Fecal Coliform TMDL Development

for

Barrington River, Rhode Island

Prepared by:
Office of Water Resources
Rhode Island Department of Environmental Management
235 Promenade Street
Providence, RI 02908

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EXECUTIVE SUMMARY

This Total Maximum Daily Load (TMDL) addresses pathogen impairments in the Barrington River. The Barrington River's stated impairment is pathogens, as evidenced by elevated fecal coliform concentrations.

Section 303(d) of the Clean Water Act and EPA's implementing regulations in 40 CFR § 130 describes the statutory and regulatory requirements for approval of TMDLs. This executive summary contains the information needed by EPA to fulfill the legal requirements under Section 303(d) and EPA regulations.

1. Description of waterbody, pollutant of concern, pollutant sources, and priority ranking

Description of the waterbody

The Barrington River, shown in Figure 1.1 lies in northeastern Rhode Island and southeastern Massachusetts. The Barrington River starts at the mouth of the Runnins River at the Mobil Dam and runs in a southeasterly direction for a distance of 6 kilometers (km) to its confluence with the Palmer River at Tyler Point in Barrington. Upstream of a feature known as the Tongue, the Barrington River is narrow, between 10 to 200 meters (m) wide, and less than 0.5 m deep in many areas. A side embayment, known as Hundred Acre Cove, opens to the east of the main channel below the Tongue. The Cove is shallow, with low tide depths less than 0.3 m in most areas. The average tidal range for the area is approximately 1.4 m. The Barrington River is part of the Warren River watershed.

Rhode Island's Water Quality Regulations divide the Barrington River between two waterbody units based on the River's water quality. The Class SA portion of the river is defined as the *"Barrington River from the Mobil Dam in East Providence to the East Bay Bike Path in Warren approximately 1000 feet north of the confluence with the Palmer River."* It is identified with number RI007021E-01A. The remainder of the River, waterbody number RI007021E-01B, from the Bike Path Bridge to the Barrington River's confluence with the Palmer River at Tyler Point is in Class SB1 waters (RIDEM, 1997c). The entire Class SA portion of the Barrington River is listed as impaired by Rhode Island's 303(d) list (RIDEM, 1998b). This TMDL addresses the impaired Class SA reach of the Barrington River. The Class SB1 reach of the Barrington River is not impaired and not addressed by this TMDL.

RIDEM sampling and a computer model, WQMAP, were used to determine the current water quality conditions in the Barrington River. Table 1 characterizes instream fecal coliform concentrations in fecal coliforms per 100 milliliters (fc/100 ml) during critical conditions. Critical conditions occur during the summer months from July 1 to October 31. Figure 3.1 shows the station locations.

Priority ranking

The Barrington River is listed as a Group 1 waterbody (highest priority) on the State of Rhode Island's 303(d) list of water quality impaired waterbodies (RIDEM, 1998b).

Table 1 Current water quality characterization in the Barrington River[1].

Station[2]	Dry Weather (fc/100 ml)		Wet Weather (fc/100 ml)	
	Geometric Mean	90th Percentile Value	Event Mean Concentration	90th Percentile Value
GA2-1 (Tongue)	93.1	173.0	155.1	348.85
GA2-1A	40.7	84.6	81.6	150.0
GA2-2 (Hundred Acre Cove)	40.6	42.5	50.9	66.8
GA2-3 (White Church Bridge)	23.9	52.1	65.8	94.5
GA2-4	12.3	37.7	55.7	98.2
GA2-5 (Bike Path Bridge)	6.9	26.2	43.4	95.2

[1] Values were derived using a water quality computer model.
[2] Stations are listed from upstream to downstream. Locations are shown in Figure 3.1.

Pollutant of concern
The 303(d) listing was based on the results of ambient water sampling for fecal coliform; a parameter used by Rhode Island as indicator of possible pathogen contamination in a waterbody (RIDEM, 1998b).

Pollutant sources
To identify fecal coliform sources for the Barrington River, all known sources within the Warren River watershed were examined. The sources identified as significant have varying impacts on the Barrington River depending on their fecal coliform load and their location within the watershed.

Nonpoint fecal coliform sources in the Warren River watershed include storm water runoff, agricultural runoff and practices, and wildlife and waterfowl. The sources can be broken into five areas or subwatersheds, the Runnins River, Palmer River, Barrington River, Warren River, and upper Narragansett Bay. In each subwatershed, sources exist in the form of storm pipes. Though the storm pipes were considered nonpoint sources for this analysis due to a lack of specific site information, they will be regulated by Rhode Island under EPA's Storm Water Phase II regulations. The Runnins River discharges directly to the head of the Barrington River. Loadings from the Warren River, the Palmer River, and upper Narragansett Bay enter the Barrington River at its mouth. Separate bacterial TMDLs are being developed for the Runnins and Palmer Rivers. The Warren River is not listed for bacterial impairments.

The source strength of the Runnins River, Palmer River, and upper Narragansett Bay were measured during wet weather surveys. Direct storm water inputs to the Barrington and Warren Rivers were not measured during wet weather. The strength of direct storm water inputs along these rivers was estimated using a modified form of the Rational Method. The areas from the Bike Path Bridge to the southeastern corner of Hundred Acre Cove on the east bank and from the bridge to the Tongue on the west bank were assumed to contribute to the Barrington River's wet weather load. A runoff coefficient estimate was calculated using Runnins River flow data collected during an October 1998 storm. An assumed wet weather concentration was derived from measured sources to the Runnins River during an October 1995 storm. The Warren River direct storm water loading was calculated in the same way. Table 2 shows the relative source strengths of the sources in fc/100 ml and fecal coliforms per day (fc/day) for dry and wet weather.

Table 2 Existing nonpoint sources of fecal coliform by subwatershed.

Source	Dry Weather			Wet Weather		
	Discharge (m^3/sec)	Existing GMC[1] (fc/100 ml)	Existing Load (fc/day)	Discharge[2]	Existing EMC[3] (fc/100 ml)	Existing Load[2]
Runnins River	0.242	1576	3.3×10^{11}	0.54 m^3/sec	3211	1.50×10^{12}
Palmer River	0.224	714	1.4×10^{11}	1.32 m^3/sec	5480	5.23×10^{12}
Barrington River	0.001	418	3.6×10^{8}	1.7×10^{4} m^3	2000	3.40×10^{11}
Warren River	0	0	0	3.2×10^{3} m^3	2000	6.40×10^{10}
Upper Narragansett Bay	NA	0.5	NA	NA	5	NA

[1]GMC is the geometric mean concentration.
[2]Wet weather discharge for the Runnins and Palmer Rivers is the average storm discharge during the period of increased flow, from October 14-18, 1998. Existing load is in fc/day for the period from October 14-18, 1998. For the Barrington and Warren Rivers, discharge and existing load is the total estimated for the storm event in m^3 and fc, respectively.
[3]EMC is the event mean concentration.

Two point sources discharge into the Warren River. Blount Seafood and the Warren Wastewater Treatment Facility (WWTF) are assigned Rhode Island Permit Discharge Elimination System (RIPDES) numbers RI0001121 and RI0100056, respectively. See table 5 in the Implementation Section for more information on the RIPDES point sources.

Natural background

Natural background was not separated from the total nonpoint source load because of a lack of detailed site-specific information. Without detailed site-specific information on fecal coliform contributions from wildlife and other sources downstream of the Barrington River, it is difficult to meaningfully separate natural background from the total nonpoint source load.

2. Description of applicable water quality standards and numeric water quality target

State water quality standard and numeric water quality target

The state's water quality standard for fecal coliform concentrations in Class SA waters are "*not to exceed a geometric mean MPN value of 14 and not more than 10% of the samples shall exceed an MPN value of 49 for a three-tube decimal dilution,"* where MPN is the most probable number (RIDEM, 1997c). This standard is the numeric water quality target for the Barrington River TMDL.

Designated uses

Class SA waters are *"designated for shellfish harvesting for direct human consumption, primary and secondary contact recreational activities and fish and wildlife habitat. They shall be suitable for aquacultural uses, navigation, and industrial cooling. These waters shall have good aesthetic value"* (RIDEM, 1997c). The Barrington River is regionally significant as a habitat and shellfish resource. The area is also locally used for recreational boating, fishing, and swimming.

Antidegradation policy

Rhode Island's antidegradation policy requires that, at a minimum, the water quality necessary to support existing uses be maintained. If water quality exceeds levels necessary to support the protection and propagation of fish, shellfish, and wildlife, and recreation in and on the water, the quality should be maintained and protected unless, through a public process, some lowering of water quality is deemed necessary to allow important economic and social development to occur. In waterbodies identified as having exceptional recreational and ecological significance, water quality should be maintained and protected (RIDEM, 1997c). The designated and existing uses for the Barrington River include fishing, shellfishing, swimming, and boating between the Bike Path Bridge and the Mobil Dam. The goal of the TMDL is to restore all existing and designated uses to the Barrington River that are impacted by elevated levels of fecal coliform.

3. TMDL endpoint – linking water quality and pollutant sources

Loading capacity

The loading capacity for this TMDL is expressed as a concentration and is set equal to the State geometric mean standard minus a 10% explicit margin of safety (MOS). The loading capacity for the Barrington River is therefore, a geometric mean of 12.6 fc/100 ml with a 90^{th} percentile value no greater than 49 fc/100 ml.

In the case of bacterial impairments, it has been determined by USEPA, Region 1 that it is appropriate to express a TMDL in terms of concentration for the following reasons:

1) Expressing bacteria TMDLs in terms of concentration provides a direct link between existing water quality, the numeric target, and the water quality standard.
2) Using concentrations in bacteria TMDLs is more relevant and consistent with the water quality standards, which apply for a range of flow and environmental conditions.
3) Bacteria TMDLs expressed in terms of daily loads are typically more confusing and more difficult to interpret, since they are completely dependent on flow conditions, which are often difficult to determine.
4) Follow-up monitoring will compare concentrations, not loads, to water quality standards.

Linking pollutant loading to a numeric target

A numerical water quality model, WQMAP, was used to calculate the existing water quality under design conditions in dry and wet weather. The model consists of linked hydrodynamics, mass transport, and mass constituent models utilizing a common grid representation of the system. The shoreline of the area is simulated by a gridding component of the model to define the geometry of each of the interior computational elements, and is therefore called a "boundary fitted" grid system. The hydrodynamics model is driven by the tides at the mouth of the Warren River and freshwater inputs from the Runnins and Palmer River tributaries. The pollutant transport model solves the conservation of mass equation on the boundary fitted grid to predict time varying levels of selected pollutant constituents in each model element. The predictions are driven by time-varying inputs from point sources at the external boundaries of the model domain and by local processes which includes decay.

The WQMAP model was applied to the Barrington, Palmer, and Warren system using the RIGIS mapped shorelines and NOAA bathymetry for the area. Tide predictions from NOAA, observed tributary flows, and fecal coliform loadings were used to predict water level oscillations, water column salinities, and fecal coliform concentrations at interior points in the model domain. Friction and dispersion coefficients were adjusted to minimize the error of model-predicted salinity concentrations in the interior of the model domain. First order decay rates for fecal coliform were adjusted to obtain the best fit to dry and wet weather fecal coliform data. The model was then validated and used to quantify the existing dry and wet weather fecal coliform concentrations throughout the Barrington River.

Data from RIDEM's 1996 dry weather surveys of the Barrington, Palmer, Warren River estuary were used to calibrate and validate the model. During these surveys, the Barrington River met water quality standards. The computer model was used to determine existing water quality in the Barrington River for the design dry weather contributions using average summer flow and characteristic summer season source concentration values for the Runnins and Palmer Rivers (RIDEM, 2002a; RIDEM 2002b). Tables 2 and 5 detail the existing loads used in the computer during dry weather. Table 1 summarizes the model-predicted geometric mean and 90th percentile values at each shellfish station in the Barrington River. The model predicted fecal coliform concentrations at each water quality station in the river at ten-minute intervals over an eight-day spring to neap tide period.

Data from RIDEM's 1998 wet weather survey of the Barrington, Palmer, Warren River estuary were used in the model's simulation of existing wet weather conditions in the Barrington River (see Section 6.5.4). Tables 2 and 5 detail the strength of the sources entered into the computer model. As described in Section 5.2, direct storm water loadings to the Barrington and Warren Rivers were estimated. Table 1 summarizes the model-predicted geometric mean and 90th percentile values at each shellfish station in the Barrington River. The model predicted fecal coliform concentrations at each water quality station in the river at ten-minute intervals over the four-day period of increased flow.

After the geometric mean and 90th percentile were calculated for each station, the values were compared to the applicable portion of the standard. Required reductions were specified that ensured all stations in the Barrington River met both parts of the standard. It is assumed that the combined fecal coliform loads are directly related to the observed fecal coliform concentrations in the receiving water and that required percent reductions in waterbody concentrations will be achieved by an equal percent reduction in a combination of all source loads.

Supporting documentation for the TMDL analysis

Past water quality studies considered significant to the determination of the TMDL are presented in Table 3. Included are those studies containing information used to characterize the present water quality conditions, significant sources, factors significant in affecting bacterial conditions in the river, and the analysis framework. References to external documents are cited in the reference section of this document.

Table 3 Supporting documentation.

Study name	Reference
Oceanography of the Hundred Acre Cove System	Brown University, 1997
Runnins River Wet Weather Study	RIDEM, 1996b
Water Quality Regulations	RIDEM, 1997c
Characterization to Support TMDL Development for the Barrington, Palmer, and Runnins River Watershed	RIDEM, 1999c
Fecal Coliform Development for Runnins River	RIDEM, 2002b

Critical conditions and seasonal variations

Due to its proximity to the Barrington River, its discharge volume, and its source strength, the Runnins River constitutes the principal influence on fecal coliform conditions in the Barrington River. Mr. Doug Rayner is a volunteer monitor who has sampled the Runnins River continuously for the last ten years. Mr. Rayner's data shows that the loads from the Runnins River are low in the winter, spring, and early summer. Concentrations and loads in the Runnins River are at their highest levels between July 1 and October 31 (RIDEM, 2000). The endpoints determined in this TMDL ensure that the Barrington River will meet water quality standards during this critical time period.

Strengths/weaknesses in the overall analysis process

<u>Strengths</u>

- The TMDL is based on an extensive knowledge of land use and potential bacteria sources in the watershed.
- The TMDL endpoints allow water quality standards to be met in critical conditions. Critical conditions were determined based on a ten-year data set.
- Data from several studies were used to more completely characterize the water quality conditions in the Runnins and Barrington Rivers.
- A relatively large amount of information was available to calibrate and validate the WQMAP model in dry weather conditions. The information included time series measurements of tidal properties and variations in salinity at the White Church Bridge in the Barrington River. The model was able to simulate the response of the Warren River system, which includes the Barrington River, to changes in freshwater inputs. Good model-data agreement was obtained for a range of seasonal and flow conditions.
- Wet weather reductions were based on a storm that produced 0.93 inches of rain in the Warren River watershed. Eighty-one percent of all storms in the area produce 0.93 inches of rain or less.

<u>Weaknesses</u>

- One wet weather event was available for analysis. After the water quality model was calibrated and validated for dry weather conditions, a modeling exercise was performed for wet weather using the same parameters that were used for dry weather. Error statistics for the wet weather event were within acceptable values.
- Wet weather sources along the Barrington and Warren Rivers were not sampled in wet weather due to a lack of resources. The existing loads were estimated.
- Loads from streams along the upper Barrington River could not be quantified because the streams are tidal and difficult to access during low tide. Using data in the Barrington River upstream and downstream of these sources, RIDEM determined that these sources were small when compared to the load from the Runnins River.
- The model representation of the upper Barrington River between the Mobil Dam and the Tongue was too coarse to completely resolve its physical mixing properties. This did not seem to impact the calibration and validation results, as all monitored stations are downstream of the impacted area. This concession was made to keep model execution times more manageable.

4. Margin of safety (MOS)

There are two basic methods for incorporating the MOS into the TMDL. One can implicitly incorporate the MOS using conservative assumptions to develop the allocations or explicitly specify a portion of the TMDL as a portion of the final TMDL allocation. The TMDL uses both these methods to establish a MOS. To account for any conditions that may cause concentrations to exceed the water quality standards, a 10% explicit margin of safety was incorporated into the endpoint concentrations, setting the target geometric mean concentration to 12.6 fc/100 ml. The inclusion of an explicit MOS provides an additional buffer to allow for data variability and the presence of unknown sources.

Several conservative assumptions were used when determining the required percent reductions. The observed dry and wet weather fecal coliform concentrations were obtained by using the computer model to simulate dry and wet weather conditions. The dry weather loads for the Palmer and Runnins Rivers were composed of the average flow and the geometric mean of the fecal coliform data. Instream concentrations predicted by the computer model at the water quality station locations were analyzed over a spring to neap tidal cycle to characterize the dry weather condition. In wet weather, fecal coliform concentrations from the 1998 0.93-inch storm were used to fecal coliform conditions at the instream stations. In both wet and dry weather, the modeled geometric mean and 90th percentile concentration at each shellfish station were higher than the observed values. In addition, the design conditions occur in the critical summer month time period when bacteria concentrations are highest in the Runnins River and Barrington River. The loading reductions specified in this TMDL will therefore ensure compliance with the water quality standards during other times of the year.

5. Required Receiving Water Reductions

The water quality target based on the Class SA standard dictated the allowable fecal coliform concentrations in the Barrington River. Instream concentrations were determined using the water quality computer model, calibrated and validated with RIDEM sampling data. Reductions were specified that ensure attainment of both parts of the fecal coliform standard. A summary of the calculated reductions is presented in Table 4.

Table 4 Required Barrington River Reductions.

Station[1]	Geometric Mean fc/100 ml			90th Percentile Value fc/100 ml			Reduction Required to meet both parts of Standard
	Target	Dry Observed	Wet Observed	Target	Dry Observed	Wet Observed	
GA2-1 (Tongue)	12.6	93.1	155.1	49	173.0	348.9	93 %
GA2-1A	12.6	40.7	81.6	49	84.6	150.0	85 %
GA2-2 (Hundred Acre Cove)	12.6	40.6	50.9	49	42.5	66.8	75 %
GA2-3 (White Church Bridge)	12.6	23.9	65.8	49	52.1	94.5	81 %
GA2-4	12.6	12.3	55.7	49	37.9	98.2	77 %
GA2-5 (Bike Path Bridge)	12.6	6.9	43.4	49	26.2	95.2	74 %

[1] Stations are listed from upstream to downstream. Locations are shown in Figure 3.1.

6. Tributary Reductions

The Runnins River, a Class B stream, is the largest fecal coliform source to the Barrington River. Class SA water quality standards must be met at the Runnins River point of entry to the Barrington River (RIDEM, 2002b). In the absence of site specific data to indicate that the Barrington River water quality goals could be met if each tributary discharges at the Class B standard, this TMDL requires that the Runnins River and other freshwater streams entering the Barrington River must meet the Class SA standard at its point of entry. A geometric mean of 14 fc/100 ml and a 90th percentile value of less than 49 fc/100 ml are set as numeric targets for downstream stations in each of the tributaries.

As specified in the Palmer River TMDL, the Palmer River is a Class B waterbody that must also meet the Class SA water quality standards at its point of entry to the Barrington River (RIDEM, 2002a). This ensures that water quality standards in the Barrington River are met, particularly in wet weather.

7. Implementation plans

Fecal coliform bacteria levels in the Barrington River are related principally to conditions and loadings introduced by the Runnins River. The Palmer River watershed is a source during wet weather. Sources along the Barrington River shoreline were considered negligible in dry weather (RIDEM, 1996a) and were estimated for wet weather conditions. These point and nonpoint bacteria sources were found to be smaller contributors to fecal coliform concentrations in the Barrington River.

Mitigation measures designed to bring about water quality improvements to the Barrington River are outlined below. In all cases, the significant sources are nonpoint in nature, and the improvements achieved by implementing the measures outlined below cannot be quantified. RIDEM therefore recommends continued monitoring of the Runnins, Barrington, and Palmer Rivers to ensure that the instream numeric targets are met.

Barrington River

Areas of the Barrington River below the White Church Bridge that have historically been used as shellfishing areas are directly adjacent to the heavily developed commercial area of Barrington. Sources along this area were sampled in dry weather by RIDEM as part of the upper Barrington River surveys (RIDEM, 2000). The RIDEM Shellfish Program (RIDEM, 1999a) also sampled pipes in this area during 1994, 1996, and 1999. These studies found that loadings from sources below the Runnins River are negligibly small in dry weather.

When designing a wet weather monitoring plan for the Barrington, Palmer, and Warren Rivers, RIDEM personnel sampled only the largest bacteria sources to the watershed. These sources included the Runnins River, RIPDES sources in the Warren River, and several freshwater streams within the Palmer River watershed. RIDEM did not sample direct storm water discharges along the Barrington River because it was believed that these sources were significantly smaller in their water quality impact than the sampled sources. In other words, the much larger loads from the sampled sources would *mask* any impact from the Barrington River direct storm water sources.

The modeling calibration and validation exercises supported the decision to not sample direct storm water discharges along the Barrington River. As shown in the RIDEM Shellfish Program's Shoreline Surveys, several pipes may potentially discharge storm water to the Barrington River. After reviewing draft copies of this report, EPA requested that RIDEM examine the potential impact of these sources. Section 5.2, describes the methodology used by RIDEM to estimate direct storm water loadings to the Barrington River. After estimating the direct storm water loading, RIDEM added these sources to the calibration storm event simulation in the water quality model. The loading was divided equally between ten sources that were placed along the Barrington River shoreline. These sources did not improve the model-data agreement. A reexamination of the available water quality data collected following the storm event did not reveal any reliable evidence of direct storm water impacts. Although these outfalls are sources of bacteria, any impact from these sources could not be seen due to the much larger impact of other sources.

Storm Water Phase II Permit Program

RIDEM has amended the existing Rhode Island Pollution Discharge Elimination System (RIPDES) regulations to include the requirements of the EPA Phase II Storm Water Regulations. The new regulations became effective in March 2002. As designated by the regulations, certain 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:

- Public education and outreach program to inform the public about the impacts storm water on surface water bodies.
- Public involvement/participation program.
- Illicit discharge detection and elimination program.
- Construction site storm water runoff control program for sites disturbing one or more than acres.
- Post construction storm water runoff control program for new development and redevelopment sites disturbing one or more than acres.
- Municipal pollution prevention/good housekeeping operation and maintenance program.

