the Allowable Loading (TMDL)

As described in EPA guidelines, a TMDL identifies the pollutant loading that a waterbody can assimilate per unit of time without violating water quality standards (40 C.F.R. 130.2). The loadings are required to be expressed as mass per time, toxicity, or other appropriate measures (40 C.F.R. 130.2[I]). EPA Region 1 has determined that it is appropriate to express a bacteria TMDL in concentration units. The loading capacity for this TMDL is therefore expressed as a concentration set equal to the state water quality standard.

Extensive field surveys, water quality monitoring, and review of aerial photos/topographic maps were used to establish the link between pollutant sources and instream concentrations.

The reduction goal for each segment was determined by comparing current fecal coliform concentrations to the applicable water quality target, then calculating the percent reduction required to reach that target. Since the water quality regulations specify both a geometric mean criterion and a 90th percent criterion, two calculations are made at each location. The three step process is outlined below.

Comparison of the weighted geometric mean to the geometric mean standard

Current bacteria conditions in Crooked Brook were determined as a “weighted geometric mean” value that is the compilation of the wet and dry weather geometric means, weighted by their probability of occurrence. The amount of precipitation needed to produce runoff in the watershed was first determined. Any precipitation event in the watershed that produces runoff adequate to substantially impact water quality was considered to be a "wet" weather condition. Based on data collected in the Narrow River watershed, this amount of runoff can be expected from a 0.30-inch precipitation event. The Crooked Brook watershed is within the Narrow River watershed, therefore the 0.30-inch runoff criteria used for the Narrow River was deemed appropriate for the Crooked Brook watershed. The frequency of occurrence of precipitation events on an annual basis was determined by examining 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. It was determined that wet weather days occur 13.8% percent of the time, and dry weather days occur 86.2% percent of the time.

The overall percentage of wet weather days was adjusted to include recovery time (time required for the instream fecal coliform concentrations to return to pre-storm levels). Analysis of wet weather data for the Crooked Brook watershed shows that an additional day is required for in-stream fecal coliform concentrations to decrease to pre-storm levels. To account for this additional day, the percentage was doubled, making the percent of wet weather days equal to 27.6% and the percent of dry weather days equal to 72.4%. This takes into consideration wet weather bacteria elevations not only for the day of the storm but also for the additional day it takes for the system to recover. The weighted geometric mean value is then compared to the geometric mean portion of the applicable standard to determine if a violation has occurred.

Comparison of the combined dataset's 90th percentile value to the percent exceedence standard

The second part of the fecal coliform standard states that, in Class A waters, "*not more than 10% of the samples shall exceed a value of 200 MPN/100 ml*". To address this second portion of the fecal coliform standard, a second calculation was made. The 90th percentile value at each station was calculated from the combined set of wet and dry weather sample results using the PERCENTILE function in Microsoft Excel. This value was then compared to the applicable target to determine if a violation had occurred.

Calculation of required reductions

The weighted geometric mean and the 90th percentile were calculated as described above. These values were then compared to the applicable portion of the standard. Required reductions were specified that ensured both parts of the standard were met.

4.3 *Required reductions (Load Allocation/WLA)*

Other than the four known storm sewer outfalls, there are no point sources to Crooked Brook. The required fecal coliform reductions for Crooked Brook are presented in Table 4.1. They are calculated from observed concentrations at instream stations and represent a reduction goal that is applicable to the composite of all point and nonpoint sources contributing to the water quality impairment. For each station within a stream segment, a weighted geometric mean and a 90th percentile value was calculated. The station that had the largest violation relative to the state's fecal coliform standard was used to calculate an instream percent reduction for the reach that contained that station. The right hand column in Table 4.1 represents the instream/source reduction needed to meet the numeric target for each segment. As such, these reductions serve as both a load allocation and a waste load allocation. The reduction calculation for segment 2 does not include station CB-06 because it was not representative of the reach where it was located. Station CB-06 was sampled within a storm drain swale, therefore it is not an instream station.

4.4 Strengths and Weaknesses in the TMDL Process

Strengths:

- The TMDL is based on an extensive knowledge of land use and potential bacteria sources in the watershed.
- The TMDL incorporates the findings of several studies and utilizes data collected over several years.
- The TMDL endpoints presented in the load allocation sections allow water quality standards to be met in critical conditions.
- The phased approach allows an emphasis on mitigation strategies rather than on modeling and more complex monitoring issues to keep the focus on removing sources.
- The watershed is small and fairly accessible, therefore RIDEM was able to visually inspect nearly the entire length of the brook.
- The TMDL is based on actual data collected in the watershed.

Weaknesses:

- Due to relatively dry seasonal conditions in the watershed, the wet weather event was not ideal. Even though the minimum rainfall amount (0.3 inches) was reached, some areas of the watershed did not collect enough water to sample.
- The study only incorporates one wet weather event.
- It can not be assumed that instream concentrations in each segment can be reduced below the natural background conditions.

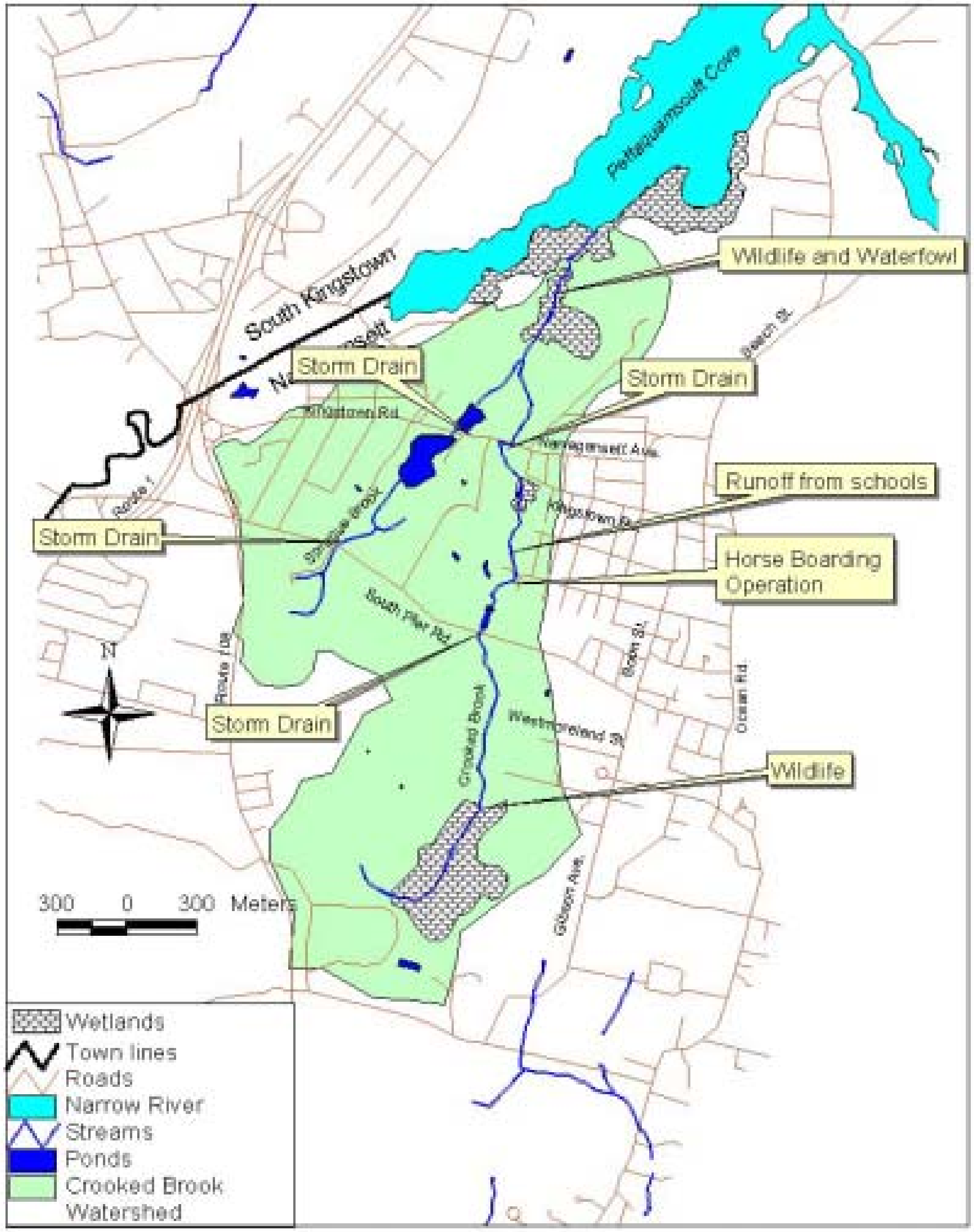

Figure 4.1 Source Identification in the Crooked Brook Watershed

Table 4.1 Required reductions for the Crooked Brook Watershed by station .