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

Operators of municipal separate storm sewer systems (MS4s) within urbanized areas (UAs) will be required to develop a SWMPP and obtain a permit (for those portions within the UA) by March 10, 2003. The Director will require permits for areas 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 the Barrington River are owned and operated by the Town of Barrington and the Rhode Island Department of Transportation (RIDOT). Areas within Rhode Island adjacent to the Barrington River are in a UA. Accordingly, the Town of Barrington and RIDOT will be required to apply for RIPDES permits March 10, 2003.

RIDEM will continue to work with the Coastal Resources Management Council (CRMC), RIDOT, and the town of Barrington to identify funding sources and to evaluate locations and designs for storm water control BMPs throughout the watershed. In accordance with the requirements of this phased TMDL, monitoring of the Barrington River will continue so that the effectiveness of ongoing remedial activities can be gauged.

Woods Pond

Based on information gathered by scientists at the University of Rhode Island and additional RIDEM sampling, detailed in Section 11, RIDEM believes that the Town of Barrington and the Rhode Island Department of Transportation (RIDOT) should consider a structural BMP to pre-treat storm water prior to discharge into Woods Pond. Woods Pond, located behind the Barrington Town Hall was constructed to handle storm water runoff from Route 114 and Maple Avenue. Woods Pond discharges to an unnamed cove in the Barrington River. The outlet of the pond, source 5 in Figure 5.7, was not flowing in 1999 during the Shellfish Growing Area Water Quality Monitoring Program's shoreline survey. In 1996 this tributary showed elevated levels of fecal coliform. The pond acts as a detention pond by reducing peak flows during storms, providing some detention time, and allowing for greater fecal coliform decay. As sediments common in storm water accumulate in the pond, the pond's effectiveness as a BMP is reduced. As with all storm water BMPs, routine maintenance, including periodic removal of accumulated sediment, is recommended.

Palmer River

The TMDL written by RIDEM for the Palmer River requires the upper Palmer River to meet the fecal coliform criteria for Class SA waters at the point of entry to Rhode Island waters (RIDEM, 2002a). The upper Palmer River is located in Massachusetts. Studies in this upper portion of the Palmer River watershed determined that significant loads were associated with agricultural operations adjacent to both the Palmer River and its freshwater tributary, Rocky Run (RIDEM, 1999c). Tributary streams to Belcher Cove represented significant sources to the system during dry and wet weather. The causes were traced to disposal of dog waste and urban runoff in one stream and to a potential range of problems, including a small cattle farm and urban storm runoff, in the second stream.

Runnins River

The draft TMDL written by RIDEM for the Runnins River requires the river to meet the fecal coliform criteria for Class SA waters at its point of entry to the Barrington River (RIDEM, 2002b). Possible dry weather sources to the Runnins River include regrowth and accumulation of bacteria in areas of dense *phragmites* growth. In wet weather, several direct storm water discharges have been identified throughout the waterbody.

RIPDES Sources

The impacts of point sources adjacent to the Barrington River were determined to be negligible in their impact on instream fecal coliform levels. The point sources are the Warren WWTF and Blount Seafood with Rhode Island Pollutant Discharge Elimination System (RIPDES) permit numbers RI0100056 and RI0001121, respectively.

The Warren WWTF experiences occasional exceedences of the daily maximum fecal coliform concentration limit. Investigation thus far has not found the cause, however equipment failures have been ruled out. The timing of the exceedences suggests that the problem may be tied to excessive infiltration and inflow (I/I) in its collection system. The Warren WWTF has been issued a Compliance Order to address excessive I/I, and the plant has completed implementation of corrective actions for inflow sources. The plant also recently submitted the results of an infiltration identification study along with a schedule for implementing corrective actions.

Allocations for the point sources are the same in dry and wet weather and have been set to their current permit limits, as listed in Table 5. Dye dilution studies have been used to establish mixing zones and effluent concentration limits for RIPDES permits at the Warren WWTF and Blount Seafood. From examining the dye study data, RIDEM has concluded that increasing or decreasing the loadings from these sources has very little impact on water quality in the Barrington River.

Table 5 Waste load allocations based on permit limits.

Point Source	Permitted Discharge[1] (MGD)	Permitted Concentration[2] (fc/100 ml)	Actual Concentration[3] (fc/100 ml	Percent Reduction
Warren WWTF	2.01	200	10.1	0 %
Blount Seafood	0.2	200/3100	29.3	0 %

[1] Warren WWTF permitted discharge is the average monthly limit while the Blount Seafood discharge is the maximum daily discharge.
[2]The permitted concentration is the average monthly limit. Blount has different concentration limits in the winter and summer. See above for explanation.
[3]Actual concentration data is from 1998-2001 plant data.

8. Proposed Monitoring

Follow-up monitoring of the Barrington, Runnins, and Palmer River will confirm whether the desired water quality standards will be achieved. The monitoring conducted by volunteers, such as those in the Pokanoket Watershed Alliance, will be valuable in the monitoring the effectiveness of the proposed BMPs and in keeping water quality issues in the public eye.

RIDEM recruited volunteers through the Pokanoket Watershed Alliance to continue sampling at three stations in the Runnins Rivers. The stations are located below the Burrs Pond Dam, Mink Street, and at School Street in the Runnins River. At these stations, volunteers would collect fecal coliform samples and record instream temperatures on a monthly basis from July through October. In addition, stage should be recorded at School Street.

The Shellfish Growing Area Water Quality Monitoring Program samples the Barrington and Palmer Rivers bimonthly. At the present time, all stations in the Barrington River exceed water quality standards. If BMPs are effective in reducing the Runnins River loading to the extent projected in this study, these stations will meet standards. At the time that these stations begin to meet water quality standards, supplemental monitoring may be required for the northernmost shellfish stations. This monitoring may involve sampling this station at high and low tide on the same day along with the School Street station in the Runnins River.

9. Public Participation

The New England Interstate Water Pollution Control Commission (NEIWPCC) established a steering committee comprised of members of local municipalities, state agencies, EPA, and the Pokanoket Watershed Alliance, in 1993. This committee, known as the Runnins River Steering Committee, holds bimonthly meetings that are open to the public. The Runnins River Steering Committee participated in the 1995 wet weather study of the Runnins River and has contributed actively to the content of the ongoing work by RIDEM. The committee has ensured that improvements to the water quality of the Runnins and Barrington River have remained on the agendas of the state and federal agency agendas. RIDEM has been an active member of the steering committee and has worked to keep committee members informed on the progress of the TMDL.

Public meetings and an open comment period are an important component of the TMDL process. RIDEM held an initial public meeting in July 1999 prior to TMDL development, which included all interested public, private, and government entities. The goal of the meeting was to provide information regarding the TMDL issues in the watershed and to solicit input regarding pollution sources and/or other concerns. Initial draft TMDL documents were presented for the Runnins and Barrington Rivers for public comment in June 2000. Public comment was solicited for a thirty-day period during and after the meeting. EPA comments on the draft Barrington River TMDL made it necessary to hold a final public meeting and notice period for both TMDLs in July - August 2002. Stakeholders were again given thirty days to review and submit comments on the draft Runnins and Barrington River TMDLs. RIDEM's response to comments made during the 2000 and 2002 comment periods are contained in Appendix C to this document.

1.0 INTRODUCTION

Rhode Island's 1998 list of impaired waters (RIDEM, 1998b) includes the Barrington River, which is listed for not meeting water quality standards. The Barrington River's stated impairment is pathogens, as evidenced by elevated fecal coliform concentrations.

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 TMDL analysis examines point source inputs, such as industrial and wastewater treatment facility discharges, and nonpoint source inputs, such as storm water runoff from agricultural and urbanized areas. Natural background levels and a margin of safety to account for any modeling or monitoring uncertainties are also included in the analysis. The goal of this process is to reduce pollutant loadings and to restore water quality in the waterbody to the limits set by the State's water quality regulations.

1.1 Background

This Barrington River TMDL will address the Class SA waters of the Barrington River from the Mobil Dam to the Bike Path Bridge as seen in Figure 1.1. At the Mobil Dam, the fecal coliform water quality standard decreases from the Class B Runnins River to the Class SA Barrington River. The standard drops from 200 fecal coliforms per 100 milliliters (fc/100 ml) to 14 fc/100 ml.

The Barrington River watershed lies in northeastern Rhode Island and southeastern Massachusetts and includes the estuarine waters of the Barrington River and Hundred Acre Cove. The Barrington River is regionally significant as a habitat and shellfish resource. Hundred Acre Cove is adjacent to one of the three largest salt marshes in the State of Rhode Island and has been designated by USEPA as a priority wetland. The cove provides habitat for a number of bird species and one of the only populations of the northern diamondback terrapins in Rhode Island.

The Barrington River supports hard and soft-shell clam, oyster, and blue crab fisheries. The State of Rhode Island has historically supported a commercial shellfishery in the Barrington River. From 1995 to 1996, the Barrington River north of Hundred Acre Cove was closed to shellfishing due to violations of the fecal coliform standards in the vicinity of the confluence of the upper reach of the Barrington River and Hundred Acre Cove. The Cove was able to reopen for one year in 1997. The entire Barrington River is now permanently closed for shellfishing because of elevated fecal coliform levels.

The Barrington River is also a popular location for recreational activities such as boating. During peak activity summer months, approximately 650 recreational and commercial vessels are either docked or moored within the residential and commercial portions of the Barrington and Warren Rivers (RIDEM, 1996a). All Rhode Island waters, including the Barrington River, are designated as no discharge areas. In a no discharge area, discharge of treated and untreated boat sewage is prohibited.

1.2 Applicable water quality standards

The standards for water quality in the Barrington River are specified in the state's Water Quality Regulations (RIDEM, 1997c). The Water Quality Standards are intended to protect public health,

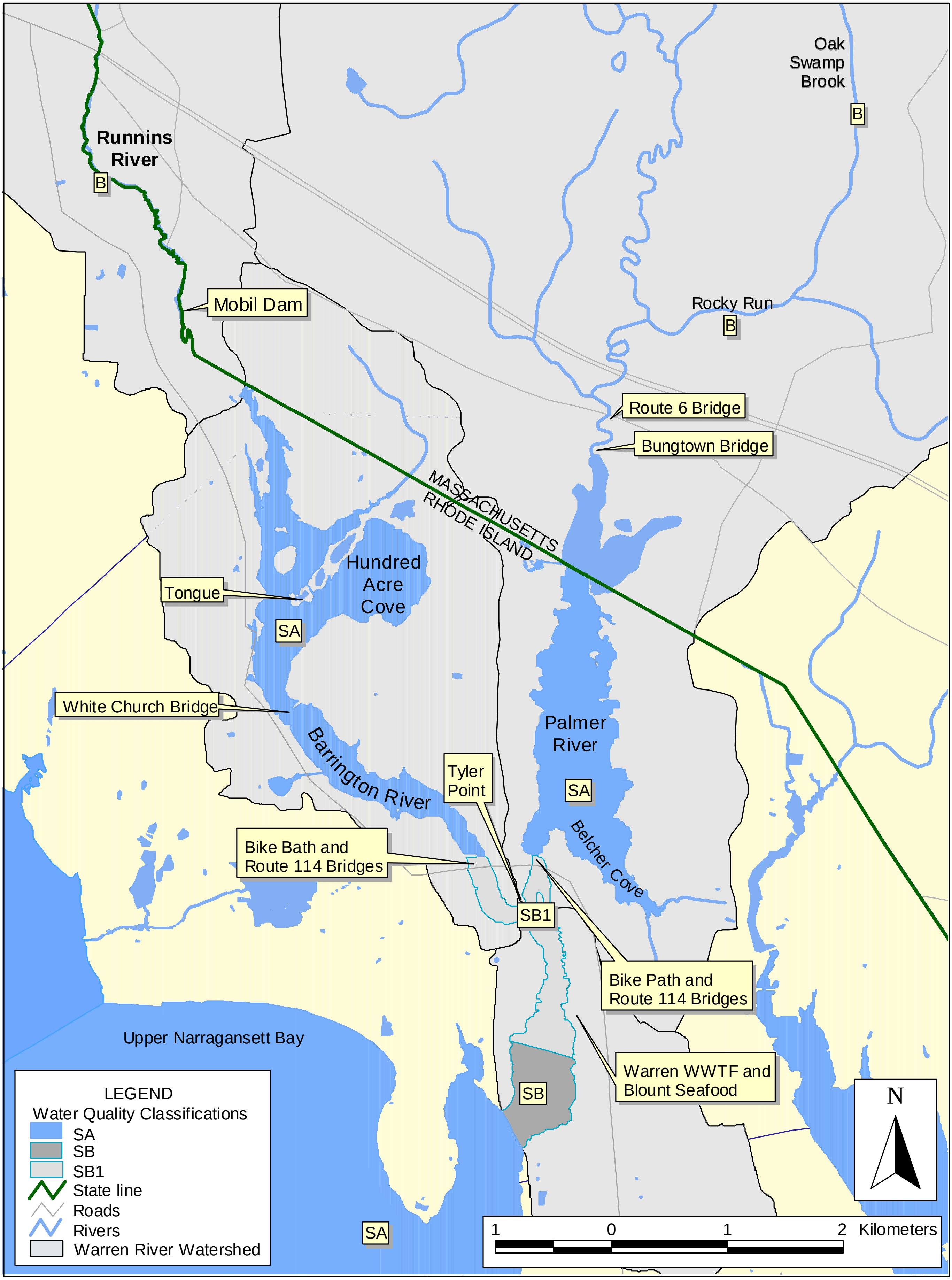


Figure 1.1 The Barrington, Palmer, and Warren Rivers and their water quality classifications.

safety, and welfare. Water quality standards meet the requirements of the federal Clean Water Act of 1972 and Rhode Island General Laws (Chapter 46-12). The regulations define two basic classes of fresh and marine waters. Classes A and B are freshwaters and Classes SA and SB are marine waters. Classes A and SA waters are of higher quality. Rhode Island's Water Quality Regulations describe Class SA waters as *"designated for shellfish harvesting for direct human consumption, primary and secondary contact recreational activities, and fish and wildlife habitat. They (Class SA waters) shall be suitable for aquacultural uses, navigation, and industrial cooling. These waters shall have good aesthetic value."* Classes B and SB waters are designated as suitable for *"primary and secondary contact recreational activities and fish and wildlife contact*", notably swimming.

The Barrington River is defined as two water bodies in Appendix A of the Water Quality Regulations. The majority of the River is designated as Class SA and is assigned the identification number RI007021E-01A, defined as "Barrington River from the Mobil Dam in East Providence to the East Bay Bike Path in Warren approximately 1000 feet north of the confluence with the Palmer River." The remainder of the River, waterbody number RI007021E-01B, from the Bike Path Bridge to the Barrington River's confluence with the Palmer River at Tyler Point is in Class SB1 waters (RIDEM, 1997c). This document addresses the fecal coliform impairment of the Class SA portion of the Barrington River between the Mobil Dam and the Bike Path Bridge, as seen in Figure 1.1.

The conditions specified in the Water Quality Regulations are water quality goals for each waterbody (Rule 8). When the waterbody does not meet these goals, the conditions presented in the Water Quality Standards serve as the regulatory basis for establishing water-quality-based treatments and strategies beyond the technology-based levels of treatment normally required by the Clean Water Act. The physical, chemical, and biological conditions to be met in Class SA waters are stated in Table 2 of Rule 8.D of the Regulations. Fecal coliform concentrations in class SA waters are *"not to exceed a geometric mean (MPN) value of 14 and not more than 10% of the samples shall exceed an MPN value of 49 for a three-tube decimal dilution,"* where MPN is the most probable number (RIDEM, 1997c).

2.0 DESCRIPTION OF THE BARRINGTON RIVER STUDY AREA

2.1 Barrington River

The Barrington River, shown in Figure 1.1, begins at the mouth of the Runnins River at the Mobil Dam on the East Providence/Seekonk border. From its head, the river runs in a southeasterly direction for a distance of 6 kilometers (km) to its confluence with the Palmer River at Tyler Point in Barrington. The Barrington River is spanned by three bridges, the Massasoit Avenue Bridge (commonly referred to as the White Church Bridge), the East Bay Bicycle Path Bridge, and the Route 114 Bridge just upstream of the Barrington River's confluence with the Palmer River. The reductions of the River's cross-section at these bridges are physical constrictions that affect the dynamics of the River.

The upstream limit of the Barrington River is the Mobil Dam, which was built in the 1920's by the Mobil Corporation to divert water to a pump house for industrial use at the Mobil facility. The concrete dam is approximately 26 meters (m) long with a spillway crest estimated to be 1.37 m NGVD (National Geodetic Vertical Datum). During normal tide ranges, the dam is the upstream limit of tidal influence, however during spring tides, the dam is routinely overtopped, and the tidal influence extends at least 1 km upstream, to a point upstream of the Mink Street Bridge in the Runnins River.

The distance from the Mobil Dam to a strip of land known as the Tongue is about 2 km. In this reach, the width of the Barrington River ranges from 10 m to about 200 m. Low tide depths are less than 0.5 m in many areas, making the area largely inaccessible by boat. The banks of the river are buffered by extensive wetlands.

As the river widens south of the Tongue, a side embayment called Hundred Acre Cove opens to the east of the main channel. Hundred Acre Cove opens off the main channel with a width of approximately 300 m and widens to a maximum width of approximately 900 m. The Cove has mean low water and high water surface areas of 1.24×10^6 m^2 and 2.30×10^6 m^2 respectively. It is shallow, with low tide depths of 0.3 m or less in most areas. A Brown University calculation of the tidal flushing of Hundred Acre Cove using tidal prism estimates (the volume of water entering the estuary on a flood tide) yielded flushing times between 6.07 and 35.62 hours for spring and neap conditions, respectively. In general, a smaller tidal prism gives a longer flushing time because less water is brought into the estuary during each tidal cycle (Brown University, 1996). Tidally averaged salinities in Hundred Acre Cove range from 15 parts per thousand (ppt) during periods of high tributary flow to 27 ppt during low flow periods. In comparison, salinity at the mouth of the Barrington River varies from 23 ppt to 27 ppt in periods of high and low flow, respectively.

White Church Bridge is south of the opening of Hundred Acre Cove. The average tidal range at the White Church Bridge is 1.4 m; the tidal ranges for the spring and neap tides are 1.52 m and 1.16 m respectively (Brown University, 1996). Tides at White Church Bridge lag behind the predicted Warren tides (entrance to the Warren River) by an average of 24.8 minutes. This lag is slightly longer during spring tides and slightly shorter during neap tides.

South of White Church Bridge, the width of the Barrington River ranges from 200 m to 350 m. In this reach, a deeper channel with depths to 4 m forms between the center and south bank of the river. The River constricts as it passes under the East Bay Bicycle Path and Route 114 bridges. The confluence with the Palmer River lies 500 m below the Route 114 bridge.

Both perennial and intermittent streams provide freshwater inputs into the Barrington River. The Runnins River, at the head of the Barrington River is the primary freshwater input into the system. Spring discharges range from approximately 0.33 cubic meters per second (m^3/s) to above 2 m^3/s. Late summer base flows range from less than 0.1 m^3/s to about 0.3 m^3/s (RIDEM, 1999c).

Compared to the Runnins River, other tributaries do not contribute a significant amount of freshwater to the Barrington River. The Rhode Island Department of Environmental Management (RIDEM) flow gauged an unnamed tributary near Warren Avenue discharging at the east bank of the Barrington River shortly upstream of the Tongue during 1996. The tributary discharge was small, 0.012 m^3/s over the period of record, with the mid-summer discharge ranging from 0.002 m^3/s to 0.009 m^3/s (RIDEM, 1999c). Other dry weather discharges along the Barrington River identified by shoreline surveys have been found to be small.

2.2 Characterization of the surrounding watershed

The Barrington River watershed lies within the towns of Barrington and Warren, Rhode Island, Rehoboth and Swansea, Massachusetts, and the city of East Providence, Rhode Island. The Runnins River with a watershed area of 10.2 square miles in Massachusetts and Rhode Island accounts for more than 70% of the Barrington River drainage area. The remainder of the drainage area is south of the Mobil Dam. The Runnins River sub-basin is comprised of relatively flat areas with extensive wetlands bordering the River. Vacant land accounts for approximately 44.4% of the sub-basin, residential land 20.6%, public parks/open space 10.8%, industrial 10%, commercial 8.3%, and agricultural, 5.9% (NEIWPCC, 1994).

The Runnins River begins in a wetlands area to the east of Turner Reservoir. The upper watershed is semi-rural, with significant areas of agricultural and low-density residential uses. The intensity of land use increases as the river flows through the Taunton Avenue area in Seekonk. Pockets of commercial development begin to occur and residential areas become larger, with smaller lot sizes. This trend continues, peaking in the southern end of Seekonk, where several large strip malls abut the river. This area is predominantly high density residential and commercial, with some industrial uses. Interstate 195 crosses the river shortly upstream of this area. Wastewater from the large commercial area near the river is treated with on-site septic systems. Retention ponds handle storm runoff from the newer facilities. Below the Route 6 bridge, the Runnins is a low gradient stream with multiple channels passing through a marsh area behind the Seekonk mall area. The Runnins River merges into a single channel flanked by extensive *Phragmites australis* wetlands below the mall area. During spring tides, some tidal influence is present below this point. The Runnins River ends at the Mobil Dam, approximately 500 m downstream of the School Street overpass.

Two treatment facilities discharge to the Warren River, the Town of Warren Wastewater Treatment Facility (WWTF) and the Blount Seafood Corporation processing plant. The Warren WWTF was built in 1981 and is run by five full-time operators. Recent improvements to the plant include upgrades to instrumentation, DO control of aerators, and dechlorination. In addition, the Town of Warren is implementing an extensive inflow and infiltration (I/I) reduction program. The current permit limits are an average monthly discharge of 2.01 million gallons per day (MGD) and an average monthly fecal coliform concentration of 200 MPN/100 ml.

The Blount Seafood Corporation's permit limits require a maximum daily flow of 0.2 MGD with average monthly fecal coliform concentration of 200 MPN/100 ml from April through October. In 1996, Blount began a conversion to thermal disinfection of effluent. During RIDEM dry weather monitoring of the Warren River watershed in 1996, the plant was constructing the thermal system. Blount received permission to pilot test the system in 1996. The chlorine disinfection system was kept as a backup system until final permit approval for the thermal system was given by RIDEM in December of 1996.

3.0 DESCRIPTION OF WATER QUALITY MONITORING ACTIVITIES

3.1 Shellfish growing area monitoring

The Shellfish Growing Area Water Quality Monitoring program is part of the State of Rhode Island's agreement with the US Food and Drug Administration National Shellfish Sanitation Program (NSSP). NSSP requires Rhode Island to conduct routine bacteriological monitoring of the State's waters where shellfish is intended for direct human consumption. Six of the sixteen monitoring stations in Growing Area (GA) 2 are in the Barrington River as shown in Figure 3.1. Five stations are in the Palmer River, and five stations are in the Warren River. The southern portion of the Warren River, adjacent to upper Narragansett Bay, includes two stations located in Conditional Area A.

The Barrington River is currently closed for shellfishing during all weather conditions. At times during the last ten years, it has been conditionally open for shellfishing and was managed as part of Conditional Area A in upper Narragansett Bay. Conditional Area A is open for shellfishing during dry weather and closed during wet weather. A dry weather period occurs at least seven days after a rainfall or snowmelt event of 0.5 inches or more, and/or seven days after a treatment facility bypass greater than 0.5 MGD by any municipal wastewater treatment facility that impacts Upper Narragansett Bay. Sampling runs in the Barrington River are conducted bimonthly during dry weather periods when the conditionally approved portions of Growing Area 2 are open to shellfish harvesting. Sampling runs may also be conducted during wet weather periods, but on a more infrequent and random basis.

To maintain compliance with the NSSP, RIDEM conducts periodic shoreline surveys of approved shellfish waters. The primary objectives of shoreline surveys are to identify and characterize new sources of pollutants to the shellfish growing area, to reevaluate point and nonpoint sources identified during previous surveys, and to update information regarding corrections made to previously identified sources. The most recent shoreline survey of the Barrington River was conducted on November 15, 16, and 22, 1999 during the ebb tide cycle. The shoreline survey evaluated all pipes, drainage ditches, and culverts discharging to the river to determine whether they represented actual or potential sources of pollution. Bacteriological samples were collected from all flowing sources (RIDEM, 1999b). In 1994, in addition to the bacteriological sampling, discharge was measured from all flowing sources. Appendix A details the loading calculation from these sources during the 1994 shoreline survey (RIDEM, 1994a).

3.2 Dry weather monitoring: Upper Barrington - Barrington River

On July 21, 1997, RIDEM conducted a dry weather survey beginning at the School Street Bridge and extending to RIDEM Shellfish Station 1, located in the Barrington River. RIDEM conducted two additional dry weather surveys on September 21 and November 5, 1998 that extended further upstream into the Runnins River and further downstream into the Barrington River. The objectives of these studies were to quantify fecal coliform levels in the upper Barrington River during dry weather and to identify any sources contributing to elevated levels for future mitigation efforts. During the three surveys, 26 instream stations and 13 tributary stations to the Runnins and Barrington Rivers were sampled (Figures 3.2 - 3.4). Instream fecal coliform samples were collected during high and low tide. Salinity, conductivity and temperature were also measured in-situ at stations in the Barrington River during all surveys. Total Suspended Solids were measured at the Barrington River stations during the September 1998 survey. To capture freshwater inflow, samples were also collected during low tide at tributary

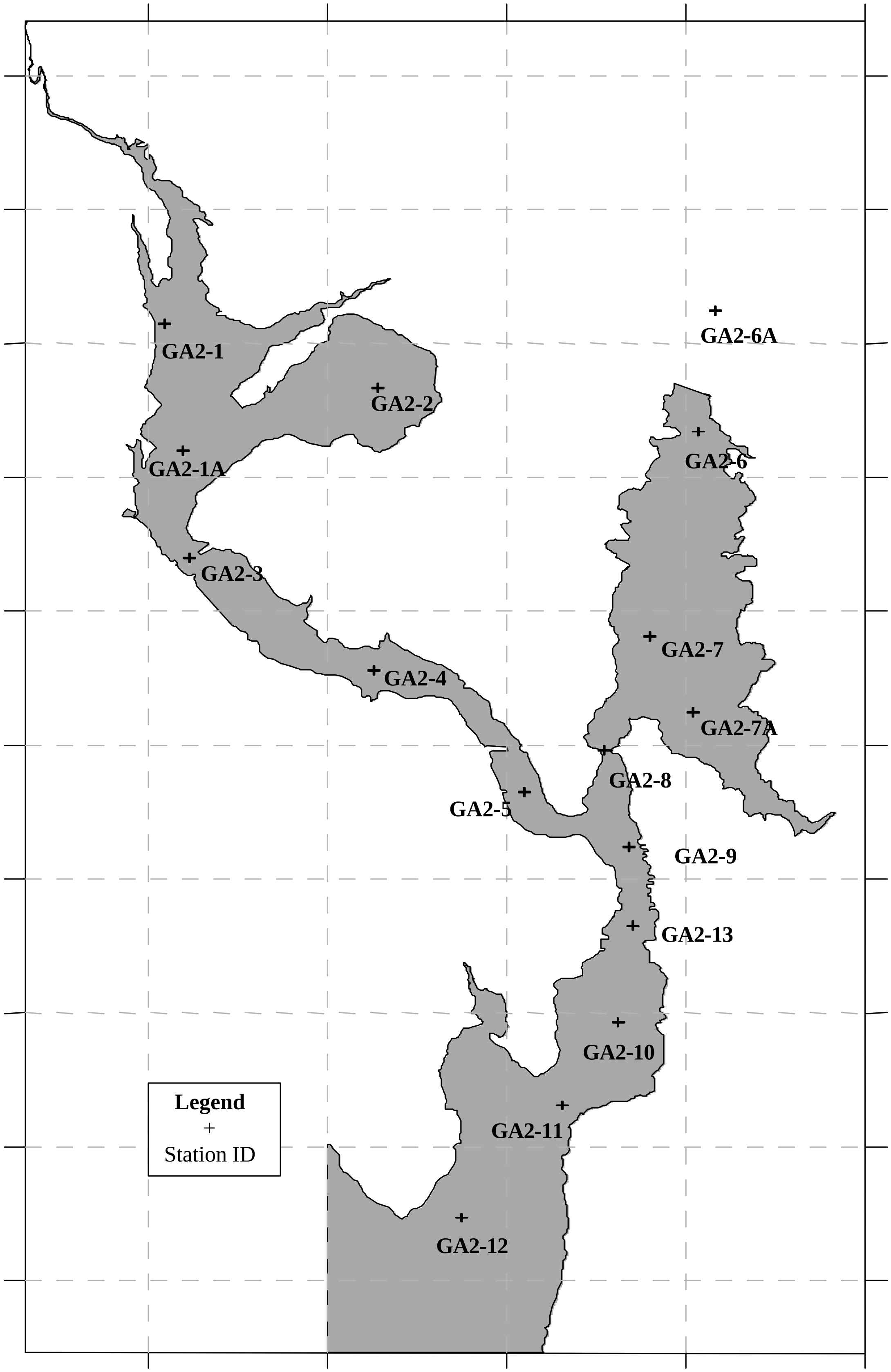


Figure 3.1 Shellfish Growing Area 2 Station Locations.

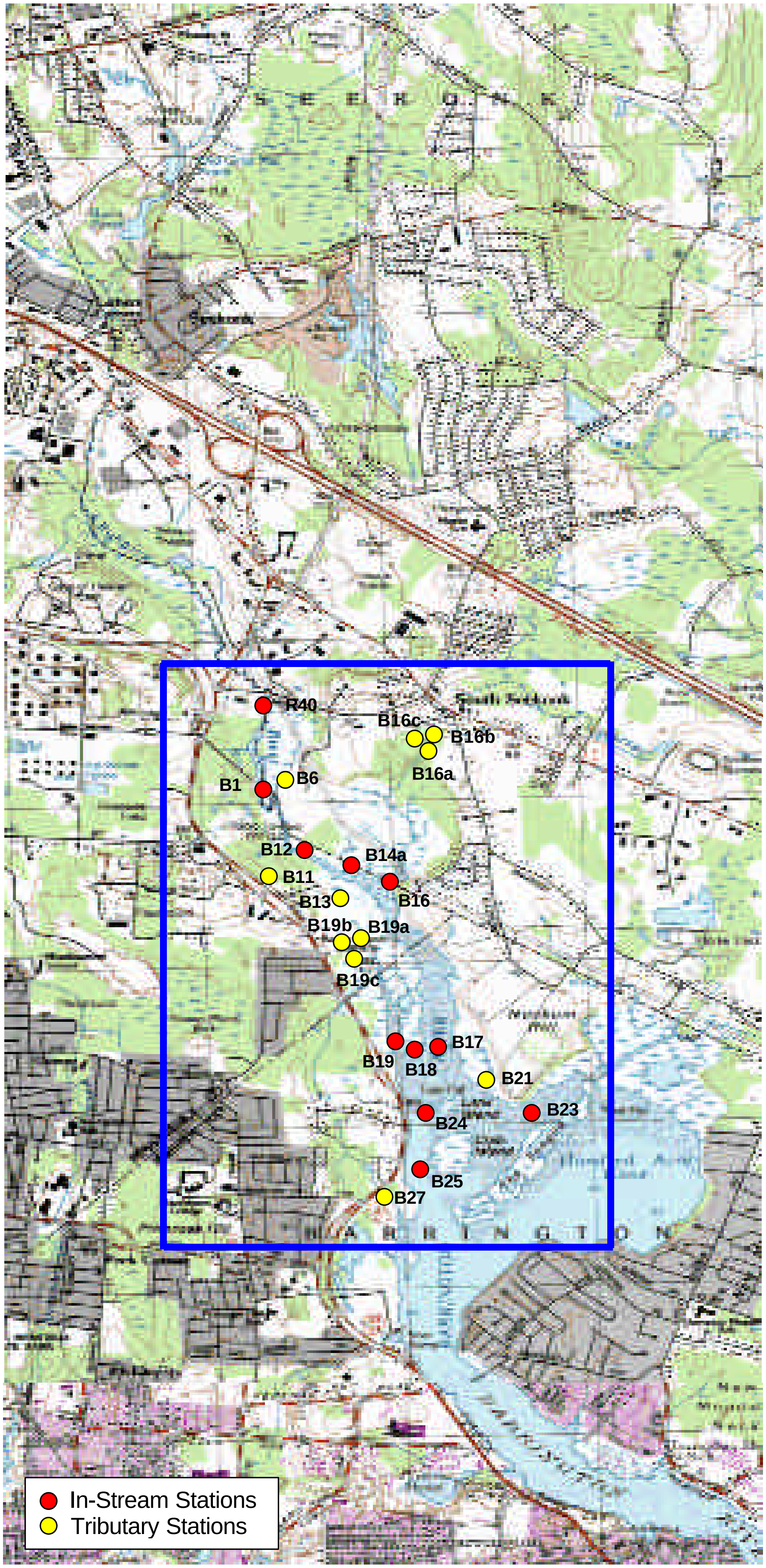


Figure 3.2 Barrington River Dry Weather Survey I Station Locations, July 21, 1997.

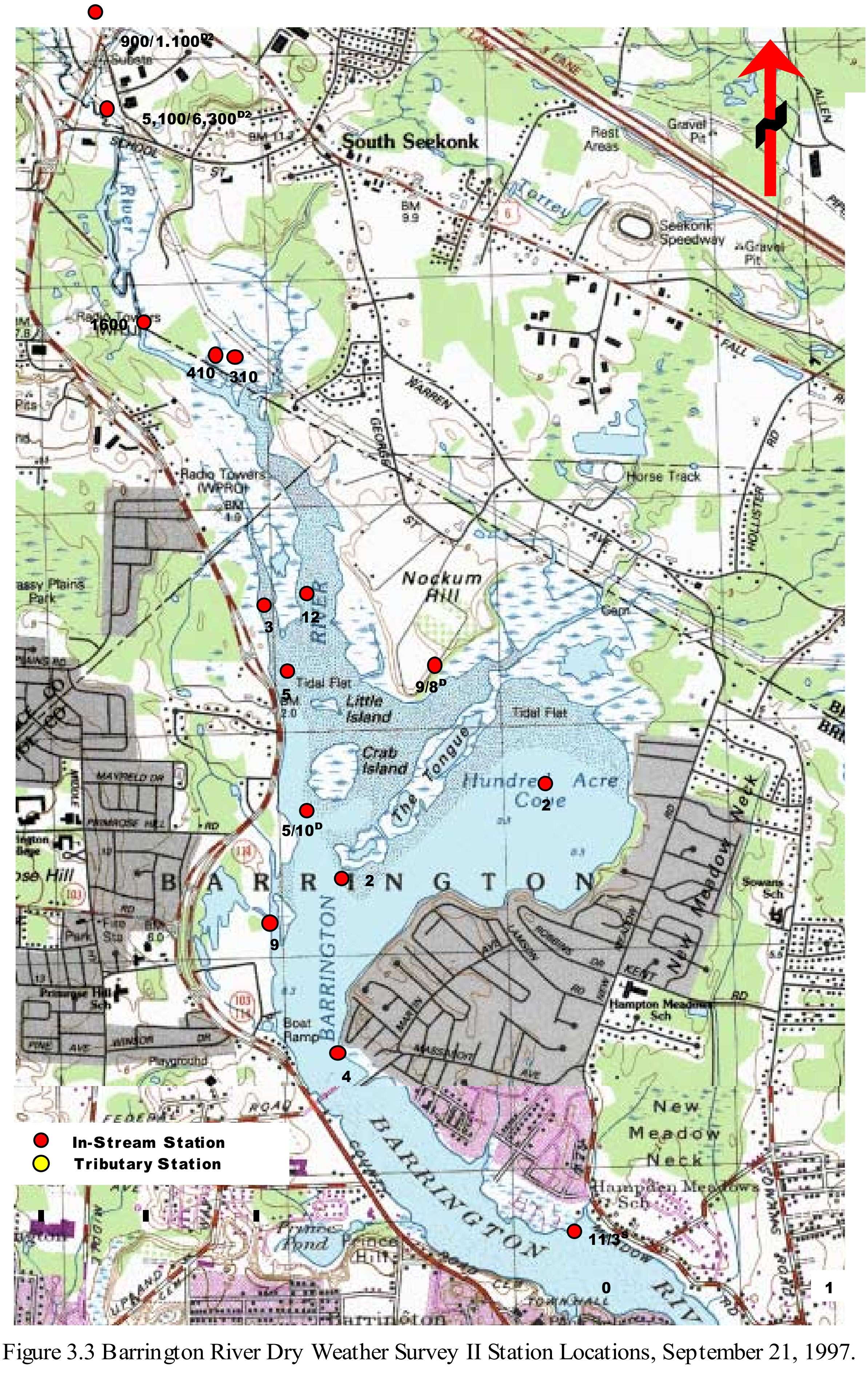


Figure 3.3 Barrington River Dry Weather Survey II Station Locations, September 21, 1997.

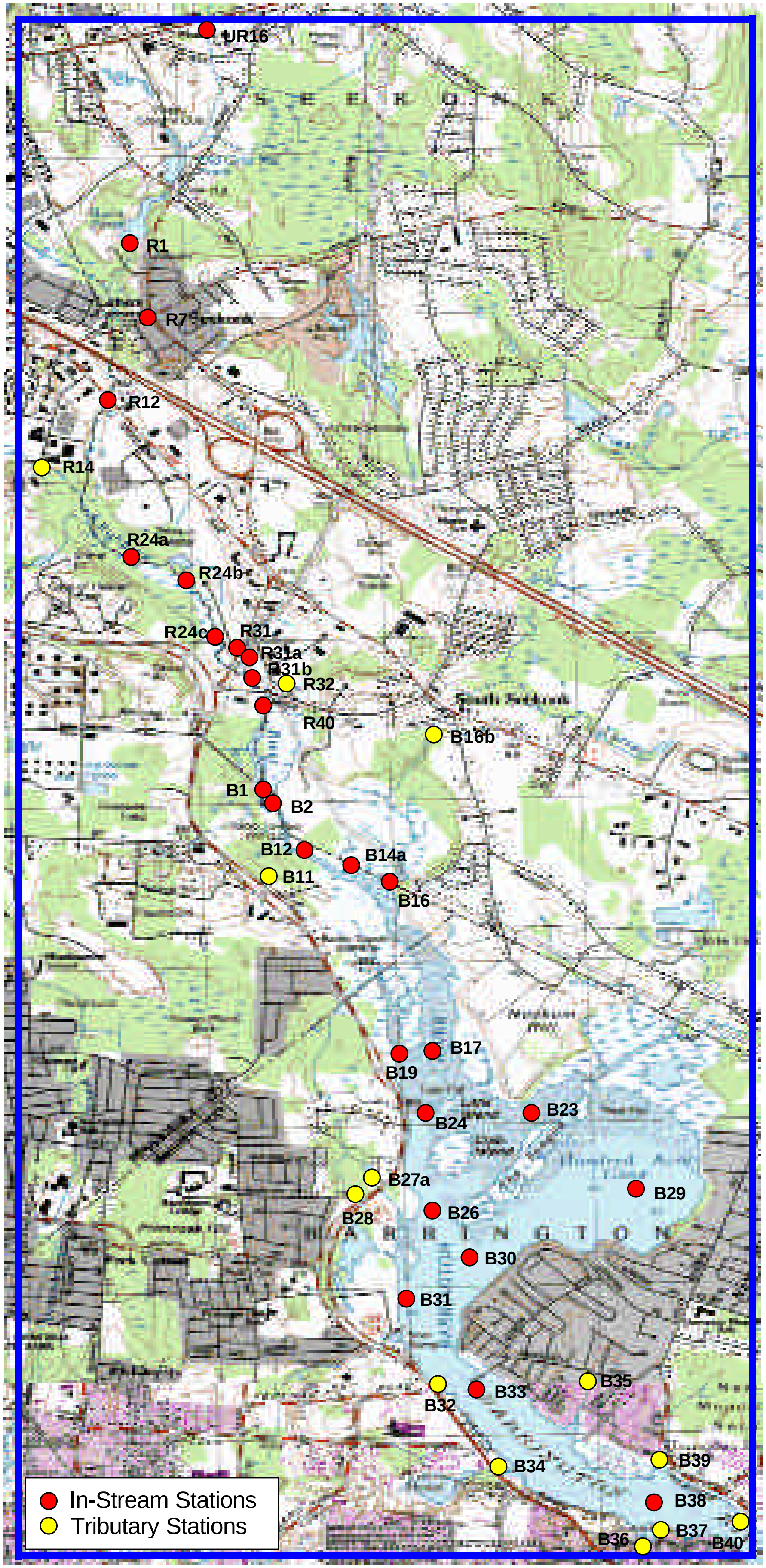


Figure 3.4 Barrington River Dry Weather Survey III Station Locations, November 5, 1998.

stations to the Barrington River during all three surveys. River stage at Mink Street and School Street were measured throughout the surveys.

3.3 Dry weather monitoring: Barrington, Palmer, and Warren Rivers

RIDEM conducted a series of surveys from 1996 to 1998 in the Barrington, Palmer, and Warren Rivers (BPW) to characterize wet and dry weather instream conditions and the tributaries and point sources that contributed significantly to the system. These activities are described in RIDEM (1999c). During dry weather, point sources and tributaries were sampled as described in Table 3.1. In general, these measurements were made the day before the instream surveys, at monthly intervals. Station locations are shown in Figure 3.5.

Table 3.1 RIDEM Dry weather tributary and point source stations.

Station	Location	Stage/ Discharge	Fecal Coliform Sampling
T1	Runnins River, Route 6	♦	♦
T2	Runnins River, School St.	♦	
T3	Palmer River, Reed St.	♦	♦
T4	Oak Swamp Brook, Rocky Run	♦	
T5	Rocky Run, Davis St.	♦	♦
T6	Rocky Run, Mason St.		♦
T7	Blount Seafood	♦	♦
T8	Warren WWTF	♦	♦
T9	Unnamed tributary, Warren Ave.	♦	
T10	Runnins River, Mink St.	♦	

A summary of the dates and types of measurements made in the tributaries and point sources is presented in Table 3.2. Measurements of tributary discharge were made on additional dates during 1996 and 1997 to better characterize tributary discharge rates. Continuous stage measurements were made in the Palmer River at the Reed Street Bridge from August 1 through November 8, 1996. The Runnins River at Mink Street was gauged continuously from July 11 through November 8, 1996 and from June 9 through October 17 during 1997.

The 1996 dry weather surveys consisted of sampling cruises carried out six times during the winter through fall of 1996 and in July of 1997. Each estuary survey cruise was accompanied by a sampling of the tributaries and point sources described Tables 3.1 and 3.2. In addition to fecal coliform sampling, the parameters measured in the water column included salinity, temperature, dissolved oxygen, in vivo fluorescence, and a number of nutrient parameters.

Each estuary cruise was conducted over a 12 hour period spanning a tidal cycle, with high and low tide surveys conducted during each cruise. Measurements were taken around the time of high and low tide, preferably within 1.5 hours of slack water. The measurements at each station consisted of water sample collection and vertical profiling. Figure 3.5 shows station locations in the Barrington, Palmer, and Warren Rivers. At the two Warren River stations and the Upper Narragansett Bay station, water samples were collected from two depths, 1 m from the surface and 1 m from the bottom. At the remaining stations, one sample was collected at the 0.5 or 1 m depth, depending on local water depth. Six stations were located in the Barrington River.