Segment number	Stations	Target 90th percentile concentration (fc/100 ml)	Observed 90th percentile concentration (fc/100 ml)	Target geometric mean concentration (fc/100 ml)	Observed dry weather geometric mean concentration (fc/100 ml)	Observed wet weather geometric mean concentration (fc/100 ml)	Segment weighted geometric mean concentration (fc/100 ml)	% Reduction required to meet water quality target
1	**CB-09**	200	3580	20	331	3450	**1192**	98
	CB-10	200	220	20	131	NF		
Segment number	Stations	Target 90th percentile concentration (fc/100 ml)	Observed 90th percentile concentration (fc/100 ml)	Target geometric mean concentration (fc/100 ml)	Observed dry weather geometric mean concentration (fc/100 ml)	Observed wet weather geometric mean concentration (fc/100 ml)	Segment weighted geometric mean concentration (fc/100 ml)	% Reduction required to meet water quality target
2**	CB-07	200	1860	20	1088	1100	**18587**	99+
	CB-08	200	52420	20	893	65000		
	CB-03	200	3950	20	413	3350		
	CB-04	200	791	20	738	NF		
	CB-05	200	1170	20	441	1200		
Segment number	Stations	Target 90th percentile concentration (fc/100 ml)	Observed 90th percentile concentration (fc/100 ml)	Target geometric mean concentration (fc/100 ml)	Observed dry weather geometric mean concentration (fc/100 ml)	Observed wet weather geometric mean concentration (fc/100 ml)	Segment weighted geometric mean concentration (fc/100 ml)	% Reduction required to meet water quality target
3	CB-11	200	239	20	17	117	45	70
	CB-12	200	**672**	20	22	84		
	CB-14	200	NF	20	NF	NF		
Segment number	Stations	Target 90th percentile concentration (fc/100 ml)	Observed 90th percentile concentration (fc/100 ml)	Target geometric mean concentration (fc/100 ml)	Observed dry weather geometric mean concentration (fc/100 ml)	Observed wet weather geometric mean concentration (fc/100 ml)	Segment weighted geometric mean concentration (fc/100 ml)	% Reduction required to meet water quality target
4	**CB-01**	49	**5760**	14	435	3547	1522	99
	CB-02	200	8430	20	459	4312		

* Station and data from which reduction was calculated in bold print
** Station CB-06 left out of calculation because not an instream station
NF = No Flow

4.5 Supporting documentation

Recent water quality studies considered significant to this TMDL are presented in Table 4.2. These references were used to characterize the present water quality conditions or identify water quality trends.

Table 4.2 Supporting documentation.

Primary Organization or Authors	Title	Date of Report	Approximate Date of Study
RIDEM	Fecal Coliform TMDL for the Narrow (Pettaquamscutt) River Watershed, Rhode Island	2001	Spring 1999
Applied Science Associates, RI Watershed Watch, SAIC Engineering Inc., UWR (Urish, Wright, and Runge)	Narrow River Stormwater Management Study Problem Assessment and Design Feasibility	1995	Spring 1992
Simmons and Nevins	Water Quality in the Crooked Brook Watershed	1989	Fall 1989

5.0 Implementation

Recommended remedial measures to bring about water quality improvements in the Crooked Brook watershed are summarized in Table 5.1. This TMDL relies upon phased implementation to reach water quality goals. As BMPs are installed, the corresponding response in fecal coliform bacteria concentrations will be measured. As appropriate, additional measures will be required to control anthropogenic sources.

Because bacteria sources to Crooked Brook are primarily non-point in nature, RIDEM feels that significant reductions can be achieved through simple good housekeeping efforts of the municipalities and local residents. Good housekeeping measures include minimizing fertilizer applications, periodic street sweeping, policing pet waste, and discouraging waterfowl from residing in specific areas.

Additionally, three other areas of concern were noted within the watershed. At station CB-14, which is along South Pier Road (see Figure 3.3), an abundance of sand from wintertime street sanding activities was noticed in the stream channel. It is recommended that more frequent street sweeping be conducted to minimize the amount of sand and sediment being introduced to the stream. Station CB-04 through station CB-07 are located along a path which connects Kingstown Road with the local high school. This path is located on the Town of Narragansett's property. It was observed that an abundance of litter was collecting in this area. It is recommended that maintenance and policing of this area take place to minimize the amount of trash dumping taking place in this area.

Horse farm
The horse farm on upper Crooked Brook is a significant bacteria source immediately upstream of station CB-08. The BMPs proposed below will address the pathogen contributions to the brook from the pasture area and will reduce both dry and wet weather impacts. A description of the BMPs recommended for the horse farm is provided below:

1. Create a buffer around the stream to keep horses away and to reduce the introduction of bacteria to the stream from manure on the ground. This would include the installation of fencing on both sides of the stream to create a buffer. Natural vegetation should be allowed to grow in the buffer area to enhance retention of bacteria in the buffer area. A bridge should be installed to allow horses to access both sides of the stream.
2. Move and cover the manure pile that is presently adjacent to the stream so bacteria will not be washed off the pile and into the stream by rain or snowmelt.
3. Runoff from the horse barn should be diverted away from the area of the manure pile and grazing area so that overland runoff and the resulting wet weather bacteria loadings are minimized.

Stormwater
RIDEM has reviewed current stormwater BMP technologies, and many appear to be effective at removing total suspended solids (TSS). Although bacteria may attach to solids and the removal of solids may reduce the amount of bacteria in storm water, significant concentrations of fecal coliform bacteria may still exist in runoff low in TSS. A review of the effectiveness several conventional structural BMPs is provided in Table 5.2. It should be noted that BMPs must be extremely efficient if they are to produce storm outflows that meet the 20 fc/100ml standard for fecal coliform bacteria from a site. Given existing stormwater fecal coliform levels equivalent to the national mean of 15,000 fc/100ml (CWP 1999), so watershed practices may need to achieve a 99+% removal rate to meet standards. To date, performance monitoring studies research has indicated that no stormwater practice can reliably achieve a 99% removal rate of any urban pollutant on a consistent basis.

Table 4.1 indicates that removal rates of up to 99+% are needed to achieve water quality goals in Crooked Brook. Because reductions are higher than can be achieved through conventional structural stormwater BMPs alone, a combination of structural and nonstructural BMPs, shown in Table 5.3, should be implemented. The effectiveness of combined measures cannot be predicted, so this TMDL is phased to allow the effectiveness of each measure to be determined through continued monitoring.

Table 5.1 Suggested remedial measures by station.

Description of Impacted Area	Causes of Impairment	Station Number	Abatement Measure	Status
Stream channel running through Sprague Park	Storm drain discharge from Kingstown Road, pet waste	CB-03	Non structural/structural stormwater BMP, enforce existing town pet ordinances	Targeted for future BMP
Stream channel passing behind Pier Ice Plant	Overland stormwater runoff coming from Kingstown Road	CB-04	Non structural/structural stormwater BMP	Targeted for future BMP
Storm swale passing by high school	Run off from middle and high school parking lots and associated fields	CB-06	Non structural/structural stormwater BMP	Targeted for future BMP
Stream channel passing by Horse farm	Run off collecting bacteria from horses and associated pasture area	CB-08	Agricultural BMP including manure and runoff management, deter horses from stream	RIDEM Div. Of Agriculture has contacted property owner to devise effective management strategy
Stream channel upstream of South Pier Road	Storm drain discharge from South Pier Road	CB-09	Non structural/structural stormwater BMP	Targeted for future BMP
Kingstown Road outfall to Sprague Pond	Storm drain discharge from Kingstown Road, pet waste	CB-12	Non structural/structural stormwater BMP, enforce existing town pet ordinances	Targeted for future BMP

Table 5.2 Effectiveness of conventional stormwater BMPs in reducing bacteria concentrations in runoff.

BMP	Reduction in Fecal Coliform	Reduction in Fecal Streptococci	Reduction in E. coli
Detention 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.

Phase II stormwater management
As mandated by EPA, RIDEM is required to amend the existing Rhode Island Pollution Discharge Elimination System (RIPDES) regulations to include Phase II Storm Water Regulations. The new regulations became effective in 2002. Automatically designated municipalities must develop a storm water management program plan (SWMPP) that describes the Best Management Practices (BMPs) for each of the following minimum control measures:

1. A public education and outreach program to inform the public about the impacts of storm water on surface water bodies,
2. A public involvement/participation program,
3. An illicit discharge detection and elimination program,
4. A construction site storm water runoff control program for sites disturbing more than 1 acre,
5. A post construction storm water runoff control program for new development and redevelopment sites disturbing more than 1 acre and
6. A municipal pollution prevention/good housekeeping operation and maintenance program.

The SWMPP must include measurable goals for each control measure (narrative or numeric) that may be used to gauge the success of the program. It must also contain an implementation schedule that includes interim milestones, frequency of activities and reporting of results. The Director can require additional permit requirements based on the recommendations of a TMDL.

Operators of municipal separate storm sewer systems (MS4s) in urbanized areas (UAs) or densely populated areas (DPAs) will be required to develop a SWMPP and obtain a permit (for those portions within the UA or DPA) by March 10, 2003. DPAs include places that have equal to or greater than 1,000 people per square mile and have, or are part of, a block of contiguous census designated places with a total population of at least 10,000 people, as determined by the latest Decennial Census. The Director will also require permits for MS4s that contribute to a violation of a water quality standard, are significant contributors of pollutants to waters of the State or that require storm water controls based on waste load allocations (WLAs) determined through a TMDL.

The MS4s that discharge to Crooked Brook are owned and operated by the Town of Narragansett or by the Rhode Island Department of Transportation (RIDOT). Based on the latest census data, the Crooked Brook watershed is within the Narragansett DPA. Accordingly, the Town of Narragansett and/or RIDOT will be required to apply for a RIPDES permit for their MS4s within the DPA by March 10, 2003. The Director will require that the SWMPPs contain provisions that address the drains identified in Table 5.1 through a phased approach: six minimum measures followed by monitoring to determine the need for structural BMPs.

Because available land and funding for BMPs is limited and because only a limited number of technologies are effective at removing fecal coliform from run off, it will take some creativity to find viable solutions. RIDEM will assist the town in evaluating locations and designs for storm water control BMPs in an effort to mitigate wet weather bacteria loadings. It is difficult to quantify the improvements that may be attained by applying storm water BMPs with any real certainty. The TMDL calls for continued monitoring of Crooked Brook to ensure that water quality targets are met as remedial actions are implemented

Table 5.3 Effectiveness of manufactured and agricultural stormwater 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* and approximately 50% removal of fecal coliform.
NRCS Nutrient and 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, biological, and chemical processes for the removal of sediment and nutrients.	Livestock and pasture runoff as well as urban stormwater runoff	Removes 90-100% of TSS*.
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 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 the 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*.

Source: Innovative Stormwater Treatment Products and Services Guide. Prepared for the Stormwater Technologies Trade Show by USDA Natural Resources Conservation Service Community Assistance Partnership.

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

6.0 Public Participation

A public meeting was held on August 21st 2002 following the EPA initial review. The draft 2001 Crooked Brook TMDL was presented for public review and comment. Following the presentation, the public was given a 30-day period in which to submit comments on the study and its findings. Comments were made during the public meeting (Appendix B2), but no significant changes were required to address said comments. No additional comments were received during the 30 day period following the meeting.

7.0 Follow Up Monitoring

This is a phased TMDL. Additional monitoring is required to ensure that water quality objectives are met as remedial actions are accomplished. Monitoring by RIDEM will be the principle method of obtaining the data necessary to track water quality conditions in the watershed. Also, as proposed BMPs are installed in the watershed, post construction influent and effluent sampling will be required to assess the effectiveness of the selected technology.

Periodic monitoring should continue at a minimum of three stations to ensure that progress is being made toward the water quality targets for Crooked Brook. Station CB-09 and CB-08, which brackets off the area around the horse boarding facility, will be sampled to characterize the success of the agricultural BMPs put in place at the horse boarding facility. Station CB-03 downstream of Kingstown Road will be sampled to monitor the condition of the brook downstream of the reach receiving storm drain inputs.

8.0 References

Applied Science Associates, Rhode Island Watershed Watch, SAIC Engineering Inc., UWR (Urish, Wright, and Runge), 1995. *Narrow River Stormwater Management Study Problem Assessment and Design Feasibility*.

CWP. 1999. *Center For Watershed Protection*. Vol. 3. No. 1. April.

EPA, 1993. *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters*, U.S. Environmental Protection Agency.

RIDEM,1997. *Water Quality Regulations*, Rhode Island Department of Environmental Management, Office of Water Resources. Providence, RI.

RIDEM, 2001. *Fecal Coliform TMDL for the Narrow (Pettaquamscutt) River Watershed*, Rhode Island Department of Environmental Management. Office of Water Resources. Providence RI.

Simmons and Nevins, 1989. *Water Quality in the Crooked Brook Watershed*. Unpublished from University of Rhode Island, CVE 590X. Kingston, RI.

Appendix A: Final Data Report for the Crooked Brook Fecal Coliform TMDL
(Waterbody ID Number RI0010044R-03)

Prepared By:

Office of Water Resources
Rhode Island Department of Environmental Management
235 Promenade St.
Providence, RI 02908

November 2001

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 Introduction

Crooked Brook has been listed in Rhode Island's draft 2000 303(d) List of Impaired Waters for violating Rhode Island's fecal coliform standards. Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) requires States to develop Total Maximum Daily Loads (TMDLs) for waterbodies that are not meeting water quality standards. The objective of a TMDL is to establish water-quality-based limits for pollutant loadings that allow the impaired waterbody to meet standards.

The Crooked Brook watershed is located in the Town of Narragansett in the southern portion of the State of Rhode Island as shown in Figure 1.1. The watershed is located on glacial till soils (Rector, 1977). The aquifer is composed of unconfined glacial till with a water table generally close to the surface. Land use in this region falls into three categories: a.) residential areas, which include single and multi family homes, condominiums, parks, and associated playing fields, b.) forested/wetland, and c.) industrial/commercial, which includes restaurants, retail stores, auto shops, and a municipal garage. Residential areas comprise about 28% of the total watershed, forested/wetland comprise 68.4% of the total watershed, and industrial/commercial areas make up the remaining 3.6%. The entire watershed is sewered and served by public water supplies.

Crooked Brook is a subwatershed of the larger Narrow River watershed. Crooked Brook generally flows south to north. It originates as two distinct streams that merge and discharge to the Pettaquamscutt Cove section of Narrow River. The eastern stream will be referred to as Sprague Brook. This stream originates in a wetland area, flows north, passing through two small ponds, then continues north into a hardwood swamp before joining the western stream. The western stream will be referred to as Crooked Brook. Crooked Brook is long, meandering, and portions typically run dry during extended periods of drought. It originates in a large forested area remote from anthropogenic sources. It flows northward passing by light to moderately developed residential neighborhoods. It eventually passes under Kingstown Road in Narragansett and runs through a small park before entering the previously mentioned hardwood swamp. Within the hardwood swamp, the two sections of Crooked Brook join then flow approximately six hundred meters south to Pettaquamscutt Cove.

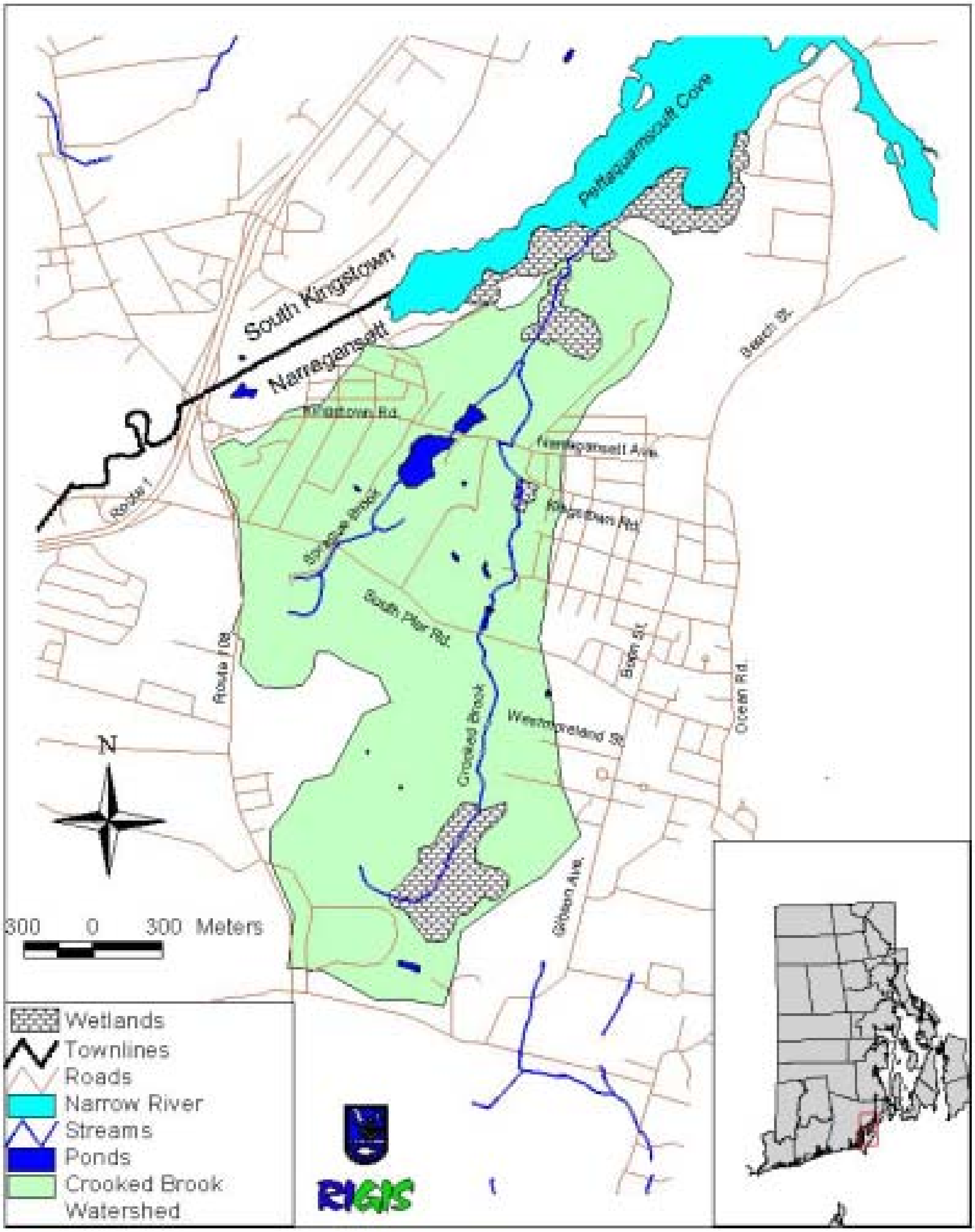

Figure 1.1 Crooked Brook Locus Map

2.0 Methods

The TMDL study was conducted in accordance with a quality assurance project plan (QAPP) that had been previously approved by EPA. The sampling program was based on information proved by earlier studies listed in Table 2.1 and on site visits by RIDEM staff. The sampling program consisted of water sample collections at 13 locations in the Crooked Brook watershed. Three dry weather studies and one wet weather study were conducted. One deviation was made from the approved plan. The rainfall amount considered suitable for a wet weather event was reduced from a 0.5" rainfall accumulation to 0.3". This change was made because historic data had indicated that a rainfall of at least 0.3" would result in elevated in-stream bacterial concentrations in the Narrow River.

Table 2.1 Supporting documentation.

Primary Organization or Authors	Title	Date of Report	Approximate Date of Study
RIDEM	Fecal Coliform TMDL for the Narrow (Pettaquamscutt) River Watershed, Rhode Island	2001	Spring 1999
Applied Science Associates, RI Watershed Watch, SAIC Engineering Inc., UWR (Urish, Wright, and Runge)	Narrow River Stormwater Management Study Problem Assessment and Design Feasibility	1995	Spring 1992
Simmons and Nevins	Water Quality in the Crooked Brook Watershed	1989	Fall 1989

2.1 Sampling stations

Sample sites selected for this study (see Figure 2.1) were chosen throughout the Crooked Brook watershed based on their proximity to potential sources such as road crossings or storm drains. Other factors influencing the selection of sample sites included accessibility and the potential for tidal influences. Table 2.2 gives each sampling station with a description of its location.

2.2 Dry weather sampling program

Crooked Brook was sampled on three independent dry weather occasions. Dry weather was defined as:

- Less than 0.03 inches of rainfall during the previous three days to a sampling event and
- Less than 0.5 inches of rainfall during the previous seven days prior to a sampling event.

The 0.03 inches/3 days guideline is based on the premise that negligible runoff would result from this amount of rainfall. The 0.5 inches/7days guideline reflects the RIDEM Shellfish program definition of dry weather conditions.