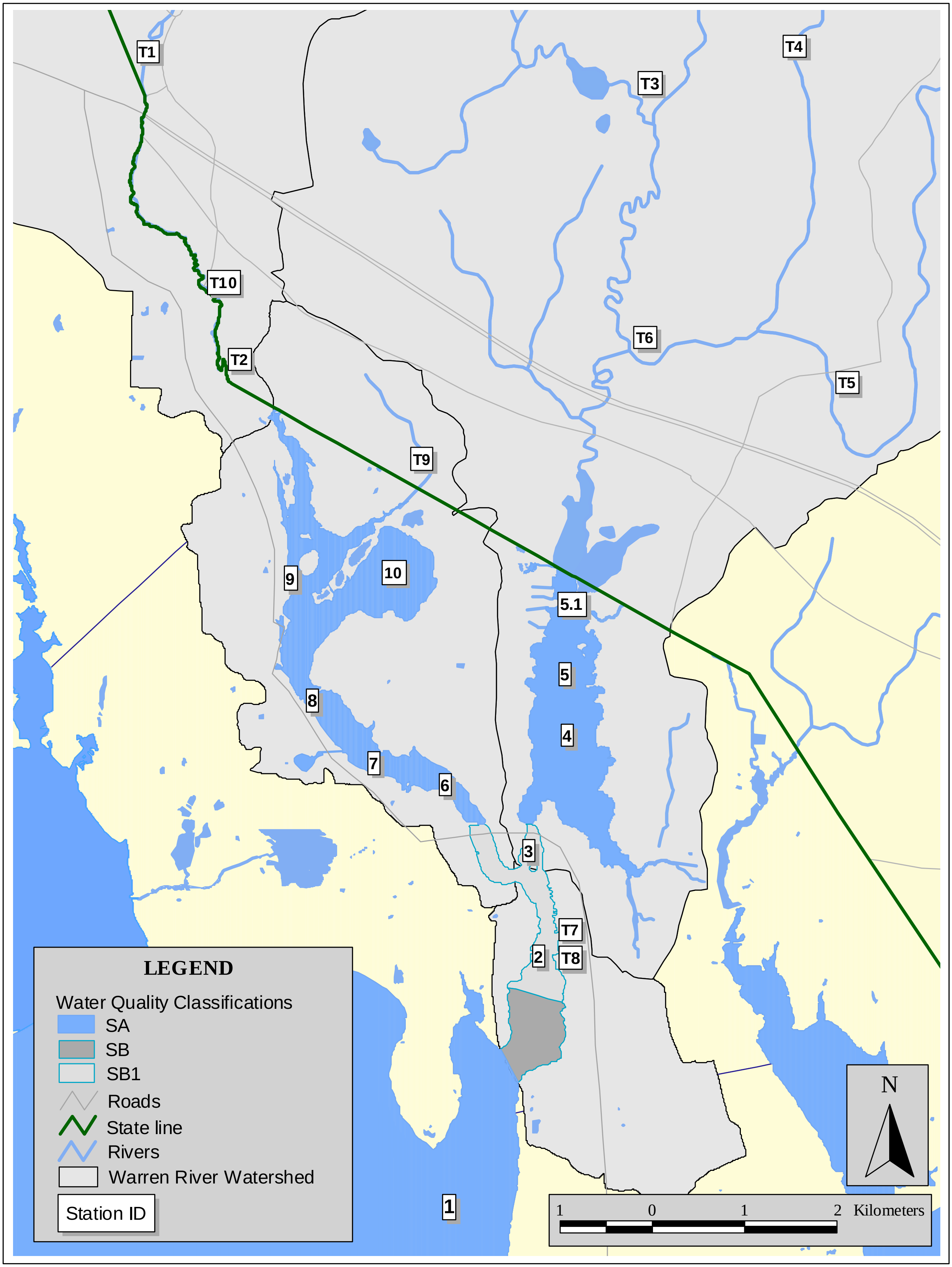


Figure 3.5 1996-97 RIDEM Dry Weather Station Location for the Barrington, Palmer and Warren Rivers.

3.4 Wet weather monitoring: Barrington, Palmer, Warren, and Runnins Rivers, 1998

Nutrient and fecal coliform loadings from the Runnins and Palmer Rivers and Rocky Run were measured during the periods surrounding a rainstorm in October 1998. The wet weather survey provided a picture of the relative increase in nutrient and bacterial loadings associated with rainfall in the area and the associated impacts on water quality in the two estuaries. This study is described in detail in RIDEM (1999c). Three Barrington River sources were sampled for a period of three days: the Runnins River at School Street, the Palmer River in the vicinity of the Route 6 bridge, and Rocky Run at Mason Street.

In the Runnins River, river stage measurements and water sample collection were performed at the downstream side of the School Street Bridge. Stage and temperature were recorded continuously at 15-minute intervals before, during, and after the storm. Water samples were collected by an ISCO discrete sampler, which collected water samples via a peristaltic pump at regular intervals.

In the Palmer River, net cross-section discharge was calculated by measuring current speed and direction with an InterOcean model S4 current meter in the eastern channel under the Route 6 bridge. Using an empirical relation developed from a series of discharge measurements made in the bridge cross-section in 1997, the current speed (in m/s) and sense (ebb/flood) measured by the S4 meter were used to calculate the net volume flow rate (m^3/sec ebb or flood) as a function of time (i.e. at 5 minute intervals). Concurrent nutrient and fecal coliform concentrations were sampled near the center of the river by an ISCO discrete sampler placed at the Bungtown Bridge, which was under repair during the period of the study. The Bungtown Bridge was selected as a sampling point because the Route 6 bridge was considered too dangerous as a sampling station under restricted visibility conditions. The distance separating the two measurement locations is approximately 500 m. While the concentration data do not necessarily represent those at Route 6, the Route 6 discharge data may be considered representative for the Bungtown bridge transect.

Measurements of local river stage and water sample collections with a third ISCO discrete sampler were made at the Mason Street Bridge in Rocky Run. Stage measurements were made from a staff gauge. The principal purpose of the Rocky Run station was to represent wet weather concentrations in this tributary. The loading from Rocky Run to the Palmer River was not calculated, however. This tributary load was accounted for at the Route 6 Station downstream.

Accumulated rainfall was measured manually at periodic intervals at locations adjacent to the School Street and Bungtown Bridge stations. Continuous rainfall data were also obtained from a station on Prudence Island and from T.F. Green Airport in Warwick.

Instream fecal coliform surveys were conducted in the Barrington, Palmer, and Warren Rivers before, during and after the October 1998 wet weather tributary. The purpose of these surveys was to quantify impacts of the event on bacterial concentrations in the estuarine areas of the Warren River Basin (which includes the Barrington River). A pre-storm survey was conducted on October 14. Post-storm surveys were conducted on October 15,16, 19, and 20. Each survey was centered on the time of low tide during daylight hours. The sixteen RIDEM Shellfish Program Warren River watershed stations were sampled during each survey, which included six stations in the Barrington River. Figure 3.1 shows the locations of the Shellfish Growing Area Water Quality Monitoring Program's Growing Area 2 water quality stations.

Table 3.2 Tributary and point source sampling summary.

Date	T1 Runnins River, Route 6	T2 Runnins River, School St	T3 Palmer River, Reed St	T4 Oak Swamp Brook	T5 Rocky Run, Davis St	T6 Rocky Run, Mason St	T7 Blount Seafood	T8 Warren WWTF	T9 Unnamed Tributary, Warren Ave	T10 Runnins River, Mink St
03/13/96	H	H, Z	H, Z	H	Z	H	Z53	Z		
03/21/96	H		H	Q	Q				Q	
05/08/96	H, Z	H	Q, Z	Q	Z	Q		Z		
05/15/96	H	H	Q	Q		Q			Q	
05/24/96	H	H	Q	Q		Q			Q	
06/07/96	H, Z	H	H, Z	H	Z	H			Q	
06/10/96							Z	Z		
06/12/96	H, Z	H	Q, Z	Q	Z	Q	Z	Z	Q	
07/02/96			H	H		H				
07/08/96	H	H	H	H		H				
07/10/96	H, Z	H	Q, Z	H	Z	Q, Z	Z	Z	Q	H
7/23/96	H, Z	H	Q, Z	Q	Z	Q, Z	Z	Z	Q	Q
8/1/96		H	Q	H		H			Q	H
8/8/96	H, Z	H	H, Z	H	Z	H	Z	Z		H
8/15/96	H, Z	H	H, Z	H	Z	H, Z	Z	Z		H
8/20/96	H	H	H	H		H				
8/22/96	H	H	H	H		H				H
8/29/96	H	H	H	H		H				
9/1/96	H	H	H	H		H				
9/11/96	H	H	Q, Z	Q	Z	Q, Z	Z	Z	Q	Q, Z
9/19/96	H		H	H		H				H
9/27/96			Q	Q		Q			Q	Q
10/1/96	H		H	H		H				H
10/10/96				H		H			Q	Q
10/23/96		H	H, Z	H	Z	H, Z	Z	Z		H, Z
10/27/96			H	H		H				H
7/14/97		H, Z	H, Z	H		H, Z	Z			H

H indicates a height measurement, Q indicates a flow measurement, and Z indicates that a fecal coliform sample was taken. The shaded boxes denote a continuous stage measurement.

4.0 BARRINGTON RIVER RECEIVING WATER CONDITIONS

4.1 Hydrography

Knowledge of the distribution and variability of salinity in an estuarine system is useful in describing how other pollutants move and accumulate. Tidal elevation and salinity information are needed to develop a computer model for fecal coliforms. Sources of tidal and salinity information include measurements from the 1996 and 1997 RIDEM studies (RIDEM, 1999c), time series measurements by Brown University (Brown University, 1996). The measurements discussed below are used in Chapter 6 as a basis for calibrating the water quality model used to define loading limits for the Barrington River.

The characteristics of the tides and salinity in the Barrington and Warren Rivers have been documented by measurements made by the Environmental Studies Program at Brown University. The continuous measurements collected at White Church Bridge between March and December 1996 are presented in Figure 4.1. The salinity time series, the upper series in the figure, shows a distinct contrast between the winter/spring and summer seasons. When freshwater inflows are higher during the spring, salinity is lower, ranging from 15 ppt to 25 ppt with a mean value of 19.2 ppt. During the summer months, salinity at the White Church Bridge rises to a mean value of 24.8 ppt, with the majority of values in between 24 ppt to 27 ppt. Due to higher freshwater inflows, salinity is more variable during the spring and winter, which is consistent with the presence of a larger salinity difference over the length of the river.

When compared with the Upper Narragansett Bay, the tidal wave undergoes minor amplification to a mean range of 1.4 m at White Church Bridge. The neap tide range is 1.16 m, and the spring tide range is 1.52 m on average (Brown University, 1996). The time required for the tide to propagate from the Warren River to the White Church Bridge is 25 minutes. It takes approximately 60 minutes for a tide wave to reach the head of the river at the Mobil Dam. In the Barrington River, the dominance by the ebb tide, in which ebb currents are stronger and the ebb period shorter, is apparent in the tide height curve. This characteristic is not apparent in the Palmer River, which appears to be flood-dominant during spring tides.

4.2 Fecal coliform concentrations

NSSP requires that the most recent fifteen data sets be utilized when compiling and reviewing monitoring data for shellfish classification each year. For example, a review of the 1997 data determines the shellfishing status of the area from May 1998 to June 1999. Two Class SA fecal coliform standards must be met. The geometric mean of all samples must be less than 14 MPN/100 ml and less than 10% of the samples can exceed 49 MPN/100 ml.

The shellfishing status of the Barrington River changed constantly during the mid-1990s. A summary of the RIDEM Shellfish Program data from 1994 through 1998 is presented in Figure 4.2. Depending on the year various portions of the river have closed for shellfishing. Figure 4.2 shows that water quality has degraded over the last five years in the Barrington River and fecal coliform concentrations increase toward the head of the River. In the last data set reviewed, 1998, all stations in the Barrington River exceed either one or both of the fecal coliform standards. The Barrington River has been permanently closed to shellfishing since May 1998.

Based on the 1994 review, the Barrington River was operated as an approved conditional shellfishing area from May 1995 to April 1996. Hundred Acre Cove was closed during that period because Stations 1 and 1A had exceeded criteria during 1994. The cove was able to

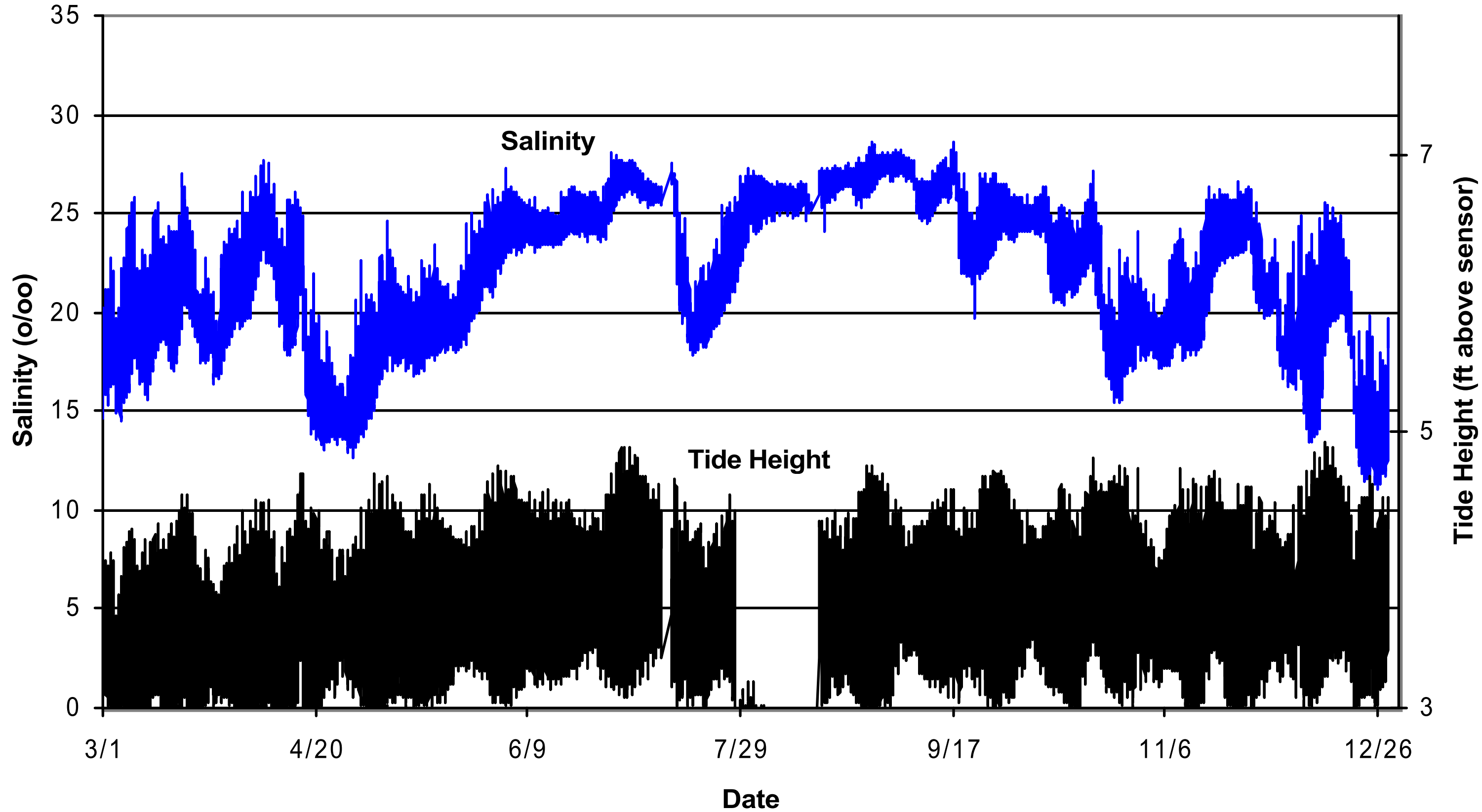


Figure 4.1 Salinity and tide height at the White Church Bridge during 1996 (Brown University).

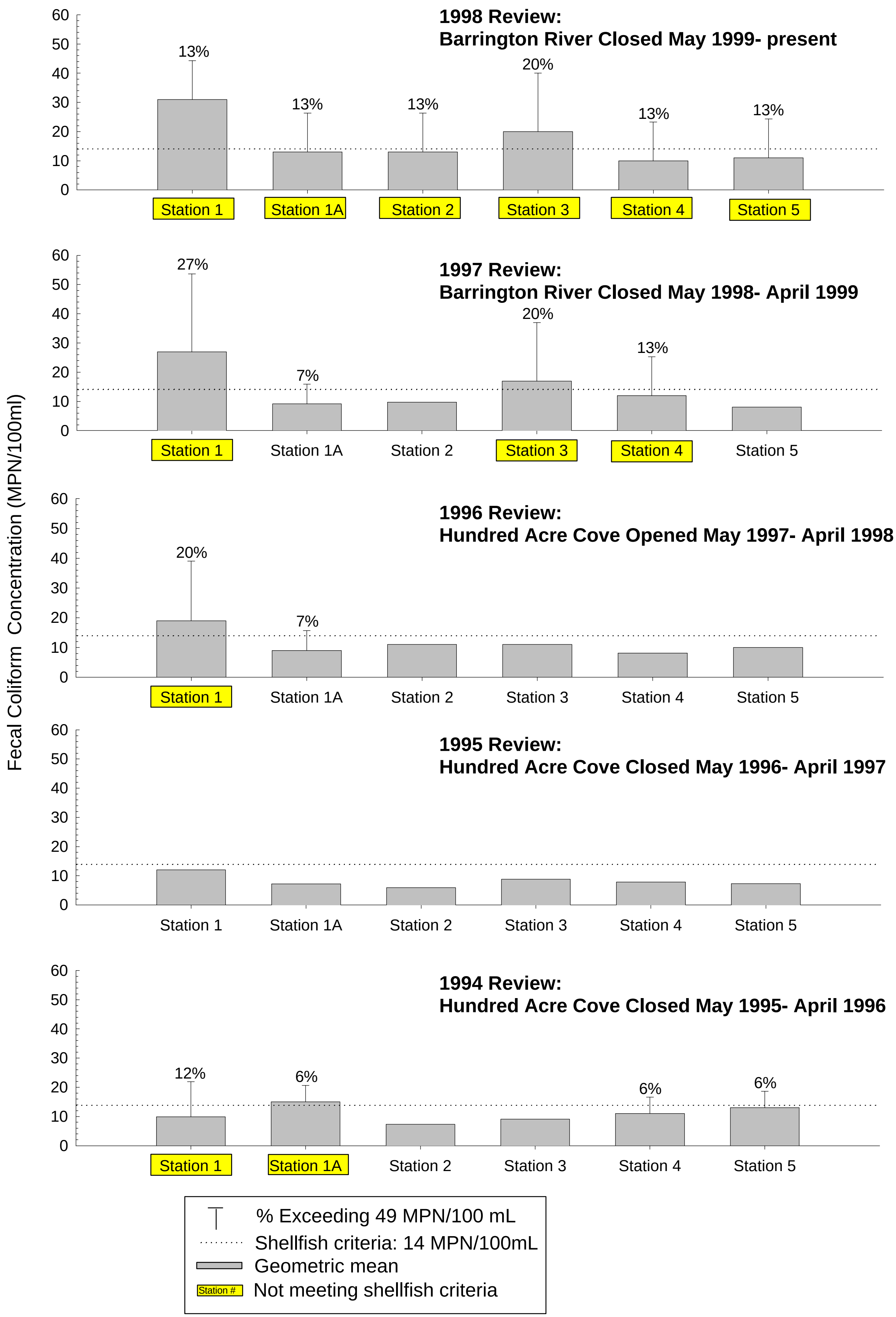


Figure 4.2 Summary of 1994-98 Shellfish Data.

reopen for shellfishing the following year because all stations met criteria in 1995. In 1996 Station 1 again rose above the geometric mean and variability criteria. Adjacent stations in the central and upper river approached the 14 MPN/100 ml limit.

Summaries of the RIDEM dry weather instream fecal coliform data collected during 1996 are presented in Tables 4.1 and 4.2. Duplicate, deep, and shallow samples have been averaged into a single value for each survey. All stations (for locations, refer to Figure 3.5) meet the water quality standard for geometric mean concentration at high and low tide. Stations 2, 5, and 9 have the highest geometric mean concentrations at low tide with geometric means of 9.4 fc/100 ml, 9.4 fc/100 ml, and 12.7 fc/100 ml, respectively. Mean fecal coliform concentrations are generally lower at high tide for most stations. During high tide dilution reduces fecal coliform concentrations at stations 2, 5, and 9 by an average of 32% of their low tide concentrations. The most significant exception to this trend occurs at station 3, a short distance downstream of the confluence of the Barrington and Palmer Rivers, where high tide concentrations are 30% higher at high tide than at low tide, 5.9 versus 4.5 fc/100 ml. These observations indicate the presence of significant sources between stations 2 and 3 and upstream of stations 5 and 9. Figures 4.3 and 4.4 show a summary of the data at low and high tide, with results presented by station and survey. The figures show that coliform conditions are generally highest during the months of June and July. During those months, Figure 4.3 shows concentration increasing up the Barrington River, with the peak value occurring at station 9 in the upper Barrington River. The maximum values and standard deviation of the Barrington River samples were also very high at station 9. The conclusion drawn from this observation would be that the most significant fecal coliform source to the Barrington during dry weather conditions in 1996 was the Runnins River.

Table 4.1 Summary of 1996 fecal coliform data at low tide (RIDEM, 1999c).

Station	1	2	3	4	5	6	7	8	9	10	11
Count	6	6	6	6	6	5	6	6	6	6	6
Mean	2.5	14.9	5.5	5.3	19.4	8.3	9.1	19.1	77.3	8.0	8.8
Geometric Mean	1.6	9.4	4.5	3.1	9.4	5.0	7.1	6.8	12.7	4.4	2.3
%>49	0%	17%	0%	0%	17%	0%	0%	17%	33%	0%	0%
Standard Deviation	3.4	18.4	3.8	6.2	26.4	7.5	6.4	23.0	126	9.4	12.5
Minimum	0.75	3	2	1	2	1	2	0.5	0.5	1	0.5
Maximum	9.5	52	11.5	17	70	16.5	18	60	320	26	26

Table 4.2 Summary of 1996 fecal coliform data at high tide (RIDEM, 1999c).