All thirteen stations were sampled on each individual survey day. Sampling was conducted downstream to upstream to minimize the potential of obtaining samples disturbed by sampling activities. Additional sampling was accomplished in the immediate vicinity of the horse boarding operation (stations CB-07, CB-08, and CB-09) to better characterize this source. Collected samples were analyzed for fecal coliform by BAL using the mTEC method. The results of the dry weather sampling studies are tabulated in Table 2.3.

Table 2.2 Crooked Brook bacteriological sampling locations.

ID	Name	Location	Rationale
CB-01	Power Lines	Discharge point to Pettaquamscutt Cove.	Establish total loading
CB-02	Swamp	Along nature path in hardwood swamp.	Establish loading within hardwood swamp
CB-03	Sprague Park	At culvert headwall in Sprague Park.	Establish loading coming from the southern branch of the brook
CB-04	Pier Ice Plant	Along the path near the bend in Kingstown road at the culvert headwall.	Possible input from road
CB-05	**Pre-Storm Drain**	**Along the path (see above) before the storm swale.**	Possible input from storm drain
CB-06	**Storm Swale**	**Sample within the storm swale.**	Determine fecal coliform concentrations within storm swale
CB-07	**Wooden Bridge**	**Past the storm swale at the wooden bridge.**	Establish loading upstream of storm drain
CB-08	**Rodman+Watso n**	**The downstream side of the dirt driveway at culvert headwall.**	Possible input from horse boarding operation
CB-09	South Pier Rd.	At culvert headwall on upstream side of the road.	Possible input from road
CB-10	Westmoreland Rd.	Along the path at the end of Westmoreland Street at the downstream culvert headwall.	Determine "background" concentrations
CB-11	Sprague Pond	At headwall below Sprague Pond. Former station SW-28.	Determine effect of ponds on water quality
CB-12	Kingstown Rd.	At culvert discharge point at the top of Sprague Pond.	Ascertain differences in fecal coliform concentrations between two ponds including potential input from road
CB-14	South Pier +Lakewood	At culvert headwall on downstream side of South Pier Road.	Establish loading upstream of ponds including possible input from road

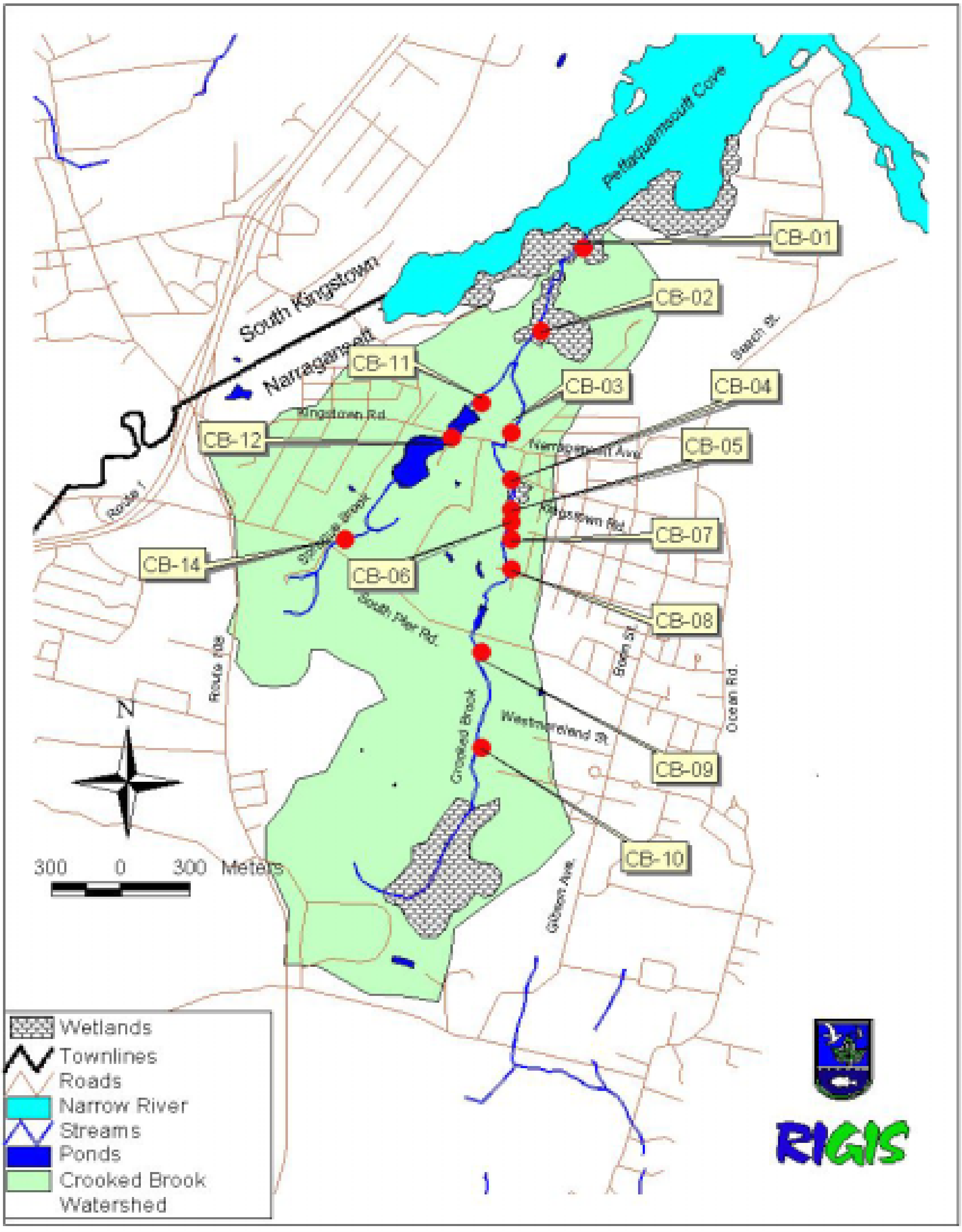

Figure 2.1 RIDEM 2001 Crooked Brook Sampling Stations

Table 2.3 RIDEM 2001 Crooked Brook dry weather sampling dates with the corresponding data and stage measurement.

Date	Time	Station	Stage	fc/100ml
7/17/01	9:45	CB-01	0.54	370
8/1/01	10:20	CB-01	0.50	810
8/10/01	15:00	CB-01	0.31	1000
8/11/01	17:35	CB-01	0.43	120
7/17/01	10:06	CB-02	0.43	285
8/1/01	10:45	CB-02	0.43	360
8/10/01	15:15	CB-02	0.44	1200
8/11/01	17:49	CB-02	0.43	360
7/17/01	10:10	CB-03	0.47	140
8/1/01	10:50	CB-03	0.46	210
8/10/01	15:20	CB-03	0.49	2400
7/17/01	10:15	CB-04	0.54	800
8/1/01	10:55	CB-04	0.53	710
8/10/01	NF	CB-04	NF	NF
7/17/01	10:17	CB-05	NS	150
8/1/01	10:59	CB-05	NS	1100
8/10/01	15::26	CB-05	NS	520
7/5/01	1352	CB-07	NS	1400
7/17/01	10:19	CB-07	0.65	340
8/1/01	11:01	CB-07	0.63	1400
8/10/01	15:27	CB-07	NS	1500
7/17/01	NF	CB-08	NF	NF
8/1/01	11:25	CB-08	0.89	380
8/7/01	0838	CB-08	NS	2100
8/10/01	NF	CB-08	NF	NF
7/5/01	1402	CB-09	NS	1800
7/17/01	10:40	CB-09	0.98	50
8/1/01	11:32	CB-09	0.99	260
8/7/01	0843	CB-09	NS	650
8/10/01	15:41	CB-09	NS	260
7/17/01	10:56	CB-10	0.52	215
8/1/01	11:45	CB-10	0.52	135
8/10/01	15:49	CB-10	NS	150
7/17/01	11:04	CB-11	0.16	10
8/1/01	11:54	CB-11	0.16	60
8/10/01	15:56	CB-11	0.16	20
8/11/01	18:01	CB-11	0.14	7.5
7/17/01	11:09	CB-12	0.46	30
8/1/01	12:00	CB-12	0.44	52
8/10/01	16:06	CB-12	0.46	20
8/11/01	18:10	CB-12	0.44	7

NS = not sampled,
CB-06 and CB-14 never had flow during dry weather.
NF = not sampled due to no flow

2.3 Wet weather sampling program

The purpose of the wet weather monitoring program was to determine the cause-effect relationship between stormwater related fecal coliform loadings and in stream water quality and to estimate the recovery rate of the receiving water. Wet weather was considered to be:

- After considering historical data, precipitation of at least 0.3 inches within a 24 hour period was considered wet weather.
- An antecedent dry period of at least three days.

The 0.3 inches or greater of rain guideline is based on the assumption that sufficient runoff would result from this amount of precipitation to ensure contributions from a majority of the watershed. The antecedent dry period was determined after a review of previous water quality data for a stream this size indicated that three days was sufficient time for instream conditions to return to pre-storm conditions. The new accumulated rainfall and antecedent dry period guidelines represent changes to the sampling plan (QAPP) that were made after its approval.

All stations with flow were sampled prior to the arrival of the storm, multiple times throughout the storm event, and again 24 hours after the beginning of the storm. Table 2.4 shows stations with the proposed sampling intervals. Due to an extended period of dry weather prior to the wet weather event, much of the Crooked Brook portion of the watershed had run dry. Only stations CB-01, CB-02, CB-11, and CB-12 were sampled throughout the proposed sampling regime. The remaining stations were sampled only when there was water flowing in the channel. Station CB-14 never developed enough flow to be sampled. The samples were analyzed for fecal coliforms by Biological Analytical Laboratories (BAL) using the mTEC method. The wet weather sampling data are tabulated in Table 2.4.

Table 2.4 RIDEM 2001 Crooked Brook wet weather sampling dates with corresponding data, time of sampling, and stage.

Date	Time	Proposed Sampling Time (hour after 1st flush)	Station	Stage	FC/100ml
8/10/01	15:00	PS	CB-01	0.31	1,000
8/10/01	17:54	1st Flush	CB-01	NS	4,400
8/10/01	20:10	2	CB-01	0.52	7,800
8/11/01	6:24	12	CB-01	0.53	1300
8/10/01	15:15	PS	CB-02	0.44	1,200
8/10/01	18:10	1st Flush	CB-02	0.43	12,000
8/10/01	21:07	2	CB-02	0.41	6900
8/10/01	22:17	4	CB-02	0.41	4350
8/11/01	6:41	12	CB-02	0.43	960
8/10/01	15:20	PS	CB-03	0.49	2,400
8/10/01	18.32	1st Flush	CB-03	0.4	4700
8/10/01	21:28	2	CB-03	0.46	2,500
8/10/01	22:29	4	CB-03	NS	3,200
8/10/01	15:26	PS	CB-05	NS	520
8/10/01	18:40	1st Flush	CB-05	NS	1,200
8/10/01	18:41	1st Flush	CB-06	NS	15,000
8/10/01	15:27	PS	CB-07	NS	2,100
8/10/01	18:45	1st Flush	CB-07	NS	1,100
8/10/01	18:54	1st Flush	CB-08	NS	65,000
8/10/01	15:41	PS	CB-09	NS	260
8/10/01	19:00	1st Flush	CB-09	1.0	2,000
8/10/01	21:50	2	CB-09	NS	5950
8/10/01	15:49	PS	CB-10	NS	150
8/10/01	15:56	PS	CB-11	0.16	20
8/10/01	19:20	1st Flush	CB-11	0.13	170
8/10/01	21:56	2	CB-11	0.13	400
8/10/01	22:37	4	CB-11	0.13	70
8/11/01	6:56	12	CB-11	0.13	40
8/10/01	16:06	PS	CB-12	0.46	20
8/10/01	19:28	1st Flush	CB-12	NS	2,100
8/10/01	22:05	2	CB-12	0.45	60
8/10/01	22:44	4	CB-12	0.45	20
8/11/01	7:02	12	CB-12	0.46	20

PS=pre-storm, NS=not sampled, Only data where a sample was taken is represented (some of the watershed had zero flow during some of the proposed sampling times)

3.0 Results

3.1 Evaluation of data quality

Replicates were taken during each sampling event. BAL laboratories also analyzed laboratory splits for several stations during the study. The precision of the mTEC membrane filtration technique for fecal coliforms is 35% at the 95% confidence interval (Rippey et al., 1987). Replicates collected in this study were compared to the confidence interval criteria mentioned above using a 95% confidence interval of 35% above and below the mean of the two values to assess data reliability. The results are presented in Table 3.1. The majority of the replicates fell within their respective confidence intervals indicating that the data are of adequate quality.

Table 3.1 Confidence intervals for the replicate and duplicate data collected in Crooked Brook.

Station	Original fecal coliform concentration (fc/100 ml)	Replicate fecal coliform concentration (fc/100 ml)	Mean fecal coliform concentration (fc/100 ml)	-95% confidence interval (fc/100 ml)	+95% confidence interval (fc/100 ml)	Does data fall within confidence interval?
CB-01	1100	1500	1300	845	1755	YES
CB-02	4100	4600	4350	2828	5873	YES
CB-02	380	190	285	185	385	YES
CB-04	750	670	710	462	959	YES
CB-09	4700	7200	5950	3868	8033	YES
CB-10	170	260	215	140	290	YES
CB-10	88	37	62.5	41	84	NO
CB-11	5	10	7.5	5	10	YES
CB-02	7300	6500	6900	4485	9315	YES
CB-03	4500	4900	4700	3055	6345	YES
CB-07	1400	1600	1500	975	2025	YES
CB-10	260	280	270	176	365	YES
CB-11	100	40	70	46	95	NO

3.2 Watershed hydrology and rainfall data

The Crooked Brook Watershed is a relatively small watershed. Rainfall collects and moves through the watershed rapidly during wet weather conditions. This characteristic produces rapid stage and flow increases during rainfall and a similarly rapid return to baseline flow and stage shortly after the rainfall has ended.

Stream flow is derived from the combination of surface water runoff moving into the stream from the adjacent land area and groundwater discharge up through stream beds. Crooked Brook is dependent on rainfall to maintain flow during the summer months. The Crooked Brook watershed often runs dry during late summer and dry periods when precipitation and runoff are minimal.

The rainfall accumulation for August 10-11 was 0.31 inches. The rainfall data represents a weighted average from adjacent monitoring sites because no measurements were made at the study site. The storm was relatively small, but met the wet weather criterion. The watershed had also undergone an extended dry period, so the stream channel was dry in several locations. Three stations, CB-04, CB-10, and CB-14, did not develop flow during the storm, so no wet weather samples were collected at these locations. All other stations were sampled only when flowing water was present.

3.3 Summary of flow data

Flow measurements were taken several times during the course of this study in both dry and wet weather. This was done at stations throughout the watershed to develop stage-discharge relationships. During dry weather, flow measurements were accomplished at stations CB-02, CB-04, and CB-10. During wet weather flow was monitored at stations CB-02, CB-04, CB-06, and CB-10. The wet weather event was preceded by a period of drought. Therefore, many portions of the watershed were dry or had insufficient flow. The only station that maintained adequate flow to measure was station CB-02 near the mouth of the brook.

Stage-discharge relationships are shown in Figures 3.1a – 3.1c. The graphs indicate inverse relationships since the stage was measured from the top of the gauge or culvert to the water surface. Flow in Crooked Brook ranged from a minimum value of 0.001 m^3/s to a maximum value of 0.06 m^3/s.

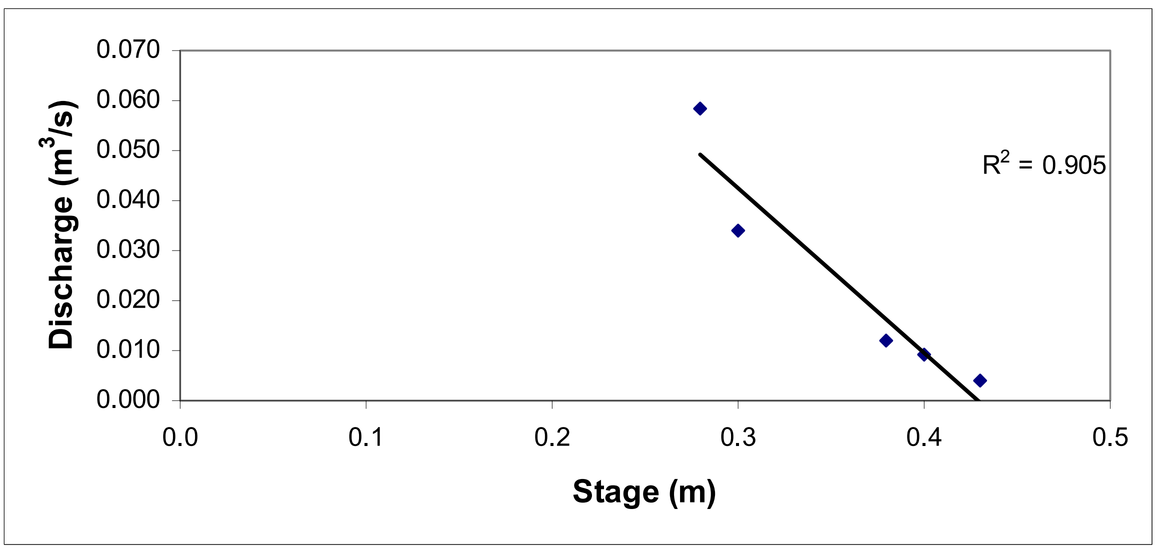

Figure 3.1 Stage-Discharge Relationship for Station CB-02.

Equation for Best-Fit Line Is: y = -0.3296x+0.1415

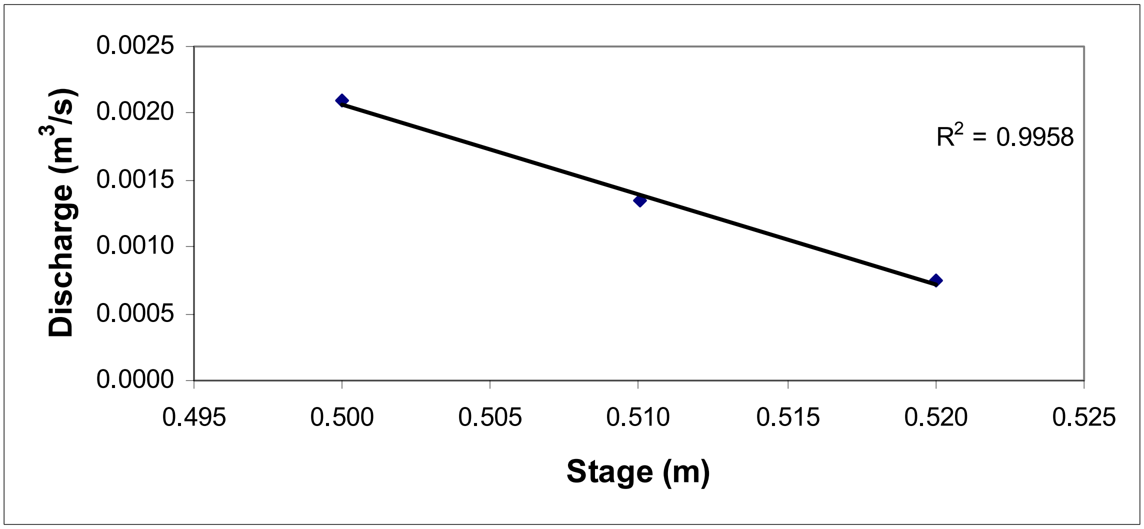

Figure 3.2 Stage-Discharge Relationship for Station CB-04.