Station	1	2	3	4	5	6	7	8	9	10	11
Count	6	6	6	6	6	6	6	6	6	6	6
Mean	2.9	3.7	35.3	4.2	7.3	8.2	10.9	24.2	6.9	6.8	6.3
Geometric Mean	1.3	1.5	5.9	2.4	3.8	2.8	3.1	7.1	5.0	4.1	2.9
%>49	0%	0%	17%	0%	0%	0%	17%	17%	0%	0%	0%
Standard Deviation	4.2	6.1	73.5	5.8	6.8	14.2	21.2	45.7	5.1	6.9	9.8
Minimum	0.5	0.5	0.5	1	0.5	0.5	0.5	1	1	1	1
Maximum	11.1	16	185	16	17	37	54	117	15	17	26

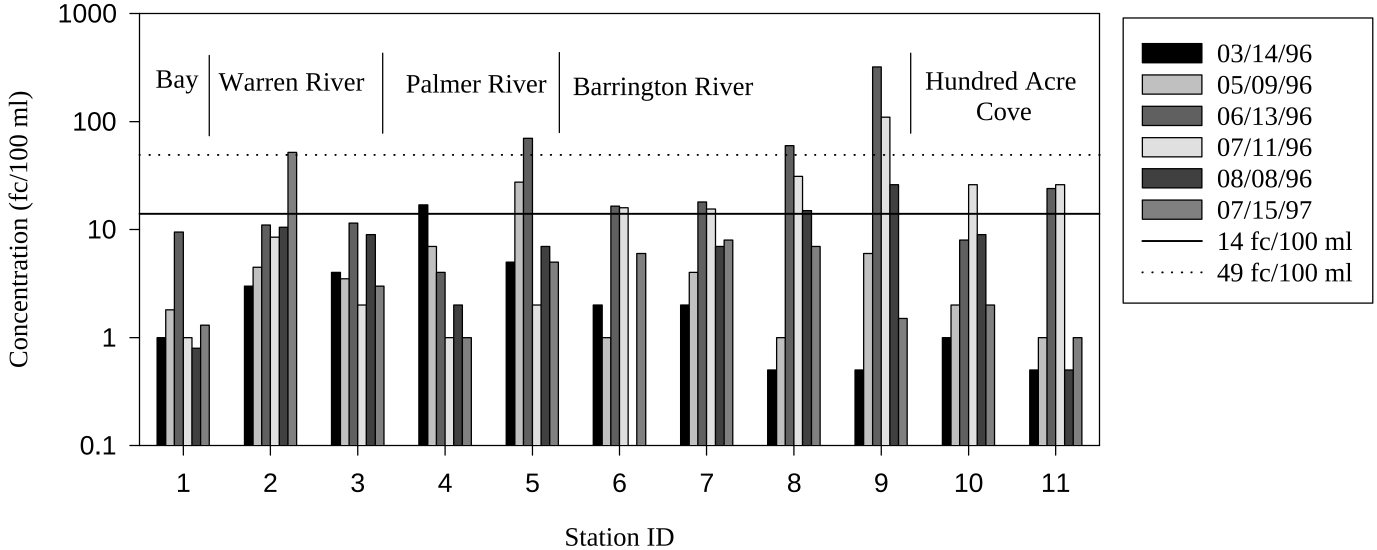


Figure 4.3 Low Tide Instream Fecal Coliform Concentrations (RIDEM, 1999c)

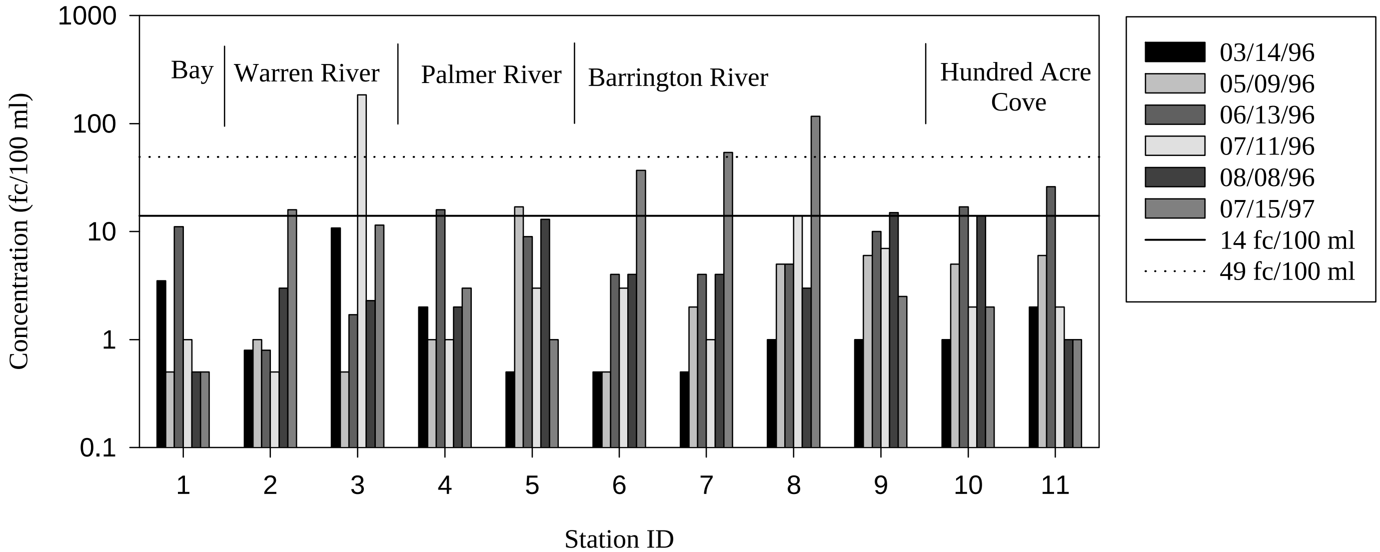


Figure 4.4 High Tide Instream Fecal Coliform Concentrations (RIDEM, 1999c)

During 1997, the Shellfish Program data in Figure 4.2 show stations 1, 3 and 4 out of compliance in the Barrington River. Stations 1 and 3 exceeded both the geometric mean standard, 14 MPN/100 ml and the variability standard, 10% exceeding 49 MPN/100 ml. Station 4 exceeded the variability criterion during 1997. A review of the data shows that ten of fifteen samples at Station 1 and nine of the fifteen samples at Station 3 were above the 14 MPN/100 ml limit. The violations at stations 3 and 4 seem to result from a small number of high results, three at station 3 and two at station 4 (RIDEM, 1998a). Based on the sampling results for 1997, the entire Barrington River was closed in May 1998 and has remained in a permanently closed status since that time.

During 1998, all stations in the Barrington River were out of compliance with the standard. The geometric mean concentrations at stations 1 and 3 exceeded the geometric mean criterion, while 1A, 2, 4, and 5 were close to the limit. All six Barrington River stations exceeded the criterion for variability. Stations 6, 6a, and 7a in the Palmer River were out of compliance during 1997 and 1998 (RIDEM, 1999a).

The RIDEM surveys of the upper Barrington River during 1997 and 1998 focused on the area of the Barrington River north of Hundred Acre Cove with the intention of resolving whether other significant sources existed between the Cove and School Street in the Runnins River. The surveys better defined the fecal coliform concentration gradient in the upper reach of the Barrington River upstream of the shellfishing area. Fecal coliform concentrations in the Runnins River at School Street ranged from 1,200 to 10,000 fc/100 ml. Consistent with RIDEM's earlier data, fecal coliform concentrations are lower during high tide than at low tide. At high tide, fecal coliform concentrations range from 60 to 820 fc/100 ml in the Monarch Drive area and from 3 to 60 fc/100 ml near the Tongue. Low tide concentrations are significant in the Monarch Drive area, between 1,100 to 29,000 fc/100 ml. At the Tongue, low tide concentrations are approximately an order of magnitude higher than concentrations at high tide. The low tide concentrations at the Tongue range from a low value of 25 to 3,800 fc/100 ml.

The fecal coliform data are shown as a function of downstream distance from Mink Street in Figures 4.5 through 4.7. The figures show how the tides influence concentrations in the upper river. Reductions in instream concentrations coincide with the increased area of the river's cross-section. Station B16 at the entrance to the stream draining the Monarch Drive area, and B23 near the mouth of the unnamed Warren Avenue stream above the Tongue have higher concentrations than adjacent stations, indicating that the two streams are sources of a lesser, insignificant magnitude.

Instream concentrations of fecal coliforms were measured by RIDEM during one wet weather event sampled in October 1998 (RIDEM, 1999). Fecal coliform samples were collected during one pre-storm and four post-storm surveys during this period. The sixteen RIDEM shellfish stations in Growing Area 2 (Figure 3.1), which includes the Barrington, Palmer, and Warren Rivers, were sampled during low tide conditions on each date. The sequence of results by survey is shown in Figures 4.8 through 4.12, beginning with the pre-storm condition on October 14, 1998. The pre-storm survey was conducted before the start of rainfall. The figures show relatively high concentrations at the start of the storm, with values ranging between 14 and 255 fc/100 ml in the Barrington River. Levels were significantly higher in the Palmer River, ranging between 120 fc/100 ml at the mouth to 1000 fc/ 100 ml at station GA2-6 near the head of the

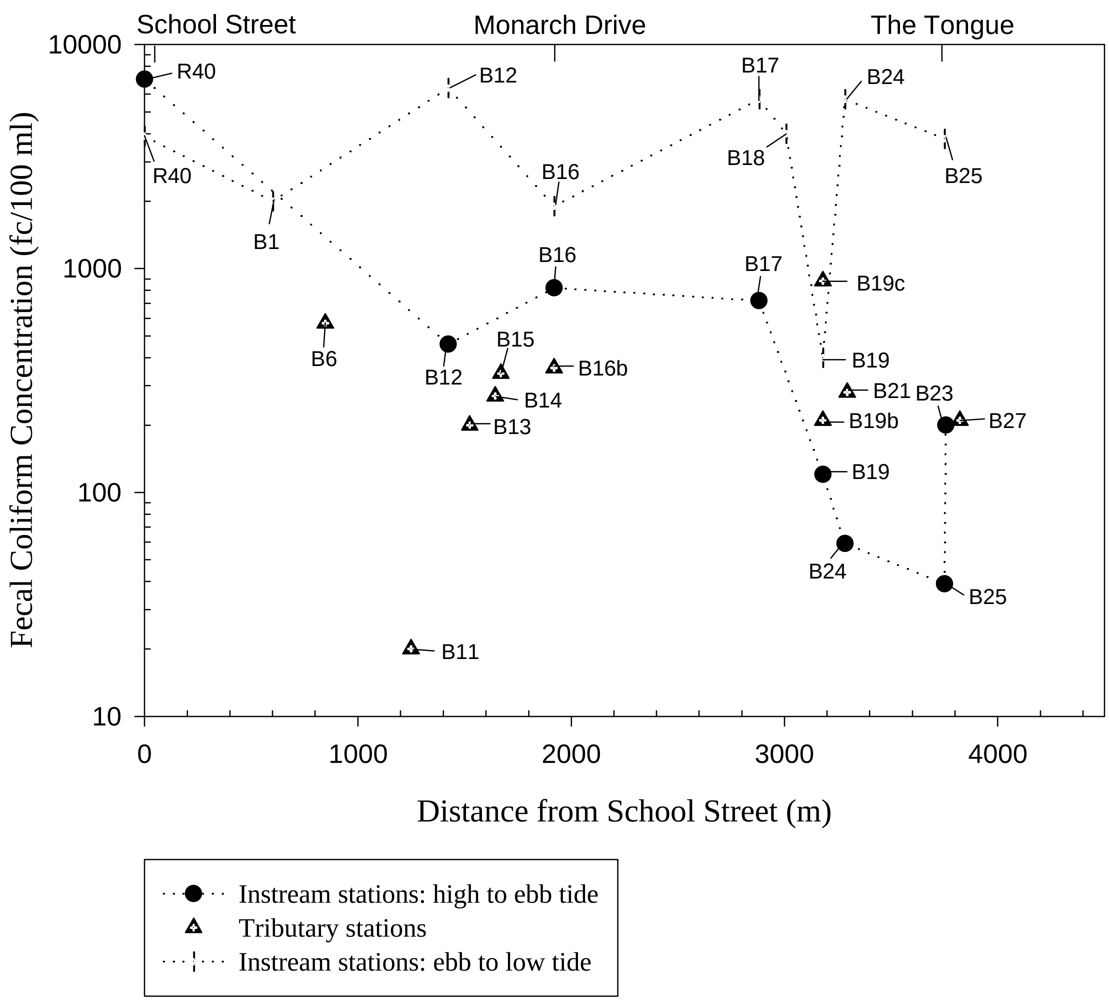


Figure 4.5 Fecal Coliform versus Distance from School Street on July 21, 1997.

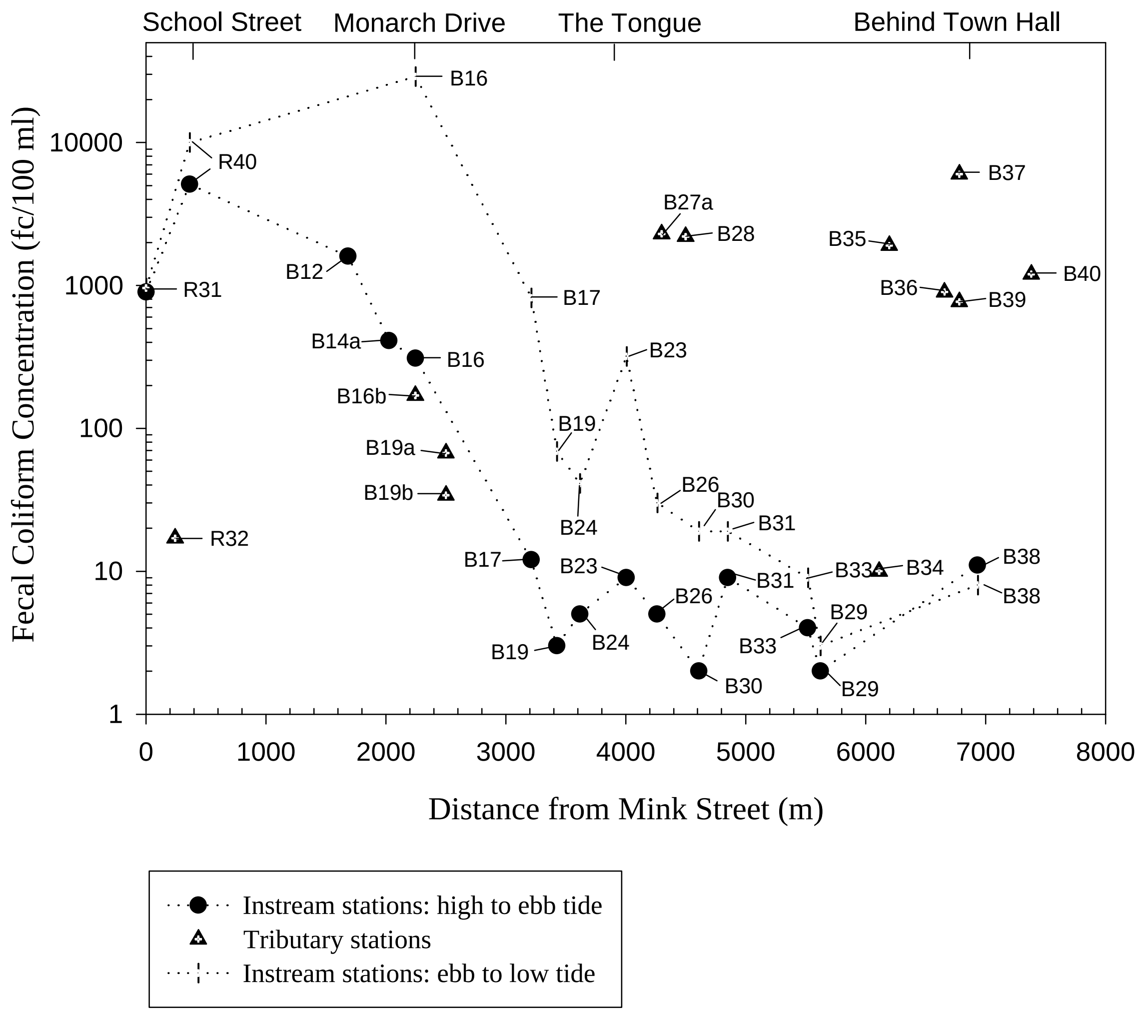


Figure 4.6 Fecal Coliform versus Distance from Mink Street on September 21, 1998.

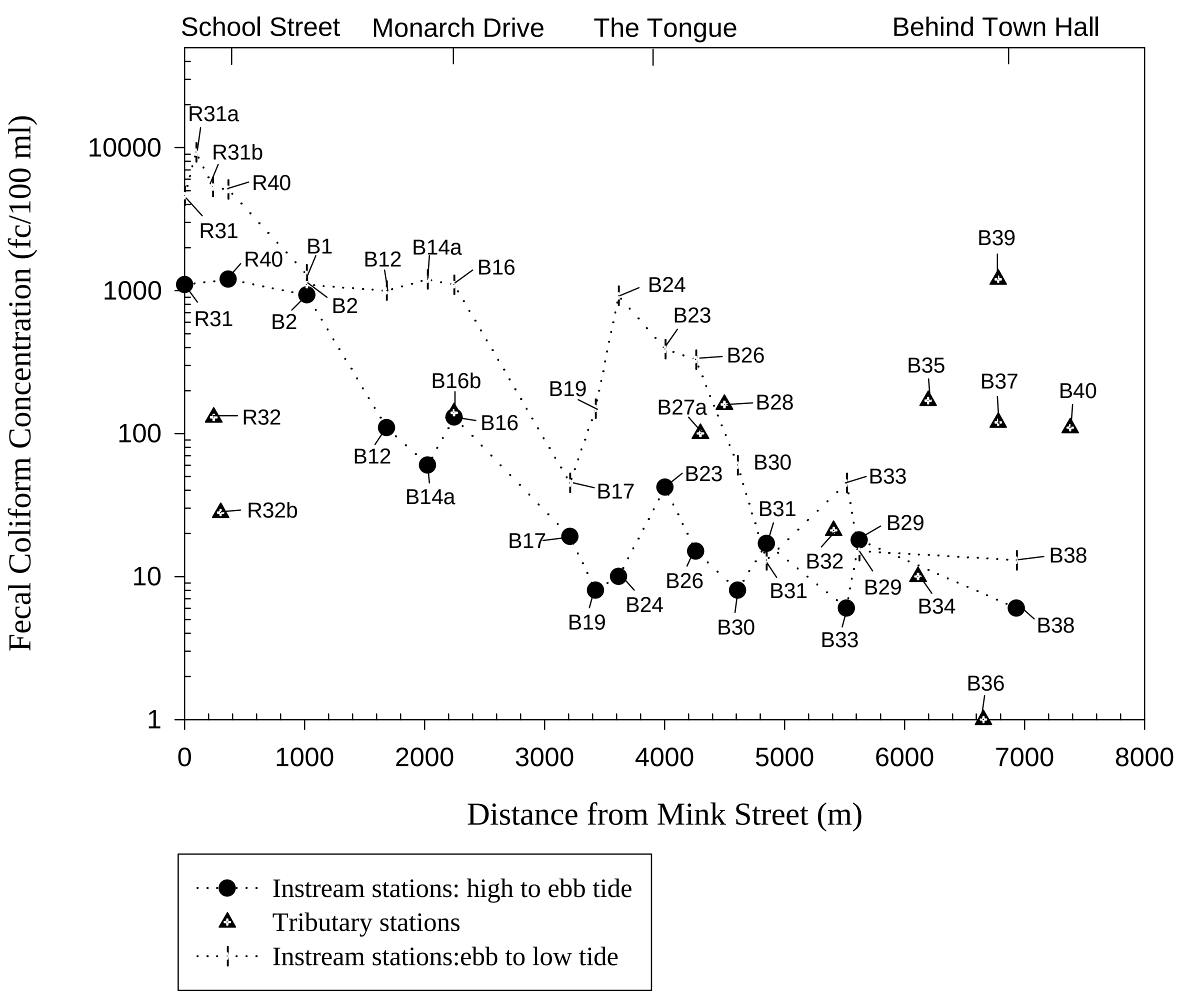


Figure 4.7 Fecal Coliform versus Distance from Mink Street on November 5, 1998.

Palmer River in Massachusetts. No data were collected at station 6A during the initial survey because of low water depths above station 6. The elevated concentrations are apparently residual from a rainstorm of 1.9 inches on October 10.

Figure 4.9 shows the condition of the area during low tide on October 15, the day after the storm. Concentrations are highest in the upper Palmer River at 16000 and 4400 fc/100 ml at stations 6A and 6, respectively. Concentrations are in the range of 220 to 420 fc/100 ml in the upper Barrington River and 240 to 850 fc/100 ml in the Palmer River and the upper Warren River. Two days after the storm Figure 4.10 shows a concentration peak located near the Warren WWTF in the central Warren River. Concentrations have declined to 120 fc/100 ml or below in the Barrington River, however station 1A located above the Tongue remains high. Surveys were not conducted on Saturday, October 17 or Sunday, October 18. The October 19 and 20 surveys (Figures 4.11 and 4.12) show the area has returned to concentrations below the pre-storm condition. With the exception of station 6A at the head of the Palmer River, all stations meet water quality standards.

Instream concentration data are shown in Figure 4.13 as a function of time for selected areas. In some areas a geometric mean of all the stations in the area is used. The time series show concentrations in the upper Barrington and Palmer Rivers reaching their peak values on October 15, the day after the storm. Concentrations reach peak a day later in the lower Barrington and Palmer Rivers and in the central Warren River.

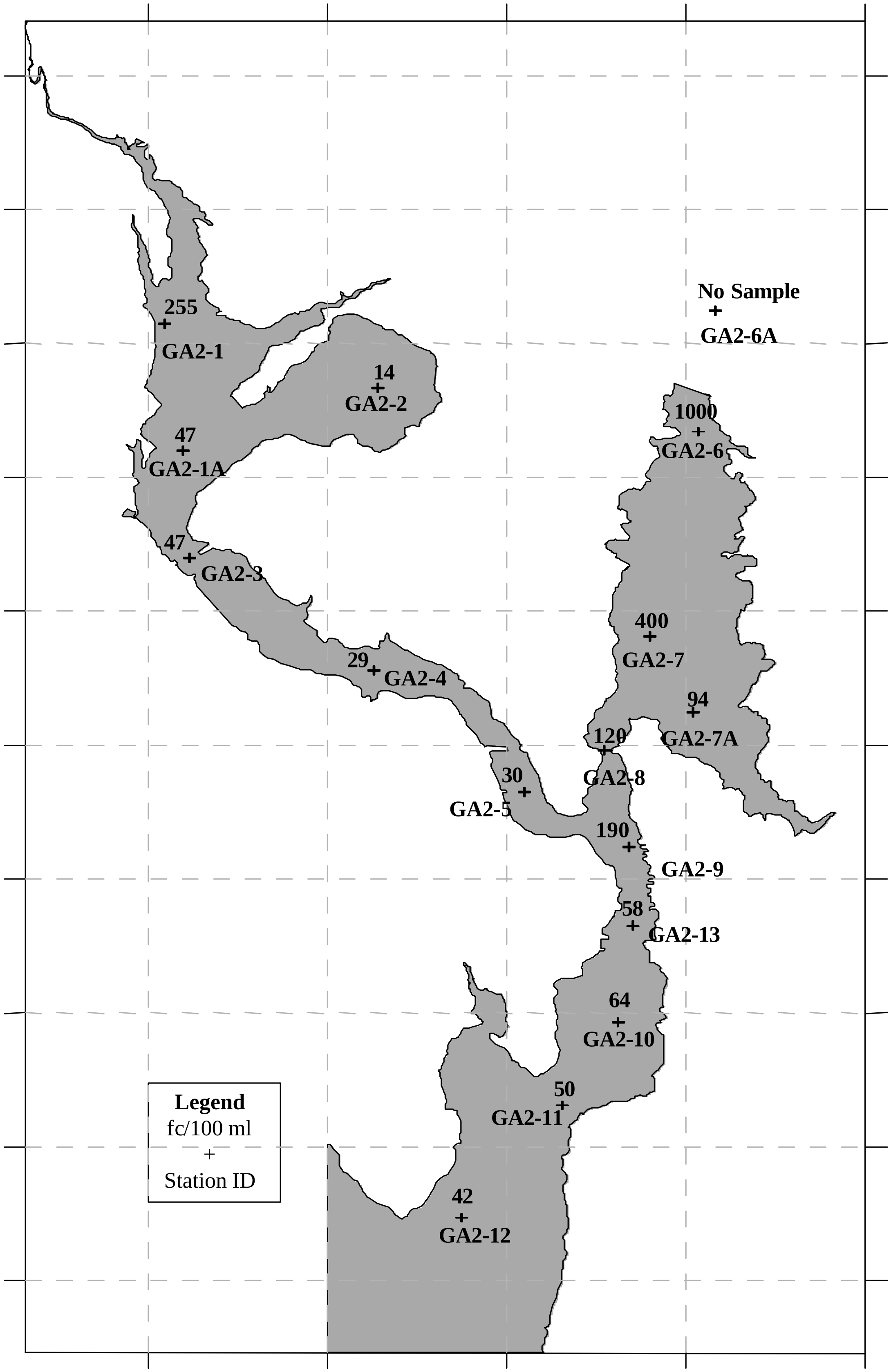


Figure 4.8 Pre-storm low tide fecal coliform survey, October 14, 1998.