Equation for Best-Fit Line Is: y = -0.0672x+0.0357

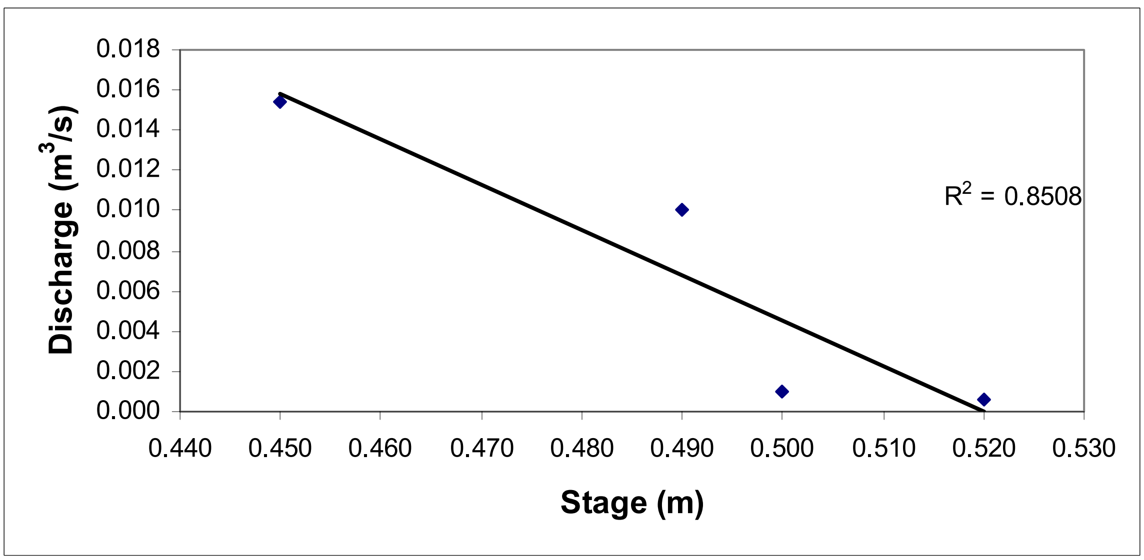

Figure 3.3 Stage-Discharge Relationship for Station CB-10.

Equation for Best-Fit Line Is: y = -0.2262x+0.1176

3.4 Summary of water quality data

The geometric mean concentration during dry and wet weather, and the 90th percentile concentration of the combined dry and wet data set at each station are presented in Table 3.3.

Table 3.2 Flow data by date.

CB-02			CB-04			CB-10		
Date	Flow (m^3/s)	Stage (m)	Date	Flow (m^3/s)	Stage (m)	Date	Flow (m^3/s)	Stage (m)
6/20/01	0.058	0.280	7/3/01	0.0007	0.520	6/20/01	0.015	0.450
6/22/01	0.034	0.300	7/11/01	0.0013	0.510	6/22/01	0.010	0.490
7/3/01	0.012	0.380	7/13/01	0.0021	0.500	7/3/01	0.001	0.52
7/11/01	0.009	0.400				7/13/01	0.001	0.5
8/10/01	0.004	0.43						

Table 3.3 Summary of dry and wet weather water quality conditions.

Segment Number	Station	Dry Weather Geometric Mean (fc/100 ml)	Wet Weather Geometric Mean (fc/100 ml)	90th Percentile (fc/100 ml)
4	CB-01	435	3547	5760
	CB-02	459	4312	8430
2	CB-03	413	3350	3950
	CB-04	754	NF	791
	CB-05	441	1200	1170
	CB-06	NF	15000	15000
	CB-07	1107	1100	1860
	CB-08	893	65000	52420
1	CB-09	331	3450	3580
	CB-10	131	NF	220
3	CB-11	17	117	239
	CB-12	22	84	672
	CB-14	NF	NF	NF

4.0 Data Discussion and Analysis

Several trends were found in the 2001 Crooked Brook TMDL data. Fecal coliform concentrations were relatively low in the upper undeveloped portion of the Crooked Brook Watershed, but they were still greater than the water quality standard for a Class A waterbody. Concentrations increased dramatically as the brook entered the developed portion of the watershed. The increase was associated with the horse boarding operation. Concentrations remained elevated to varying degrees throughout the rest of the Crooked Brook branch of the watershed. The Sprague Brook branch of the watershed had significantly lower fecal coliform concentrations. This branch of the brook only violated the State's fecal coliform standard by a small margin.

4.1 Weighted Geometric Mean Approach

The dry and wet weather data sets were combined to develop an assessment of water quality conditions in the watershed. RIDEM calculated a "weighted geometric mean" concentration for each station that was based on the geometric mean dry and wet weather concentrations for each station and the percentages of dry and wet days that occur annually in the watershed. The approach also incorporates the time needed for the stream to return to steady state conditions after a rain event. Current bacterial conditions in the Crooked Brook watershed were determined based on this "weighted geometric mean" approach.

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

Weighted Geometric Mean (for each WQ station) =
(% of dry weather days) x (Dry weather geometric mean) +
(% of wet weather days) x (Wet weather geometric mean)

The amount of precipitation needed to produce enough runoff to impact water quality in the brook was first determined. Any precipitation event in the watershed that produces at last this quantity of runoff was considered to cause "wet" weather conditions. Historic water quality data collected in Narrow River indicated that significant in-stream coliform concentration increases would follow any event of 0.30 inches rainfall or greater. The abundance of wetland areas (which have high water retention) within the Crooked Brook watershed also leads to the conclusion that 0.30 inches of rainfall is needed to produce significant runoff. Although some runoff was observed from precipitation events of less than 0.30 inches, the amount of runoff was considered insignificant and impacts to water quality in the system would be limited.

Figure 4.1 shows the frequency of occurrence of precipitation events on an annual basis. This 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. Upon examination of meteorological data recorded at T.F. Green Airport over the past 15 years, it was determined that wet weather days, as determined above, occur 13.8% percent of the time, and dry weather days occur 86.2% percent of the time. This means that annually, wet weather conditions dominate the watershed approximately 13.8% of the time.

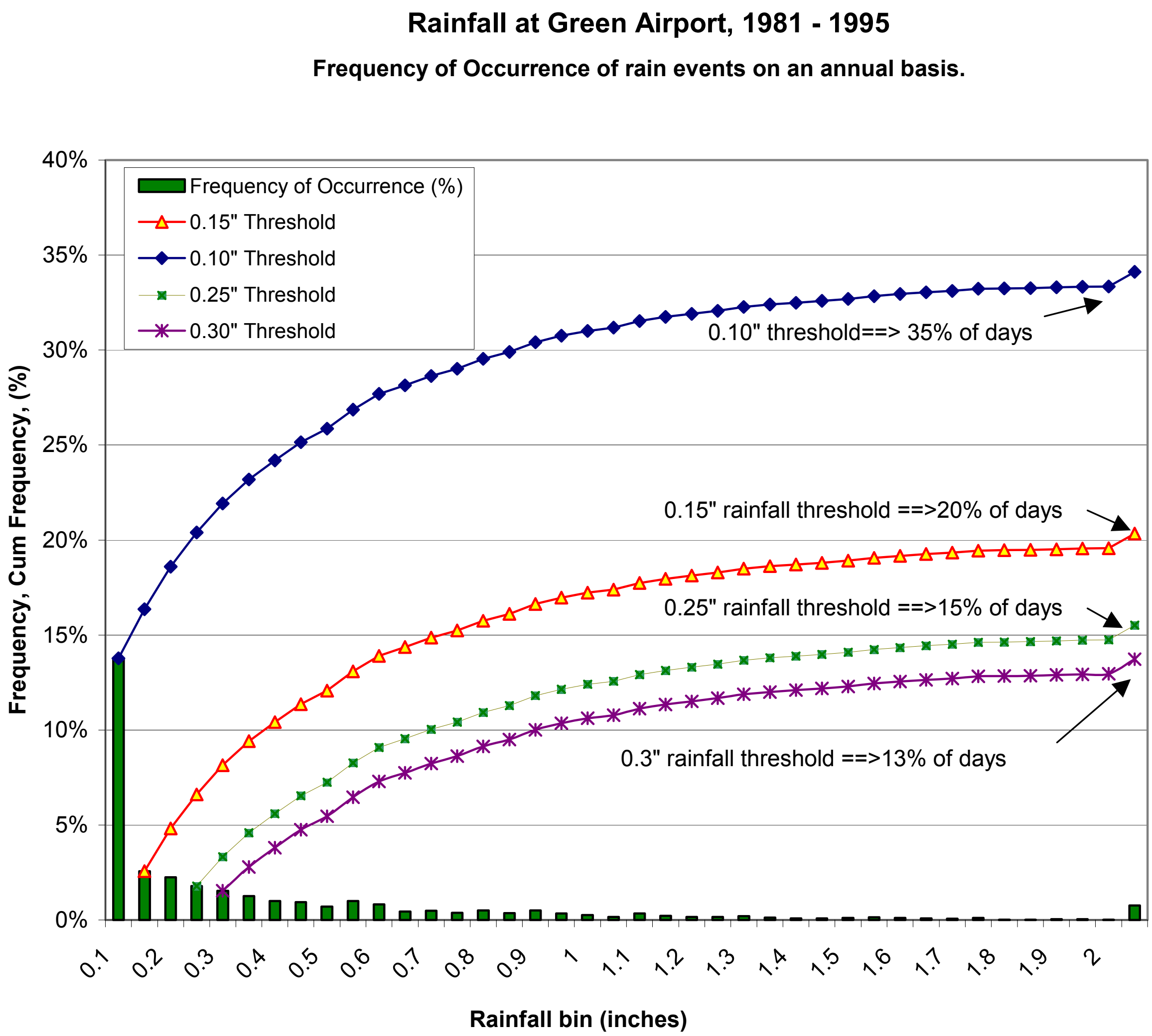

Figure 4.1 Rainfall Data from T.F. Green Airport for Years 1981-1995

The percentage of wet weather days was adjusted to include recovery time (time required for the in-stream fecal coliform concentrations to return to pre-storm levels). Analysis of wet weather data for the Crooked Brook watershed show that an additional day is required for in-stream fecal coliform concentrations to drop to pre-storm levels. For an additional day of recovery needed, the percentage was doubled, making the percent of wet weather days equal to 27.6% (13.8% x 2). This takes into consideration wet weather bacteria violations not only for the day of the storm but also for the additional day it takes for the system to recover. Therefore, the percent of dry weather days is 72.4%.

The weighted geometric mean calculation for Crooked Brook is shown below:

Weighted Geometric mean (for each WQ station) =
(0.276) X (Wet weather geometric mean) + (0.724) X (Dry weather geometric mean)

The results of this calculation are shown in Table 4.1. Once computed, the weighted average geometric mean can 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 4.1 Weighted geometric mean for each segment of the Crooked Brook Watershed.

Segment number	Stations	Segment weighted geometric mean concentration (fc/100 ml)	Pollution Sources
1	CB-09 CB-10	1192	Wildlife, storm drain (South Pier Road)
2	CB-07 CB-08 CB-03 CB-04 CB-05 CB-06	18587	Wildlife, farm, swale (behind High School), storm drain (Kingstown Road)
3	CB-11 CB-12 CB-14	45	Wildlife, storm drain (Kingstown Road)
4	CB-01 CB-02	1522	Wildlife, waterfowl

4.2 Calculation of the Percent Exceedence Value

State water quality standards require that, for Class A waterbodies, not more than 10% of the samples may exceed a value of 200 MPN/100ml. To determine compliance with this portion of the standard, the wet and dry weather data sets from the RIDEM 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 in Table 3.2.

4.3 Water quality impairments and source identification

RIDEM water quality investigations document that bacteria impairments in the Crooked Brook watershed are due to nonpoint sources of pollution and discharges from municipal separate stormwater sewer systems (MS4s).

The water quality assessment conducted by RIDEM sought to characterize current conditions in Crooked Brook. Both dry and wet weather data were used for this characterization. Dry weather data was used to identify dry weather sources of pollution and to assess steady state conditions when the waters are most likely to be utilized for the designated uses of primary and secondary recreation activities. Wet weather data was used primarily to assess worst case conditions and to help locate nonpoint source pollution areas in the watershed.

In seeking to identify sources of pathogen contamination, RIDEM staff reviewed aerial photos, topographic maps, GIS land use data, and other available resources. In addition, RIDEM staff conducted wet and dry field reconnaissance and, where possible, talked to area residents and Narragansett town officials regarding potential sources of bacteria pollution. The water quality assessment conducted by RIDEM sought to identify pollution sources to Crooked Brook. The information is provided below by station and is shown in Table 4.1.

CB-01
Station CB-01 was located just prior to the discharge point of Crooked Brook into Pettaquamscutt Cove. The dry and wet weather geometric mean fecal coliform values were 435 fc/100 ml and 3547 fc/100ml, respectively. The weighted geometric mean at CB-01 was 1294 fc/100ml. The brook at this station violates the State standard during both dry and wet weather.

Sources in this region may be attributed to upstream inputs and waterfowl along with wildlife inputs. The upstream inputs may be significant in this watershed. One of the main causes of bacterial die-off is ultraviolet (UV) radiation from the sun. In the Crooked Brook watershed, however, the majority of the stream is completely shaded, which effectively eliminates UV radiation as a die-off factor. This region is also tidal. It has been documented that bacteria may be retained on roots and other vegetation as tidal stage decreases. Bacteria may multiply given moist warm conditions and become resuspended as the area becomes inundated at high tide.

CB-02
Station CB-02 was located upstream of CB-01 within a large hardwood swamp. The dry and wet weather geometric mean fecal coliform values were 459 fc/100 ml and 4312 fc/100ml, respectively. The weighted geometric mean at CB-02 was 1522 fc/100ml.

Visual inspection by RIDEM Office of Water Resources did not reveal any anthropogenic sources in this area. Bacteria levels are likely attributed to upstream contributions and wildlife inputs.

CB-03
Station CB-03 was located upstream of CB-02 within a public park. The dry and wet weather geometric mean fecal coliform values were 413 fc/100 ml and 3350 fc/100ml,

respectively. The resulting weighted geometric mean at CB-03 was 1224 fc/100ml.
The dry weather elevations at CB-03 are most likely due to upstream bacteria contributions, as no dry weather sources were identified in this area. Visual inspection by RIDEM revealed a storm drain on Kingstown Road that discharges directly to the brook. Additionally, the inspection also revealed that pets frequent the adjacent park. Sources contributing to the bacteria concentrations at CB-03 are storm drain runoff from Kingstown Road and runoff collecting pet waste as it comes through the park during wet weather.

CB-04

Station CB-04 was located upstream of CB-03 at one end of a wooded wetland area. Dry weather geometric mean fecal coliform values were 754 fc/100 ml. Wet weather fecal coliform geometric means were not able to be determined due to a dry stream channel at the time of the wet weather sampling event. The weighted geometric mean at CB-04 was 546 fc/100ml. This weighted geometric mean is calculated using only dry weather data.

This station was dry during the wet weather study. In addition to upstream influences, wildlife is assumed to be a contributing source of bacteria during both dry and wet weather. Overland runoff from Kingstown Road impacts water quality during wet weather.

CB-05

Station CB-05 was located upstream of CB-04 within a wooded wetland area. The dry and wet weather geometric mean fecal coliform values were 441 fc/100 ml and 1200 fc/100ml, respectively. The weighted geometric mean at CB-05 was 651 fc/100ml.

This station has wildlife inputs and is effected by upstream influences. It is also downstream of a stormwater runoff swale (CB-06), which drains two large parking lots and several fields associated with two schools.

CB-06

Station CB-06 was located upstream of CB-05 and was a storm swale that drained the high school and middle school parking lots and associated fields. It is also within the previously mentioned wooded wetland area. This station is not an instream station but is a wet weather source to the brook. During wet weather, station CB-06 was sampled once and the resulting concentration was 15000 fc/100 ml.

CB-07

Station CB-07 was located upstream from CB-05. The dry and wet weather geometric mean fecal coliform values were 1107 fc/100 ml and 1100 fc/100ml, respectively. The weighted geometric mean at CB-07 was 1105 fc/100ml.

The elevated levels at station CB-07 are primarily attributable to bacterial inputs from a horse boarding operation. There may also be wildlife contributions impacting concentrations at this station since it is immediately downstream of a wooded wetland area. Factors that may influence the decrease in bacteria concentrations from CB-07 to

CB-05 are bacterial die off and the bacteria settling out of the water column, as well as variability in the data and intermittent source input.

CB-08

Station CB-08 was located upstream of CB-07 just after the stream channel passes through a horse farm. The dry and wet weather geometric mean fecal coliform values were 863 fc/100 ml and 65000 fc/100ml, respectively. The weighted geometric mean at CB-08 was 18587 fc/100ml.

Prior to this sampling station the stream passes a horse boarding operation, where it runs directly through the pasture. Visual inspection of the site by RIDEM revealed horse manure deposition and storage adjacent to the stream. The horses at the farm have direct access to the stream and have to cross it to reach the different areas of the farm. This may lead to direct manure deposition to the stream during dry weather. During wet weather, manure wash off from the land to the stream channel is a source of bacteria to Crooked Brook.

CB-09

Station CB-09 was located upstream of CB-08 at the end of a large wooded wetland area. The dry and wet weather geometric mean fecal coliform values were 331 fc/100 ml and 3450 fc/100ml, respectively. The weighted geometric mean at CB-09 was 1192 fc/100ml.

The dry weather elevations at this station are likely attributable to the upstream impacts of wildlife, as this station is immediately downstream of a large wooded wetland area where no anthropogenic sources were identified. The wet weather elevation in concentration at CB-09 is attributed to discharge from a storm drain collecting runoff along South Pier Road.

CB-10

Station CB-10 was the furthest upstream station. It was located within a wooded wetland area. Dry weather fecal coliform geometric mean values were 131 fc/100 ml. Wet weather fecal coliform geometric means were not able to be determined because flow had stopped at the station due to an extended period of drought prior to the wet weather sampling event. The weighted geometric mean at CB-10 was 95 fc/100ml.

RIDEM investigated this area and could not identify any anthropogenic or other controllable sources. The elevated concentrations must be completely attributed to wildlife.

CB-11

Station CB-11 was located upstream of CB-02 at the discharge point of Sprague Pond. The dry and wet weather geometric mean fecal coliform values were 17 fc/100 ml and 117 fc/100ml, respectively. The weighted geometric mean at CB-11 was 45 fc/100ml. This branch of the watershed has the lowest fecal coliform concentrations of the entire watershed. The low fecal coliform counts found at this station are likely due to bacterial settlement and ultra violet (uv) die off as the water enters the ponds found along this branch.

Bacteria sources to this area may be attributed to stormwater runoff from the municipal garage and associated parking areas located adjacent to the station, however effects from this area appear to be minor. Aside from a nesting pair of osprey, no waterfowl were found in this pond during any field reconnaissance. The lack of waterfowl may be due to the presence of the predatory birds, but waterfowl remains a potential source to this area.

CB-12

Station CB-12 was located upstream of CB-11 and was the input point for Sprague Pond. The dry and wet weather geometric mean fecal coliform values were 22 fc/100 ml and 84 fc/100ml, respectively. The weighted geometric mean at CB-12 was 39 fc/100ml.

Dry weather elevations may be attributed to wildlife inputs from the wooded area directly above Governor's Pond. This area is just downstream of a storm drain outfall that may contribute bacteria to this station during wet weather. No waterfowl were found in this pond during any field reconnaissance, but waterfowl remains a potential source to this area.

CB-13

Station CB-13 was going to be located at the discharge point of Sprague Brook to Governor's Pond. During field reconnaissance, RIDEM found that there was no defined channel in this region, therefore this station was dropped from the study.

CB-14

Station CB-14 was located above Governor's Pond. There was insufficient flow to sample this station during this study.