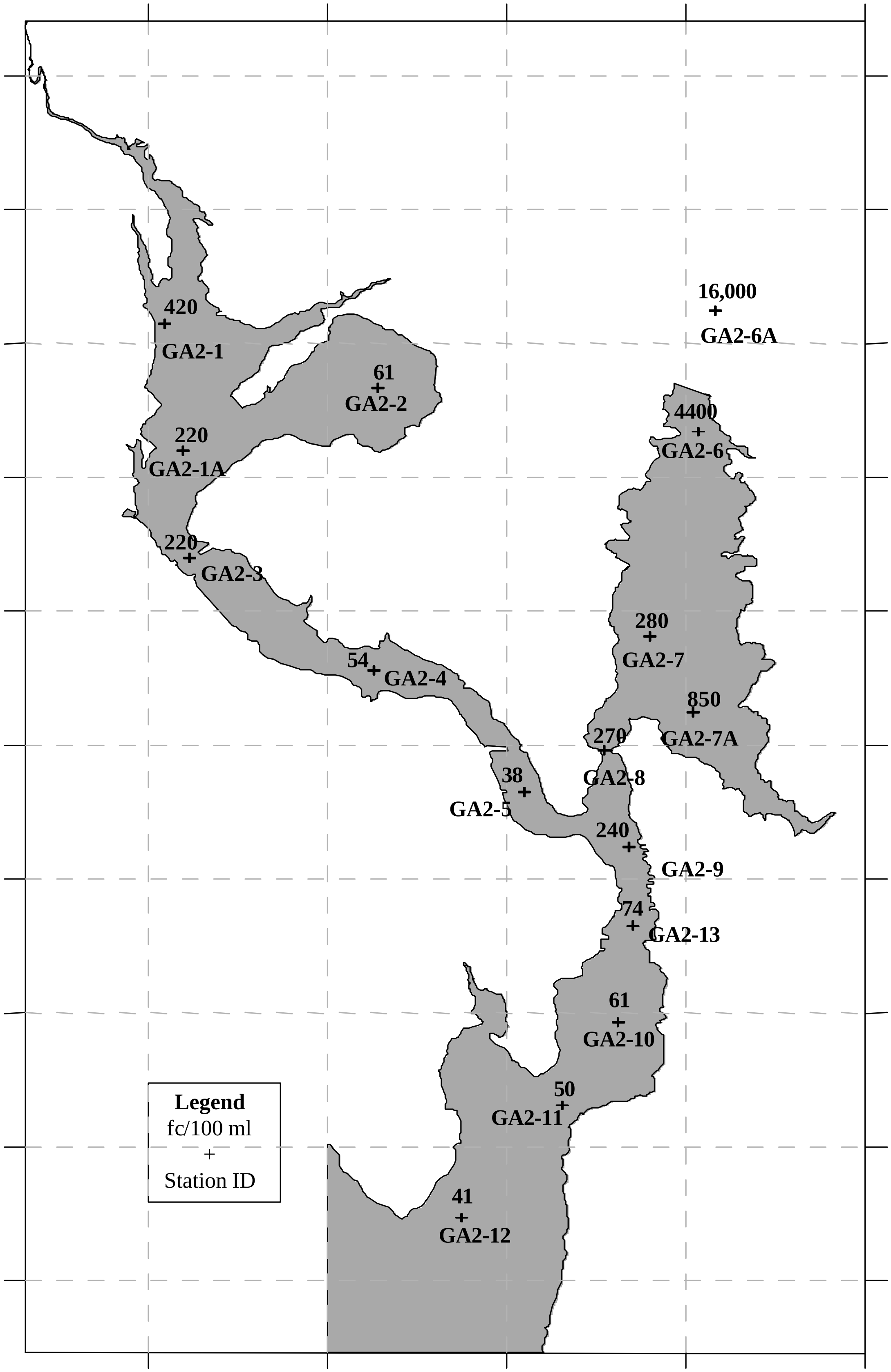


Figure 4.9 One-day after storm low tide fecal coliform survey, October 15, 1998.

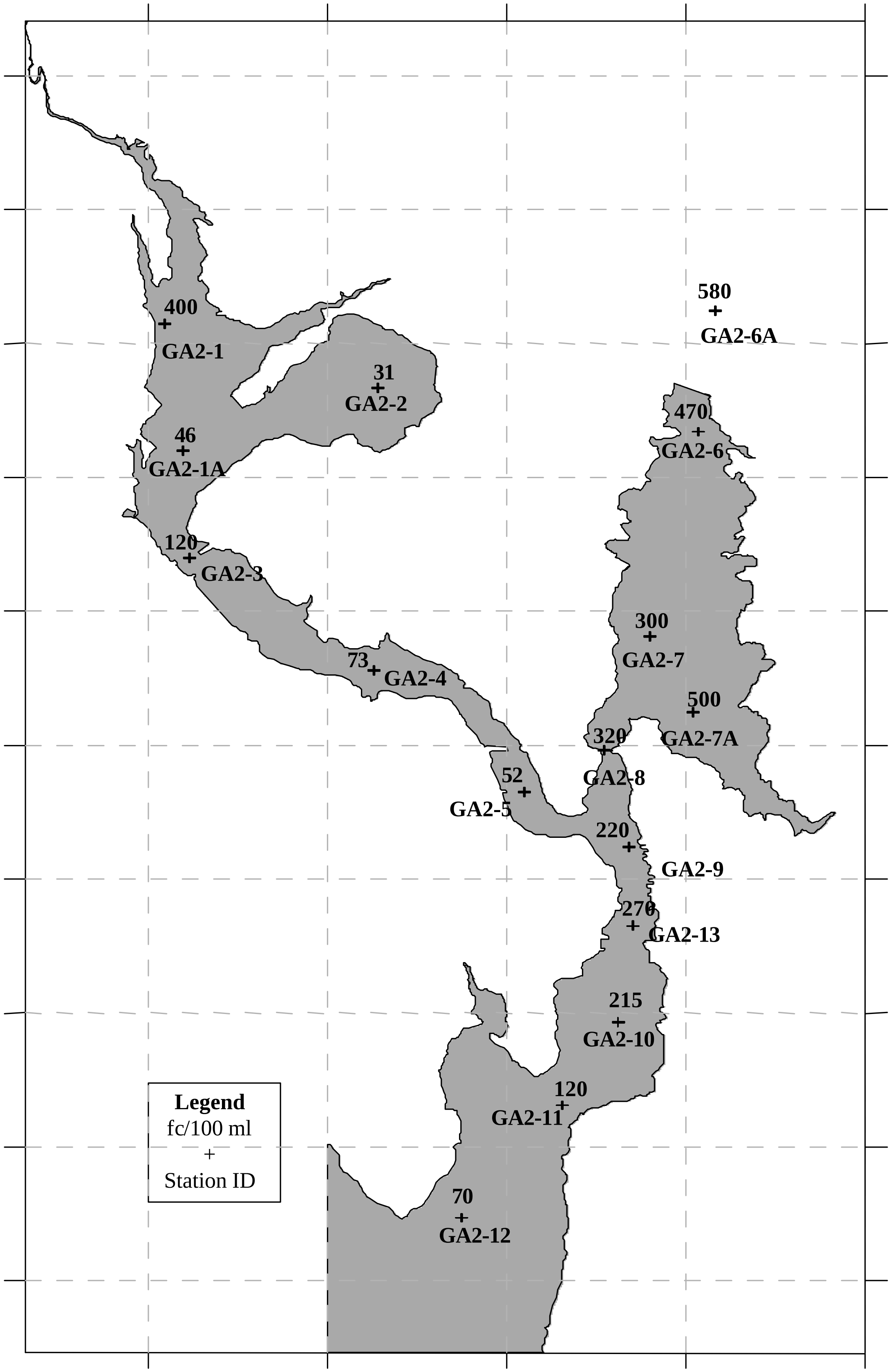


Figure 4.10 Two days after storm low tide fecal coliform survey, October 16, 1998.

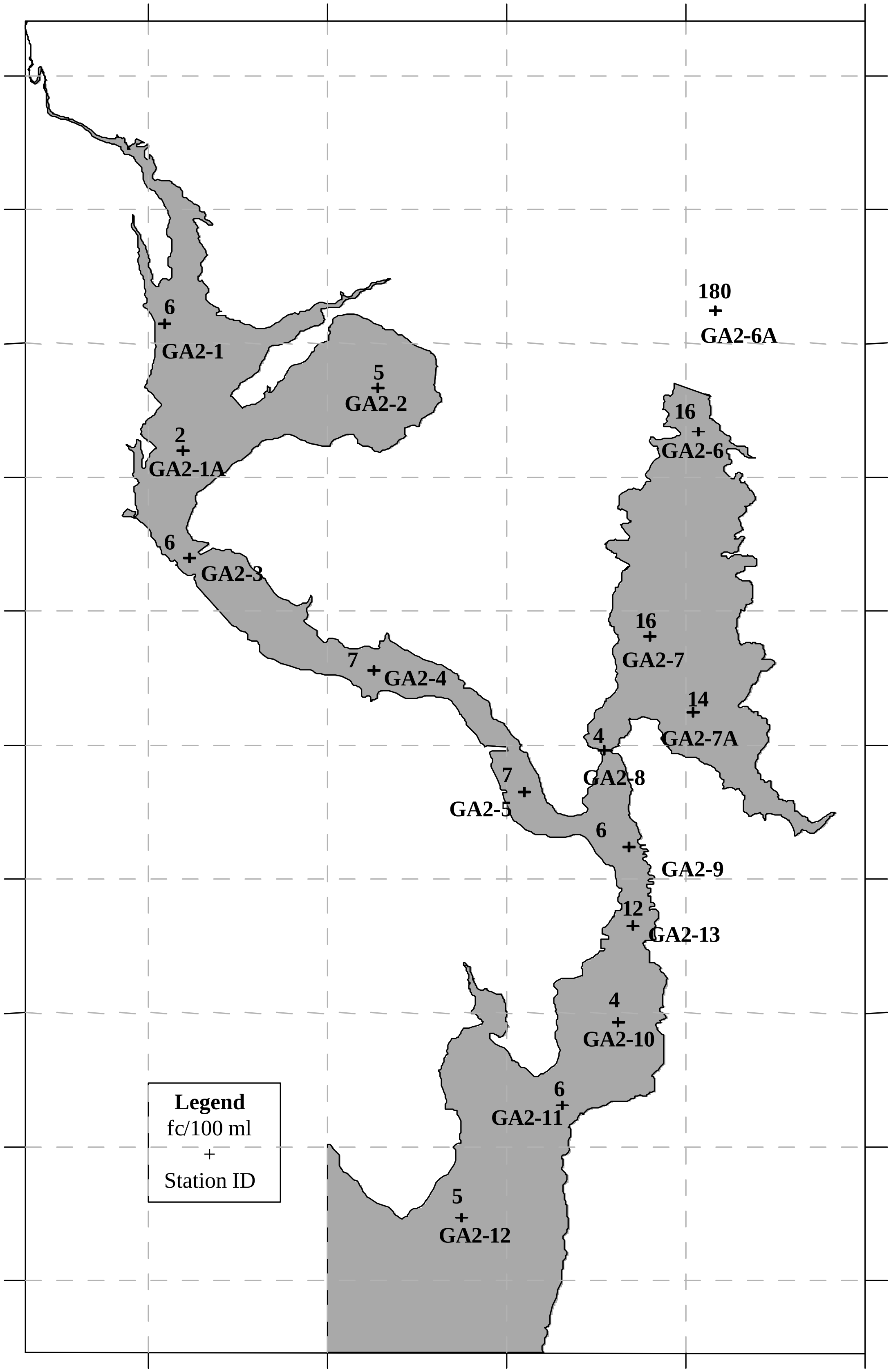


Figure 4.11 Five days after storm low tide fecal coliform survey, October 19, 1998.

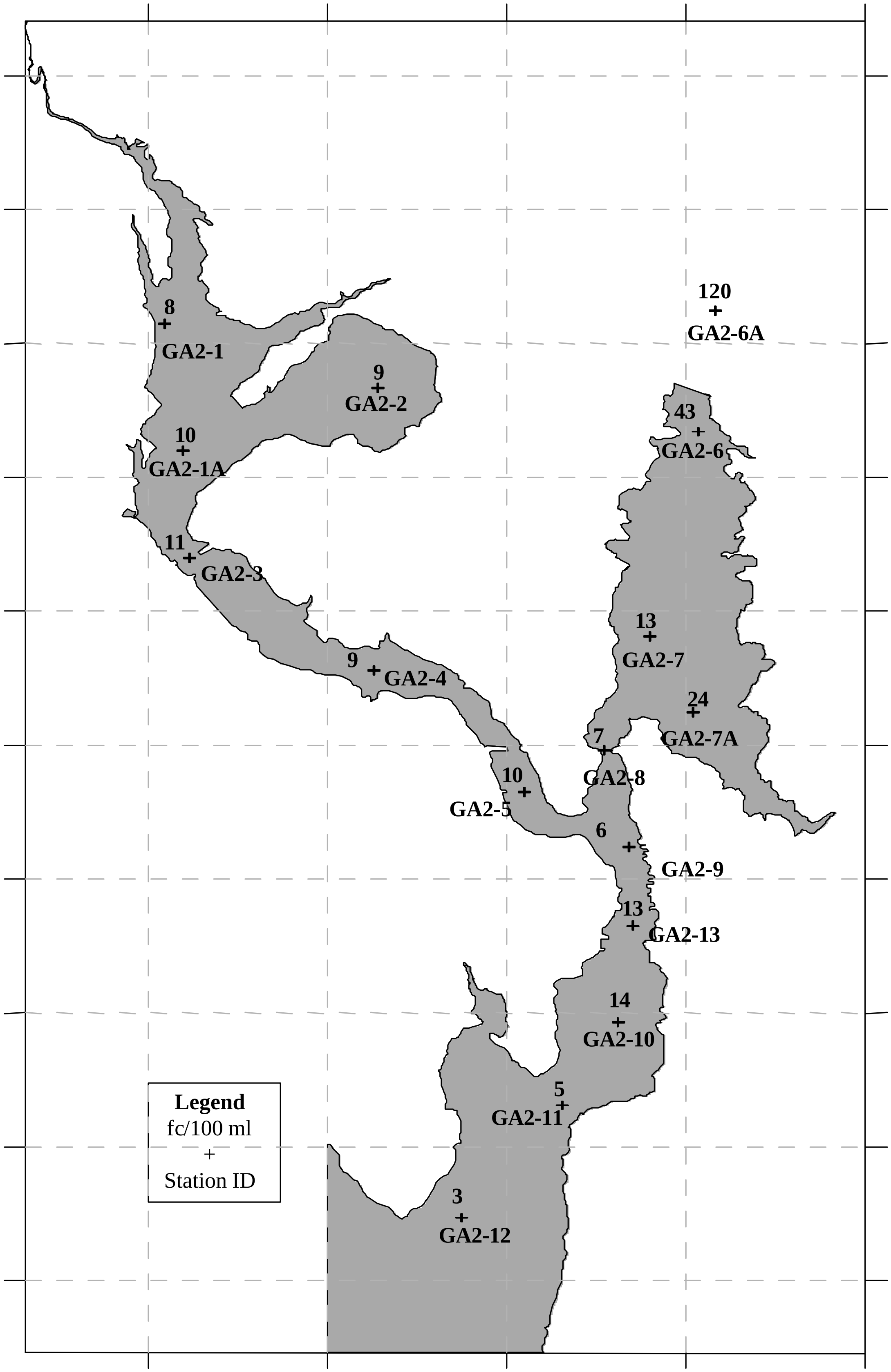


Figure 4.12 Six days after storm low tide fecal coliform survey, October 20, 1998.

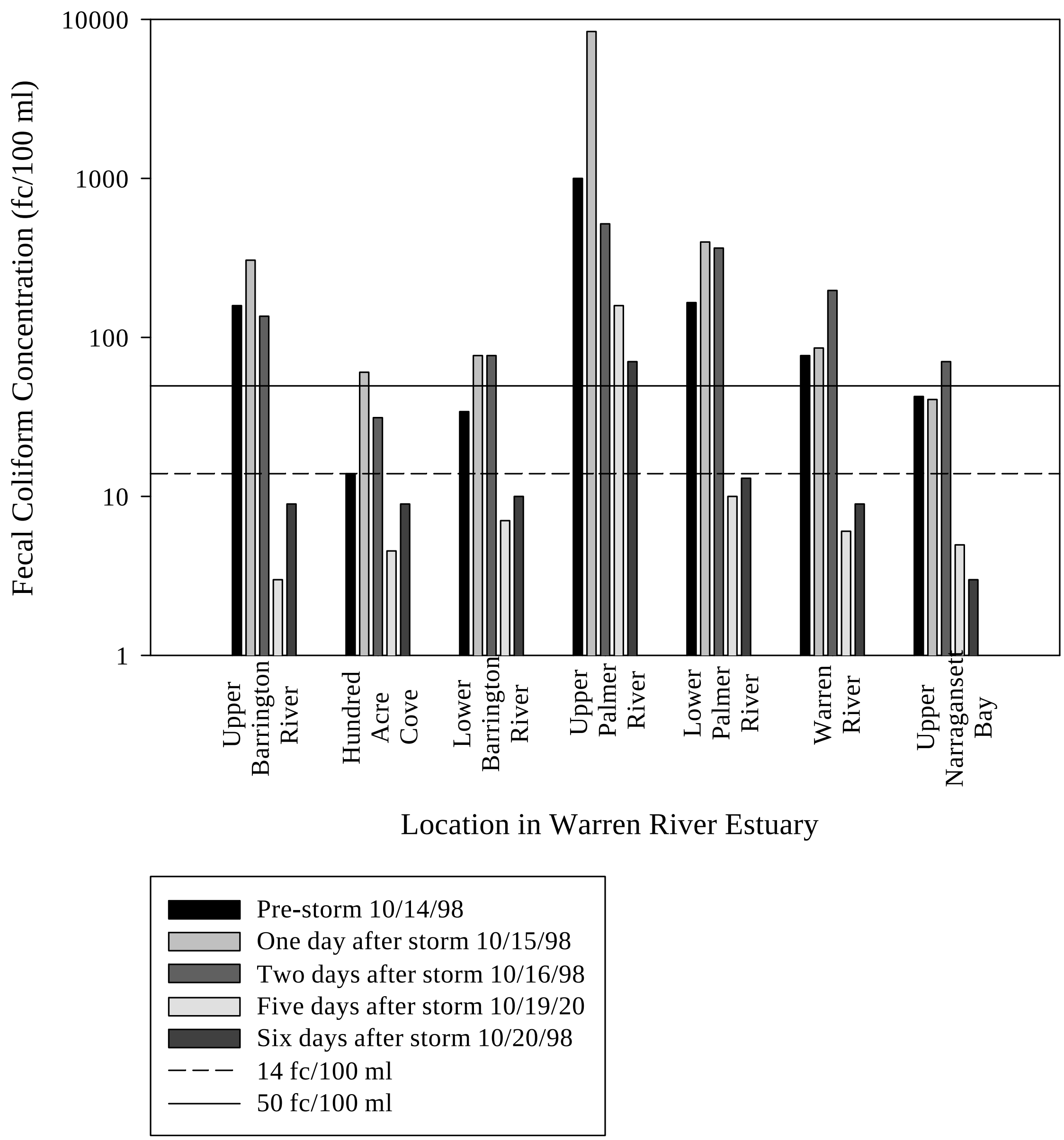


Figure 4.13 Wet weather geometric mean concentration as a function of time.

5.0 BARRINGTON RIVER TRIBUTARY AND POINT SOURCE CONDITIONS

5.1 Tributary and point source flows

Freshwater sources considered to be significant to the distribution of salinity in the Barrington River were characterized by measurements made from the Spring through Fall of 1996 as part of the BPW study by RIDEM (RIDEM, 1999c). The measurements included the Runnins River at Mink Street and the Warren Avenue tributary, which empties into the Barrington River upstream of the Tongue. Other sources measured by the RIDEM study are the Palmer River, Rocky Run, the Warren WWTF, and the Blount Seafood facility.

The Runnins River was sampled at Route 6, Mink Street, and School Street. Figure 5.1 illustrates how stream discharge varied at these three stations along the length of the Runnins River in 1996. As expected discharge is lowest at Route 6, the station furthest upstream and is highest at School Street, the station furthest downstream. The Mink Street station was gauged continuously from July through November 1996 and during the summer of 1997. The discharge at School Street and Route 6 was measured at one to two week intervals. The Mink and School Street sites are subject to tidal forcing. As a result, the time series for Mink and School Streets were manually edited to remove spikes in stages due to the tides. The missing data were estimated by linear interpolation. For the wet weather study in October 1998, the stage recorder was moved to the School Street Bridge.