5.0 Conclusions and Recommendations

Based on the results of the Crooked Brook water quality monitoring program, fecal coliform concentrations were found to be elevated throughout the entire Crooked Brook Watershed. For ease of analysis, the watershed was divided into segments. The segments and their corresponding stations are listed in Table 4.1. Segment 1 is the upper portion of the Crooked Brook branch of the watershed. This area had elevated fecal coliform concentrations (but this area had the second lowest numbers in general). The dry weather numbers from this segment are indicative of the natural background concentration of the upper watershed because no anthropogenic dry weather sources exist in this area. A potential dry and wet weather source of bacteria in this segment is input from wildlife. The only anthropogenic wet weather source is a storm drain along South Pier Road that directly discharges to Crooked Brook.

Segment 2 encompasses the developed portion of the watershed. This segment had the highest elevations of the entire watershed. Several sources are present in this area. The source with the highest fecal coliform input is a horse boarding operation located downstream of South Pier Road. The stream channel runs directly through the center of the pasture area. Manure was observed directly adjacent to the stream channel and is a bacteria source to the stream during both dry and wet weather. Downstream of the farm, the stream enters a small wetland area. Wildlife is a potential source to this area in both dry and wet weather. A storm drain swale enters the stream in this area. It drains two parking lots and various playing fields associated with the town high and middle schools. This is only a source during wet weather. There is overland stormwater flow that discharges directly to Crooked Brook from the portion of Kingstown Road near the Pier Ice Plant, this is a potential wet weather source to the stream. As the stream crosses under Kingstown Road near Sprague park, a storm drain collects stormwater from Kingstown Road and discharges it directly to Crooked Brook.

The next segment, segment 3, incorporates the entire Sprague Brook branch of the watershed. The fecal coliform concentrations are elevated in this segment, but they are the lowest concentrations in the entire watershed. Potential wildlife and waterfowl sources exist in this segment, but the retention time of the ponds on this branch of the watershed seem to minimize these effects by ultra-violet radiation die off and bacterial settling. A storm drain located along Kingstown Road is a wet weather source to this segment as it discharges directly to the Sprague Brook branch of the watershed.

The final segment of the watershed, segment 4, includes the lower watershed area within a large hardwood swamp. Instream fecal coliform concentrations increase as the stream passes through the reach despite the absence of anthropogenic sources. The concentration in this area is the second highest of the entire watershed. Wildlife and waterfowl are potential sources to this area during both dry and wet weather. Upstream effects also add to the fecal coliform elevation in this segment. The lower portion of this segment is tidal. It has been documented that bacteria may be released from roots and other vegetation as tidal stage decreases. This bacteria may multiply given moist warm conditions and become resuspended as the area becomes inundated at high tide.

Recommended future monitoring should consist of three stations situated along the Crooked Brook branch of the watershed. The first two stations to be monitored are CB-09, which is upstream of the horse boarding operation, and station CB-08, which is immediately downstream of the horse boarding operation. These two stations will bracket off this area and will determine the benefits of the BMPs implemented in this area. Station CB-03, downstream of Kingstown Road, should also be monitored to quantify the improvements to water quality in the developed portion of the watershed, which had the highest fecal coliform concentrations. Additionally, as structural BMPs are implemented in the watershed, monitoring will occur upstream and downstream of the structures to quantify water quality improvements as a result of the chosen technology.

6.0 References

Applied Science Associates, Rhode Island Watershed Watch, SAIC Engineering Inc., UWR (Urish, Wright, and Runge) 1995. *Narrow River Stormwater Management Study Problem Assessment and Design Feasibility*.

Rector, D 1977. *Soil Survey of Rhode Island*, USDA.Washington D.C.

RIDEM, 1997. *Water Quality Regulations*, Rhode Island Department of Environmental Management, Office of Water Resources. Providence, RI.

RIDEM, 2000. *Fecal Coliform TMDL for the Narrow (Pettaquamscutt) River Watershed*, Rhode Island Department of Environmental Management. Office of Water Resources. Providence RI.

Rippey, S.R., W.N. Adams, and W.D. Watkins 1987. *Enumeration of fecal coliforms and E. coli in marine and estuarine waters: an alternative to the APHA-MPN approach.* Journal of Water Pollution Control. 59(8): 795-798.

Simmons and Nevins, 1989. *Water Quality in the Crooked Brook Watershed*. Unpublished from University of Rhode Island, CVE 590X. Kingston, RI.

Appendix B1: EPA Comments for the Crooked Brook Fecal Coliform TMDL

(Waterbody ID Number RI0010044R-03)

This TMDL revision incorporates several changes to address preliminary comments received from USEPA Region 1 (EPA). The EPA Comments and RIDEM Responses are presented below:

C The TMDL needs to specify rationale for not separating natural background from the non-point source load.

R RIDEM states in the TMDL that it was not possible to separate the natural background from the total non-point source load due to a lack of site specific data on fecal coliform contributions from wildlife in the watershed.

C The TMDL needs to specify that the loading capacity is set equal to the state's water quality standard for fecal coliform bacteria. It also needs to justify the use of a concentration based approach. Lastly, the TMDL needs to provide the link between pollutant sources and instream concentrations.

R RIDEM states, as described in EPA guidelines, a TMDL identifies the pollutant loading that a waterbody can assimilate per unit of time without violating water quality standards. The loadings are required to be expressed as mass per time, toxicity, or other appropriate measures. EPA Region 1 has determined that it is appropriate to express a bacteria TMDL in concentration units. The loading capacity for this TMDL is therefore expressed as a concentration set equal to the state water quality standard.

To link pollution sources with instream concentrations RIDEM states that extensive field surveys, water quality monitoring, and review of aerial photos/topographic maps was used to establish the link between pollution sources and instream concentrations.

C It is generally not appropriate to average multiple stations because bacteria tend to manifest their impact on small spatial scales. For example, CB-08 was left out of the weighted average for segment 2 because concentrations were very high and not indicative of the delineated reach.

R RIDEM originally did not average multiple stations but rather picked the station within the reach that had the largest violation and set the percent reduction based on that station. Station CB-08 had been left out of figuring the percent reduction for segment 2, but has now been added. Percent reductions for segment 2 are now based on station CB-08.

Appendix B2: Public Comments for the Crooked Brook Fecal Coliform TMDL

(Waterbody ID Number RI0010044R-03)

Crooked Brook TMDL Public Meeting
URI/GSO Corless Auditorium 8/21/02

7:00 Jason McNamee (RIDEM) – Welcome
Introduced topic for the evening's presentation along with a brief outline of the talk. Introduced Elizabeth Scott.

Elizabeth Scott (RIDEM) – Gave a brief overview of the TMDL process including an explanation of 303(d) list.

Jason McNamee (RIDEM) – Started detailing the Crooked Brook report.

- **Reviewed study area.** Gave characteristics of watershed including land types, uses, and residential density.
- **Defined impairment.** Reviewed previous work and implicated fecal coliform as the impairment in the watershed.
- **Reviewed water quality standards and goals for the watershed.** Crooked Brook is a Class A waterbody in the upper watershed, but at its discharge point it must meet Class SA standards.
- **Gave an overview of dry and wet weather data collection along with reviewing results.** 12 stations were sampled in dry and wet weather. Central portion of Crooked Brook Branch of watershed had worst water quality, particularly in wet weather. Sprague Brook had best water quality in both dry and wet weather. Bacteria levels increased after flowing through wetland areas that are removed from human influence during dry and wet weather.
- **Reviewed how the watershed was divided up for analysis.** Went through segment delineation in watershed and gave the percent reductions for each section of the watershed.
- **Identified sources found in the watershed along with giving corrective actions that may improve water quality.** Sources were found to be a horse boarding facility, stormwater outfalls, and wildlife/waterfowl. Corrective actions will cover BMPs at horse boarding facility, and phase II minimum measures to alleviate stormwater problems.
- **Detailed Phase II program requirements.** Described SWMPPs and detailed six minimum measures that must be included in the SWMPPs.
- **Gave out contact information**
- **Question and comments**
    - *Question:* Did you see elevated bacteria levels coming from the wetland areas? (Followed with a comment about how these areas are removed from human influence)
    - *Answer:* Yes, we did have an indication that wildlife and waterfowl are a significant source of bacteria in the watershed.
    - *Question:* Are stations CB-01 and CB-02 tidally influenced?
    - *Answer:* CB-01 is tidal but sampled on outgoing tides. CB-02 is not tidally influenced.

- *Question:* I have lived in this area for a long time and I never knew this brook even existed, why aren't we able to see the brook?
- ***Answer:*** It's a small brook, which in the summer intermittently dries up. It is also overgrown in many areas.
- *Question:* Did you see an improvement in water quality in the Sprague Brook Branch of the watershed? There is some indication that detention ponds improve water quality with regard to bacteria and I wondered if the ponds along the Sprague Brook Branch would indicate this type of water quality improvement.
- *Answer:* Yes, water quality was better in the Sprague Brook Branch, most likely due to the influence of the ponds.
- *Question:* Are any of the residences in the watershed on septic systems.
- *Answer:* The entire watershed is sewered at the present time.

At this point Russ Chateauneuf (RIDEM) spoke about a new development being built in the watershed that is under ISDS review.

- Named "Goodwill Park", and gave other background information.
- Due to the prioritizing of failing systems in the area, the local waste water treatment plant does not have the capacity to accept flows from this new development.
- Developers were denied sewer hook ups, therefore the developers are currently pursuing a 19 lot development on ISDSs. The development was originally platted for 5000 square foot lots, which would have been many more than 19 houses. Current zoning does not allow for this.
- The current 19 lot proposal gives 35 of 45 acres designation as open space.
- Approval from RIDEM Freshwater Wetlands section was granted. ISDS permits are still in review.
- Area where houses are to be built are wet but not technically a wetland.

  - *Comment:* Clark Collins (Narragansett Town Planner) stated that the sewers were not allowed for the development due to a multi-town agreement on treatment plant use that has the facility maxed out with regard to the Town of Narragansett.
  - *Comment:* Area around CB-07 has a history of flooding adjacent residential properties.
  - *Response:* We have been in contact with area residents and were given the same information.

At this point Jason McNamee (RIDEM) indicated that the comment period began on that day (August 21st) and lasted 30 days. The meeting adjourned at this point.