A summary of freshwater source strengths is shown in Figure 5.2 and listed in tabular form in Table 5.1. The data show that the Runnins River is the second largest freshwater source to the BPW system behind the Palmer River. The mean discharge (for dry and wet conditions) of the Runnins River at School Street (0.315 m^3/s) is significantly less than that of the Palmer River (0.914 m^3/s). The summer (July 1 through October 31) dry weather mean discharge of the Runnins River was calculated from the 1996 and 1997 continuous stage measurements at Mink Street. To obtain this estimate, the wet weather data were removed manually from the data by determining where river stage increased after a period of rainfall and removing the flow data from the next 48 hours. The Mink Street and School Street discharges were related to each by comparing time periods where both measurements were taken concurrenty. On average, the School Street discharge was 0.088 m^3/sec higher than the discharge at Mink Street. The mean difference between the two stations was added to each record remaining in the Mink Street continuous discharge. The mean dry weather discharge of the Runnins River was 0.154 m3/sec at Mink Street and 0.242 m^3/s at School Street.

Figures 5.3 and 5.4 show the Runnins and Palmer Rivers discharges during the RIDEM wet weather study in October 1998. A maximum stream discharge of nearly 0.7 m^3/sec occurred in the Runnins River at approximately 06:00 on the morning of October 15, between 6 and 7 hours after the period of greatest rainfall. The discharge time series in Figure 5.3 reveals that the storm hydrograph was edited at this point to remove a spike caused by the overtopping of the Mobil Dam at high tide. The discharge of the Runnins River returned to its pre-storm condition after a period of about two days. This data was combined with fecal coliform data collected before, during, and after the study to calculate wet weather loadings. Measuring the current speed, sense of the tide, and the volume of water entering and leaving at the Route 6 Bridge calculated the Palmer River discharge. Storm discharge was found to be three times greater than dry weather discharge.

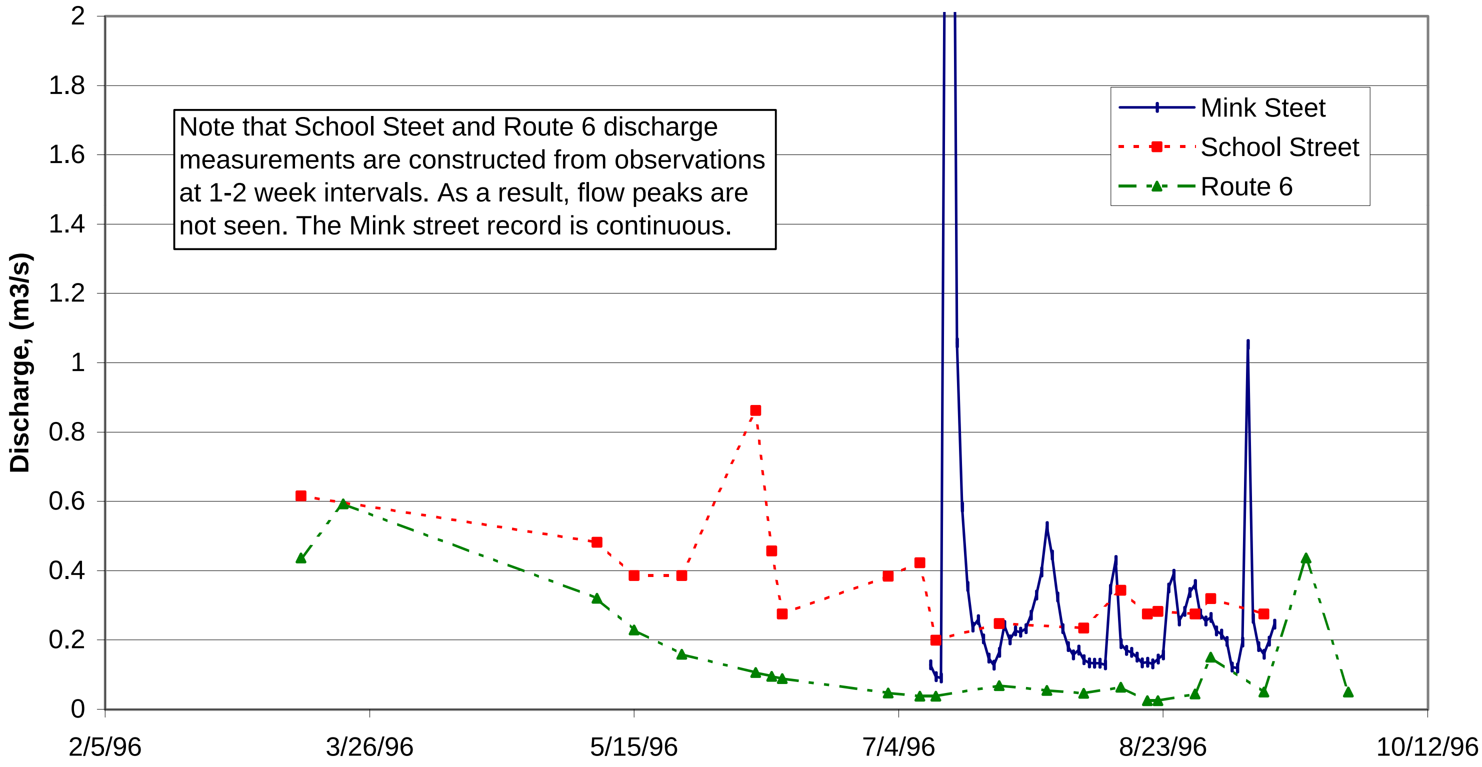


Figure 5.1: Time series of Runnins discharge at Route 6, Mink Street, and School Street.

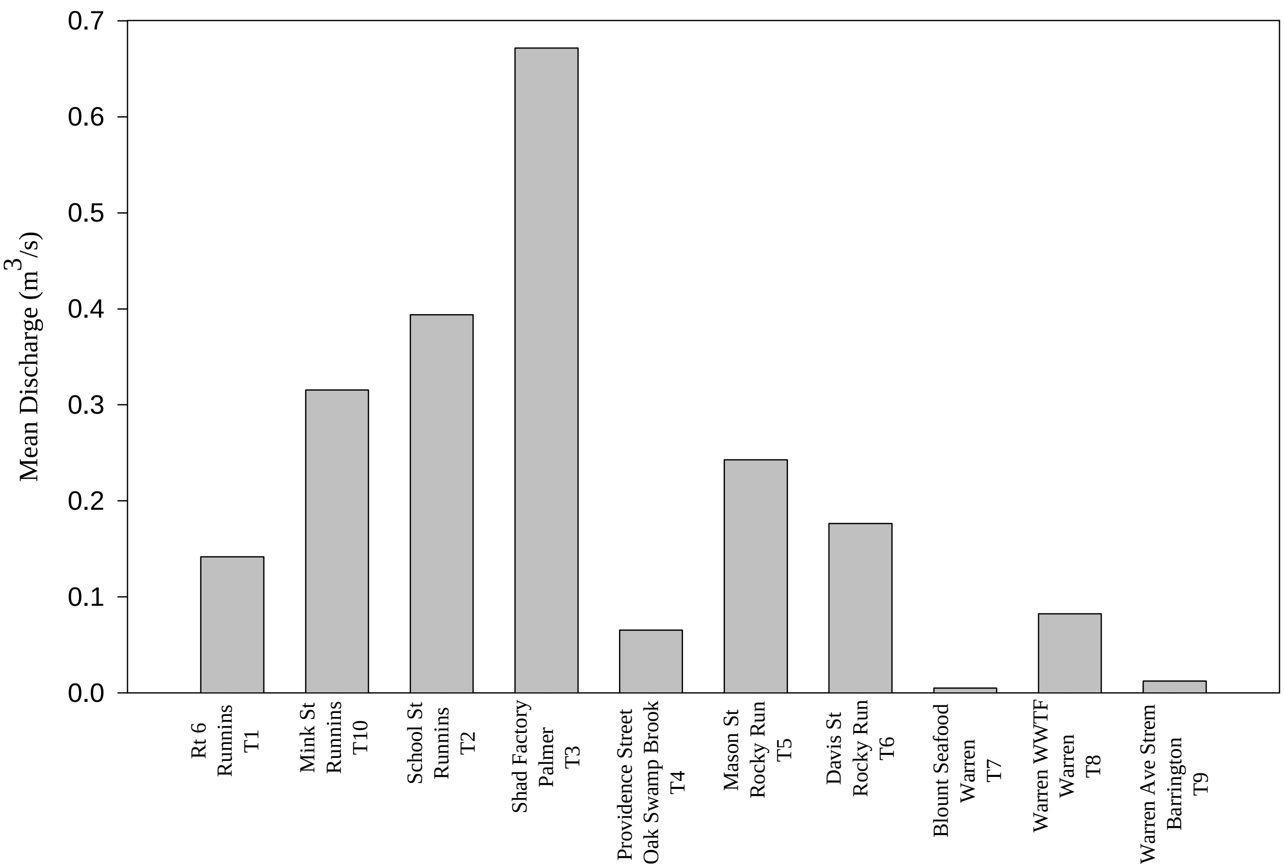


Figure 5.2 Comparison of the Warren River's Mean Tributary Discharges (Wet and Dry Weather), 1996.

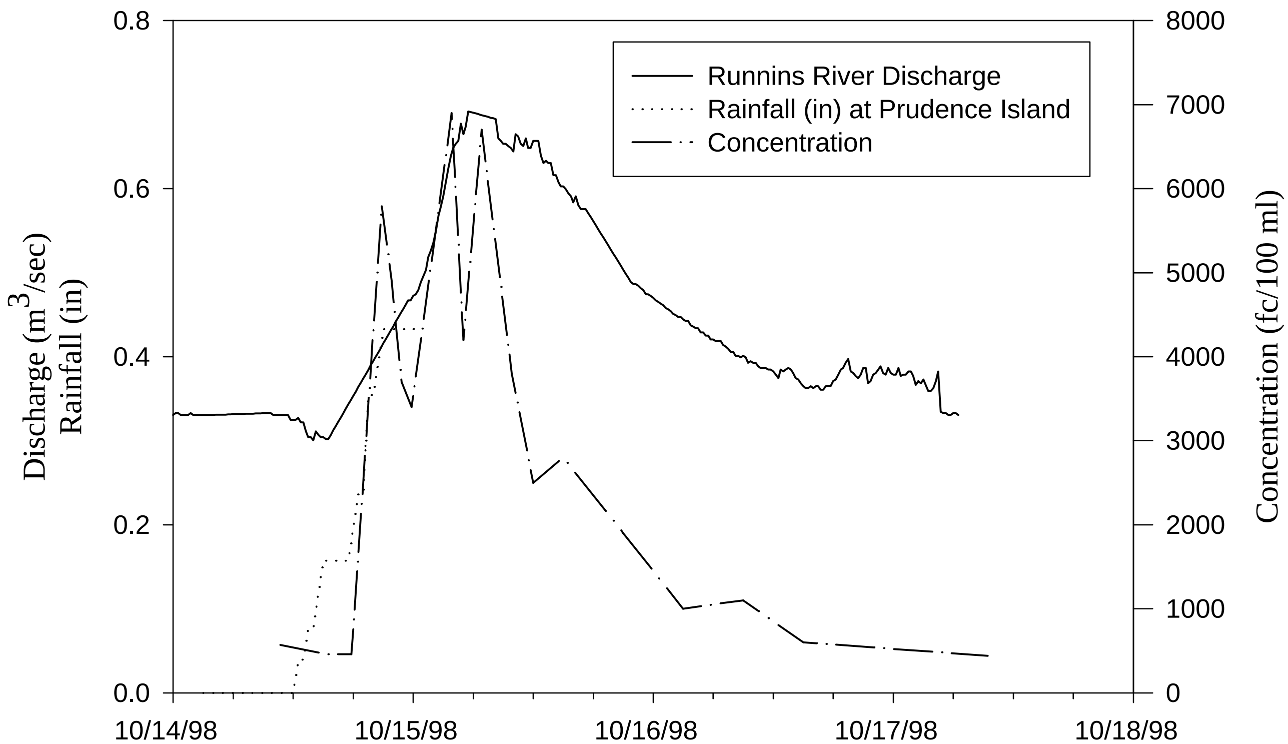
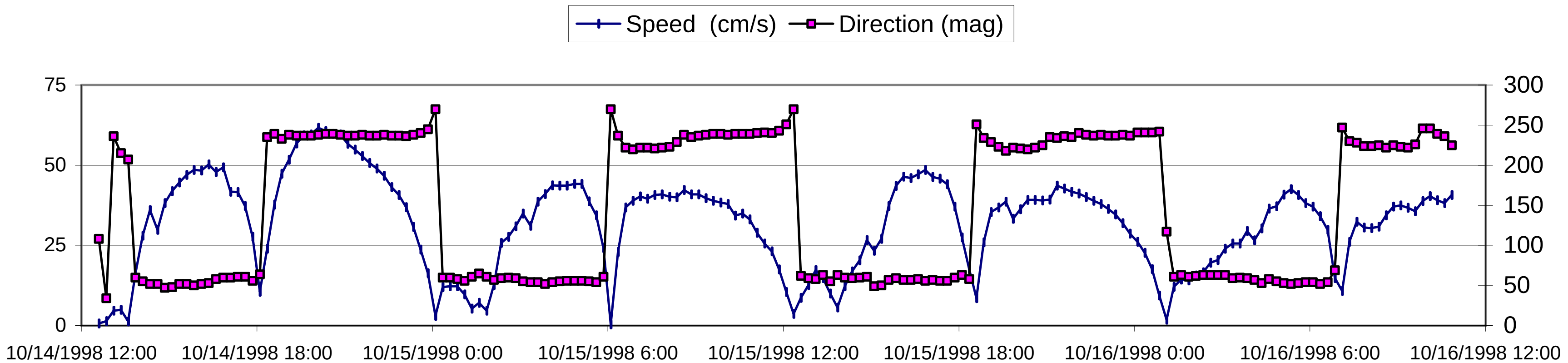


Figure 5.3 Runnins River Discharge and Fecal Coliform Concentration at School Street during the 1998 Wet Weather Survey.



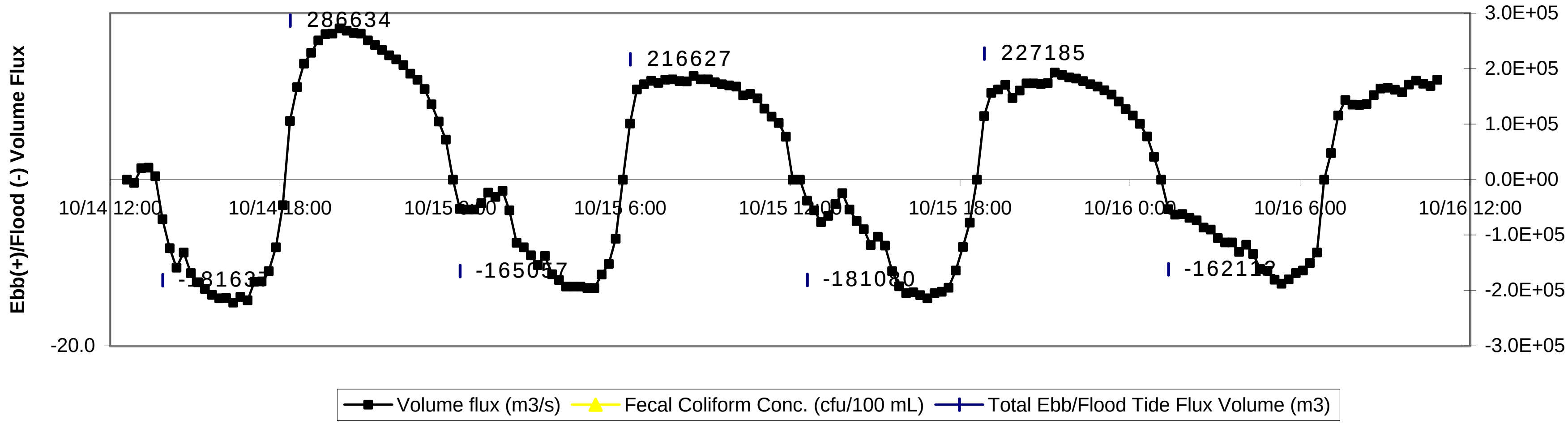


Figure 5.4: Palmer River Current and discharge during the October 1998 wet weather study

Table 5.1 Tributary and point source discharges, from direct and stage-discharge measurements .

Date	T1 Runnins River, Route 6 m^3/sec	T2 Runnins River, School St m^3/sec	T3 Palmer River, Reed St m^3/sec	T4 Oak Swamp Brook m^3/sec	T5 Rocky Run, Davis St m^3/sec	T6* Rocky Run, Mason St m^3/sec	T7 Blount Seafood m^3/sec	T8 Warren WWTF m^3/sec	T9 Unnamed Tributary, Warren Ave m^3/sec	T10 Runnins River, Mink St m^3/sec
03/13/96	0.436	0.616	2.242	0.135	0.410	0.545	0.006	0.136		
03/21/96	0.593		3.774	0.179	0.593	0.772		0.131	0.041	
05/08/96	0.320	0.482	1.583	0.085	0.329	0.414	0.002	0.096	0.018	
05/15/96	0.229	0.386	1.121	0.050	0.246	0.295		0.088	0.012	
05/24/96	0.159	0.386	0.899	0.032	0.147	0.179		0.083	0.009	
06/07/96	0.106	0.863	0.796	0.024	0.100	0.125	0.007	0.079		
06/10/96	0.095	0.457	0.662	0.019	0.089	0.108	0.007	0.074		
06/12/96	0.088	0.275	0.573	0.016	0.083	0.098	0.007	0.074	0.005	
07/02/96	0.047	0.385	0.129	0.009	0.033	0.041		0.070		
07/08/96	0.038	0.422	0.129	0.007	0.013	0.020		0.066		
07/11/96	0.038	0.199	0.129	0.010	0.015	0.025	0.008	0.066	0.002	0.094
7/23/96	0.068	0.248	0.214	0.028	0.058	0.086	0.008	0.074	0.005	0.164
8/1/96	0.055		0.123	0.022	0.061	0.083		0.074	0.009	0.528
8/8/96	0.046	0.235	0.095	0.024	0.046	0.069	0.002	0.070		0.143
8/15/96	0.064	0.343	0.114	0.032	0.104	0.136	0.001	0.070		0.189
8/20/96	0.025	0.275	0.081	0.008	0.017	0.024		0.066		0.135
8/22/96	0.025	0.282	0.079	0.009	0.026	0.034		0.066		0.145
8/29/96	0.044	0.275	0.101	0.015	0.042	0.057		0.066		0.360
9/1/96	0.151	0.319	0.085	0.119	0.034	0.153		0.066		0.265
9/11/96	0.050	0.275	0.104	0.035	0.193	0.228	0.001	0.074	0.009	0.159
9/19/96	0.436		0.344	0.247	0.791	1.038		0.123		0.246
9/27/96	0.050		0.146	0.019	0.181	0.200		0.096	0.012	0.246
10/1/96	0.088		0.2025	0.034						0.1653
10/10/96		0.894								0.7353
10/23/96				0.308	0.502	0.810				1.00605
7/14/97		0.261	2.3874	0.165	0.118	0.284				0.46455

*T6 (Rocky Run at Mason Street) is the sum of T4 (Oak Swamp Brook) and T5 (Rocky Run at Davis Street).

5.2 Fecal coliform characterization of Barrington River tributaries and Point Sources

Mr. Doug Rayner, a member of the Pokanoket Watershed Alliance, has collected fecal coliform samples in the Runnins River watershed on a routine basis since 1990. Mr. Rayner analyzed the samples using a membrane filtration method. Split samples were periodically sent to a certified laboratory to validate Mr. Rayner's analyses. Between 1990 and 1999, Mr. Rayner collected approximately 280 samples at the Mink and School Street bridges during dry weather conditions (3 days of less than 0.20 inches of rain) and 265 samples during wet weather conditions. Mr. Rayner also measured stream temperature and river stage. The length of the Rayner data set makes it very useful in documenting historical trends, seasonal variations, and the wet-dry weather contrast in fecal coliform concentrations in the lower Runnins River.

Mr. Rayner's data indicates Mink and School Streets often exceed class B standards (200 fc/100 ml), particularly during the warmer months. Figure 5.5 shows the typical seasonal trend of fecal coliform concentrations in the lower Runnins River during dry weather conditions. Instream fecal coliform concentrations begin to rise in July. The mean concentration reaches a peak value in September, dropping below the Class B water quality standard in December. The concentration remains low from December to May.

RIDEM sampled fecal coliform concentrations in the tributaries and point sources during the BPW surveys conducted between 1996 and 1998. The 1996 data set (RIDEM, 1999c) measured tributary loading, freshwater inflows, and concurrent instream conditions. This data was used to develop the water quality model for the Barrington River system under dry weather conditions discussed in Chapter 7. The data show that the Runnins River and areas of the Palmer River upstream of Route 6 are the principal fecal coliform sources to the BPW system. Observed loadings from Blount Seafood and the Warren WWTF were found to be approximately two orders of magnitude smaller (Figure 5.6).

Data from the RIDEM dry weather surveys during 1997 and 1998 were more useful in resolving the representative summer dry weather condition of the lower Runnins River. According to these surveys, the dry weather geometric mean fecal coliform concentration at School Street is 1576 fc/100 ml with a mean dry weather discharge of 0.242 m^3/sec from July through October. Under present conditions, the mean dry weather fecal coliform loading at School Street based on RIDEM data is 3.3×10^{11} fc/day.

Other downstream bacterial sources to the Barrington River include those in the Palmer and Warren Rivers and sources along the Barrington River shoreline that would discharge directly to the river. The shoreline sources are characterized in the triennial surveys conducted by the RIDEM Shellfish Program. Shoreline sources were also sampled during the 1997 and 1998 RIDEM surveys of the upper Barrington River. RIDEM evaluated all sources identified by the 1994 Shellfish Program shoreline monitoring data and concluded that the summed contributions of all source loadings would increase the mean concentration of Hundred Acre Cove by less than 0.01 fc/100 ml (refer to Appendix A for information about this calculation). The 1999 Shellfish Program shoreline survey identified over twenty-five pipes, storm drains, and streams. Four sources, labeled 5, 7, 16, and 21 in Figure 5.7 were identified as potentially significant. Sources 5 and 7 were not discharging in 1999, but showed elevated fecal coliform levels in 1996. In addition, fecal coliform levels in Sources 16 and 21 dropped from their 1996 levels in 1999.

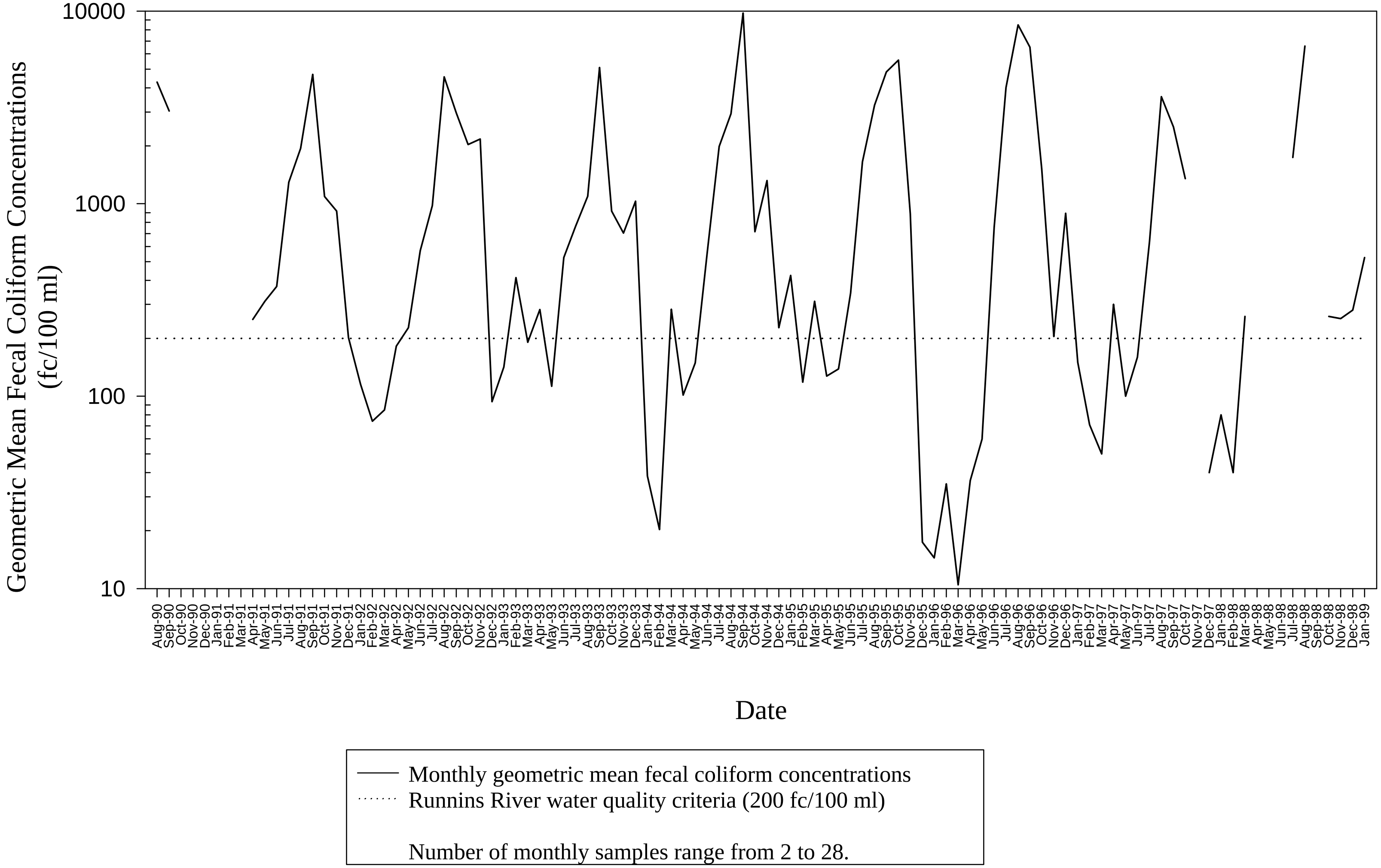


Figure 5.5 Geometric Mean Monthly Fecal Coliform Concetrations at School Street (Mr. Rayner 1990-99).

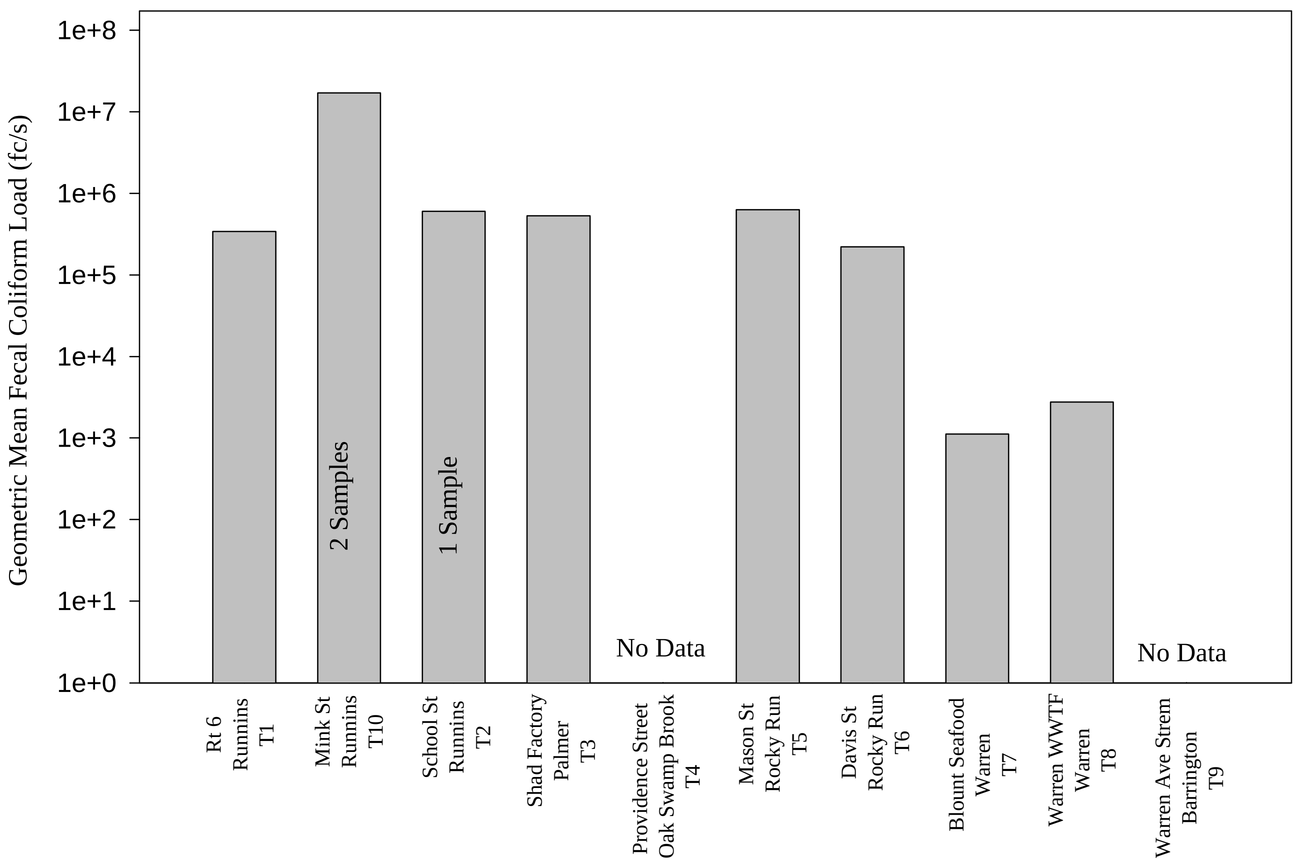


Figure 5.6 Geometric Mean Fecal Coliform Load, 1996.

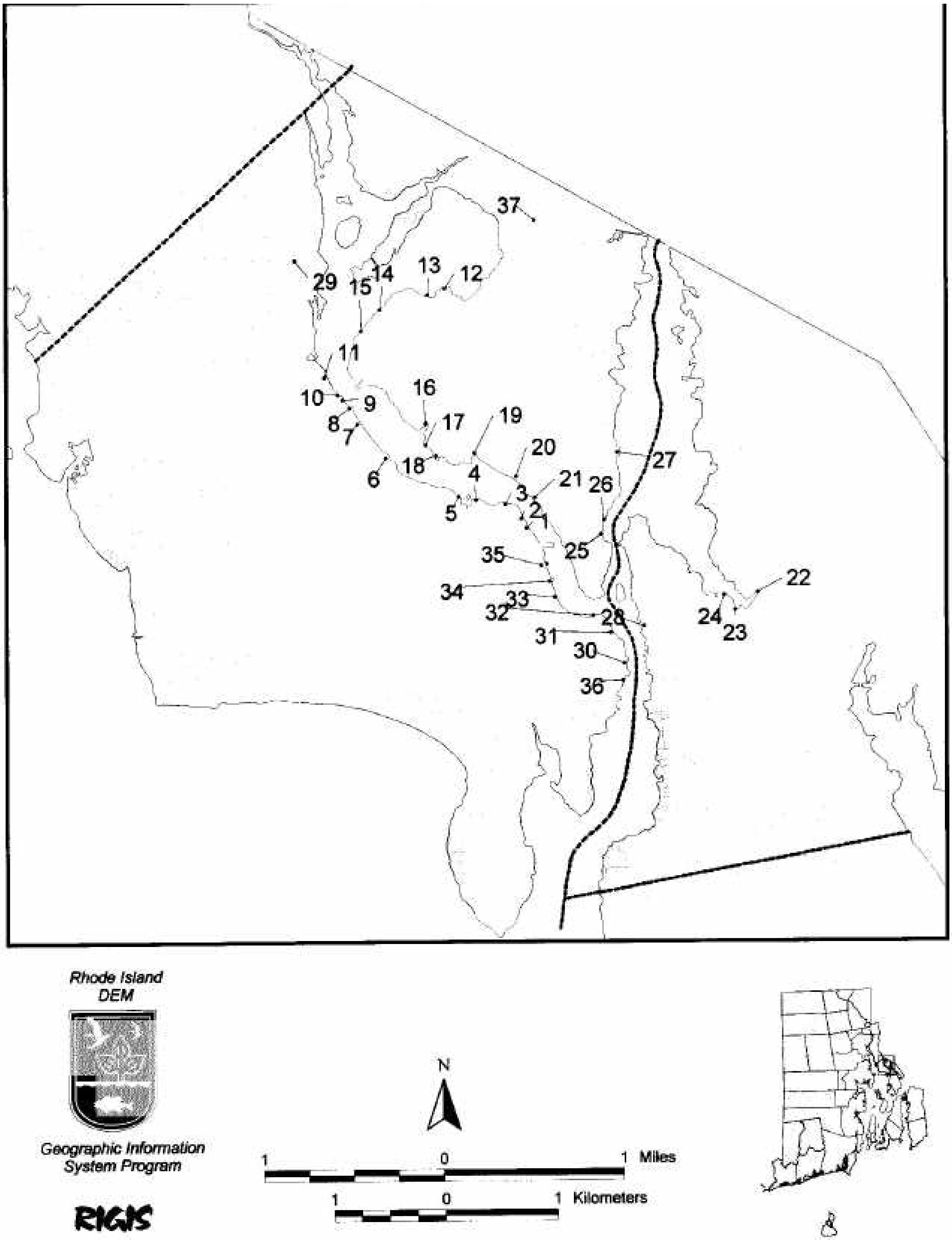


Figure 5.7 Actual and potential fecal coliform sources within the Warren River watershed (RIDEM, 1999b).

These sources may warrant mitigation efforts for wet weather flows (RIDEM, 1999b). The dry weather contributions of these sources are small and are assumed to be zero.

Possible sources at the Monarch Drive stream and the unnamed Warren Avenue Stream entering on the upstream side of the Tongue were identified during the 1997 and 1998 RIDEM dry weather surveys of the upper Barrington River. In Figures 4.5 through 4.7, the sources evidenced themselves as elevations in the tidal channels adjacent to the main channel of the Barrington River at stations B16 and B24. The Monarch stream has shown up sporadically as a source during the Pokanoket Watershed Alliance surveys. After further investigating the area and studying the data, RIDEM determined that the changes in instream concentration seen in Figures 4.5 through 4.7 were attributable to the changes in cross-sectional geometry in the vicinity of stations B16 and B24. RIDEM did not consider the streams to be major contributors to the fecal coliform budget of the Barrington River. They were not assigned a loading value in the TMDL calculation.

Wet weather fecal coliform concentrations and loadings were established for the Runnins River and the Palmer River during the 1998 wet weather event. The Runnins River was sampled for three days during the wet weather event. A peak concentration of 6900 fc/100 ml was observed. The event mean concentration for the Runnins River was 3211 fc/100 ml. In the Palmer River, fecal coliform concentrations at Bungtown Bridge were used to characterize fecal coliform concentrations. The event mean concentration was 5480 fc/100 ml.

Wet weather fecal coliform loadings entering as direct runoff to the Barrington and Warren Rivers were not measured during the 1998 study because the historical data showed that the Runnins and Palmer Rivers dominate concentrations in the Barrington River. The resources available for the wet weather study were therefore dedicated to the areas that principally cause the impairment of the Barrington River: the Runnins River and headwaters of the Palmer River.

Using a modified form of the Rational Method, RIDEM estimated direct storm water loadings to the Barrington and Warren Rivers. It was assumed that runoff characteristics in the Barrington and Warren Rivers were the same per unit watershed area as those in the Runnins River. Land uses and intensities are similar in all three watersheds. The assumed fecal coliform concentrations in runoff entering the Barrington and Warren Rivers were based on the event mean source concentrations observed in direct runoff to the Runnins River a wet weather study in October 1995. The runoff coefficient for the Barrington and Warren Rivers was based on values observed or calculated for the Runnins River during the October 1998 storm event. The bacterial loading to the Barrington and Warren Rivers was calculated as the product of the rainfall amount, the watershed area, the runoff coefficient, and the assumed event mean concentration.

Table 5.2 contains the runoff coefficient calculation. The maximum amount of runoff was calculated by multiplying the rainfall accumulation by the watershed area of the Runnins River drainage area from the Burrs Pond Dam to School Street. The volume of storm runoff entering the Runnins River from areas downstream of the Burrs Pond Dam was estimated by subtracting the pre-storm base flow of 0.33 m^3/sec from the flow rate time series during the storm event at School Street. This yielded a net or excess runoff estimate of 3.1×10^4 m^3 between 18:00 on October 14 and 18:00 on October 16. This volume represents the amount water that entered the Runnins River as surface runoff following the October 1998 storm. Dividing the maximum runoff volume by the excess runoff yields a runoff coefficient of 0.132 for the Runnins River drainage area downstream of the Burrs Pond Dam.

Table 5.2 Calculation of runoff coefficient for the Runnins River.

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
Drainage Area m^2	**Amount of Rain** in	**Amount of Rain** m	**Maximum Runoff Volume** Column 1 × Column 3 m^3	**Excess Runoff Due to Storm*** m^3	**Runoff Coefficient** Column 5 ÷ Column 4
1×10^7	0.93	2.36×10^{-2}	2.36×10^5	3.1×10^4	0.132

*[Fifteen minute flows -pre-storm flow] integrated between 10/14 -10/16/98

The maximum runoff volume was calculated by multiplying the amount of rainfall received during the October 1998 storm by the watershed area. The Barrington River watershed included the area between the Tongue and the Bike Path Bridge on the west side of the river and the area between the upstream limit of development on Hundred Acre Cove (Acre Avenue) and the Bike Path Bridge on the east side of the river. The Warren River watershed included the area between Bourne Lane and the Bike Path Bridge on the west side of the river and the area between Blount Shipyard and the Bike Path Bridge on the east side of the river.

The maximum amount of surface runoff volume reaching the river multiplied by the runoff coefficient, calculated in Table 5.2, determined the amount of runoff reaching the river. The storm water load was the product of the runoff volume reaching the river and an assumed concentration of 2000 fc/100 ml. This concentration was selected as characteristic of runoff from urban sources without hot spots. The event mean concentrations for all Runnins River sources during the 1995 study was 4400 fc/100 ml. For sources without hot spots, the event mean concentration was 1800 fc/100 ml. The direct fecal coliform loading for the Barrington and Warren Rivers was estimated to be 3.4 x 10^{11} and 6.4 x 10^{10} fc, respectively, for the 1998 wet weather event. This information is detailed in Table 5.3.

Table 5.3 Calculation of Warren and Barrington River storm loadings.

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8
Description	**Estimated Area** m^2	**0.93 in Rainfall** m	**Maximum Runoff Volume**[1] m^3	**Runoff Coefficient**[2]	**Surface Runoff Reaching River**[3] m^3	**Assumed Runoff Concentration fc/100 mL**	**Loading**[4] fc/event
Warren River							
East Side	5.4×10^5	2.36×10^{-2}	1.28×10^4	0.132	1693	2000	3.4×10^{10}
West Side	4.9×10^5	2.36×10^{-2}	1.15×10^4	0.132	1518	2000	3.0×10^{10}
						Total	6.4×10^{10}
Barrington River							
East side	3.2×10^6	2.36×10^{-2}	7.56×10^4	0.132	10,010	2000	2.0×10^{11}
West side	2.25×10^6	2.36×10^{-2}	5.31×10^4	0.132	7038	2000	1.4×10^{11}
						Total	3.4×10^{11}

[1] Column 2 × Column 3 [2]From Column 6 in Table 5.2 [3]Column 4 × Column 5 [4]Column 6 × Column 7

6.0 MODELING ANALYSIS

A numerical water quality model, WQMAP, was used to calculate the existing water quality under design conditions in dry and wet weather.

6.1 Model selection criteria

The characterization studies described in the previous chapters reveal that the fecal coliform concentrations respond to a number of processes acting on the Barrington River. The Runnins River is the most significant source to the River in both dry and wet weather. The Palmer River is a source to the lower Barrington River during wet weather. Other factors affecting fecal coliform concentrations at any given point in the River are summarized below.

Tidal oscillations

The relatively large tidal prism volume in Hundred Acre Cove produces large water mass excursions and strong vertical mixing in the Warren and Barrington Rivers. This results in three significant impacts on fecal coliform concentrations. First, salinity (density) and bacteria are vertically well-mixed over the length of the River. Second, as with any slender vertically well-mixed estuary, variations in the water column become most significant in the longitudinal direction. Finally, the upper estuary is shallow relative to the tidal range. Therefore, the fecal coliform concentration field varies significantly in the upper estuary. The variation is a result of the relatively large fraction of Narragansett Bay water introduced on the flood tide.

Geometry of the area

The length scale of the Barrington River (and Warren River) changes at three locations. The Warren River and lower Barrington River are slender and somewhat deep. The restricted cross-sectional area of this reach produces the strong tidal currents. The constrictions produce a significant 15 minute delay in the tide wave. Above the White Church Bridge, the Barrington River opens to the east into the relatively broad and shallow Hundred Acre Cove. The large surface area of Hundred Acre Cove permits a large volume of water to move through the river into the Cove at high tide. This produces the relatively strong currents discussed above and the relatively large high/low tide difference in fecal coliform concentrations. The location of Hundred Acre Cove to the east of the main axis of the Barrington River produces a lateral gradient near the Cove mouth wherein fecal coliform concentrations along the west shore of the River are significantly higher than those in the Cove. Shellfish Program data at the mouth of the Cove have shown higher fecal coliform concentrations than in the Cove itself. The third significant geometry change occurs north of the Tongue in the upper Barrington River. Here, the Barrington River shoals up and becomes narrow. The upstream tidal prism volume decreases significantly above the Cove. The upper Barrington River has a lower salinity, lower currents, and greater vertical stratification. The Runnins River exerts a strong influence, elevating fecal coliform concentration near the head of the Barrington River.

Nature of the sources

Wet weather conditions significantly increase the fecal coliform loadings from the Runnins and Palmer River tributaries. The time variation of loadings during wet weather indicates a need for a time-dependent model.

The factors described above were used to define the water quality modeling approach. The strong influences of rainfall and storm runoff dictate the use of a time-dependent water quality model. The Barrington River is relatively shallow with strong currents, resulting in a vertically well-mixed water column. The mixing behavior at the confluence of the upper Barrington River and Hundred Acre Cove at the Tongue pointed to an approach where mixing behavior is controlled by physics. A 2-D vertically averaged time-dependent model is therefore appropriate for the area.

6.2 The water quality model

The WQMAP model system, produced by Applied Science Associates (ASA) of Narragansett, Rhode Island was selected to simulate the Barrington River. The system consists of four basic elements. BFGRID is an interactive visual tool used by the modeler to generate the grid system for the model. This grid system is comprised of elements that are next used by the hydrodynamics (BFHYDRO) and pollutant transport (BFMASS) models. The hydrodynamics model solves the equations of momentum and mass in the interior domain of the model grid to define the circulation and water elevation fields throughout the area. The hydrodynamics model is driven by the tides, wind, and freshwater inputs at the external boundaries of the system. BFMASS is a pollutant transport model that solves the conservation of mass equation on the boundary fitted grid to predict time varying levels of selected pollutant constituents in each model element. The predictions are again driven by time-varying inputs from point sources at the external boundaries of the model domain and by local processes which include settling and decay at each model element internal to the system. The final WQMAP component is an embedded Geographic Information System (GIS) that ties the model domain into real space. The GIS allows the modeler to display model output information against local geographic features, such as shorelines, city and town boundaries, and water quality classifications.

The intended use of the model was to simulate the dry and wet weather behavior of fecal coliforms in the Barrington, Palmer, and Warren Rivers. The model was first applied to simulate the present condition of the area. This was accomplished using data collected in studies conducted by RIDEM between 1996 and 1998 (RIDEM, 1999c). The object of these studies were to define conditions in the upper Barrington River resulting from the interaction of loadings from the significant sources, the dispersive effects of tides and mixing, and the loss due to decay. The first modeling issue was to resolve the boundaries of the area to be modeled. The seaward boundary condition was set in upper Narragansett Bay at a sufficient distance from the area of interest so that temporal variations resulting from tidal and seasonal freshwater flow variations would be minimal and there would be a negligible influence on predictions in the Barrington River. The hydrodynamics and water quality grid system selected for the area is shown in Figure 6.1. The model domain is made up of 731 elements with dimensions ranging between 5 to 150 m in the lateral direction and 75 to 300 m in the longitudinal direction. In general, the grid elements are elongated in the direction of flow of the principal currents. The orientation of the long axis of the cells reflects the modeler's expectations of how water will flow in the River. This is done to minimize the computational time step necessary to simulate flow and transport while ensuring that the model calculation remains stable. The model employs between three to five lateral elements in the lower Barrington River and two lateral elements near the Mobil dam in the upper Barrington River. The Palmer River was included in the model domain to account for the influences of loadings to the Palmer River, particularly during wet weather.

The Palmer and Runnins Rivers were incorporated to account for the majority of the gradient in salinity observed during the 1996 and 1997 studies. The Palmer River discharge was taken as the sum of discharges from the Palmer River at Reed Street, Oak Swamp Brook at Providence Street, and Rocky Run at Davis Street. The Runnins River discharge was taken at Mink Street

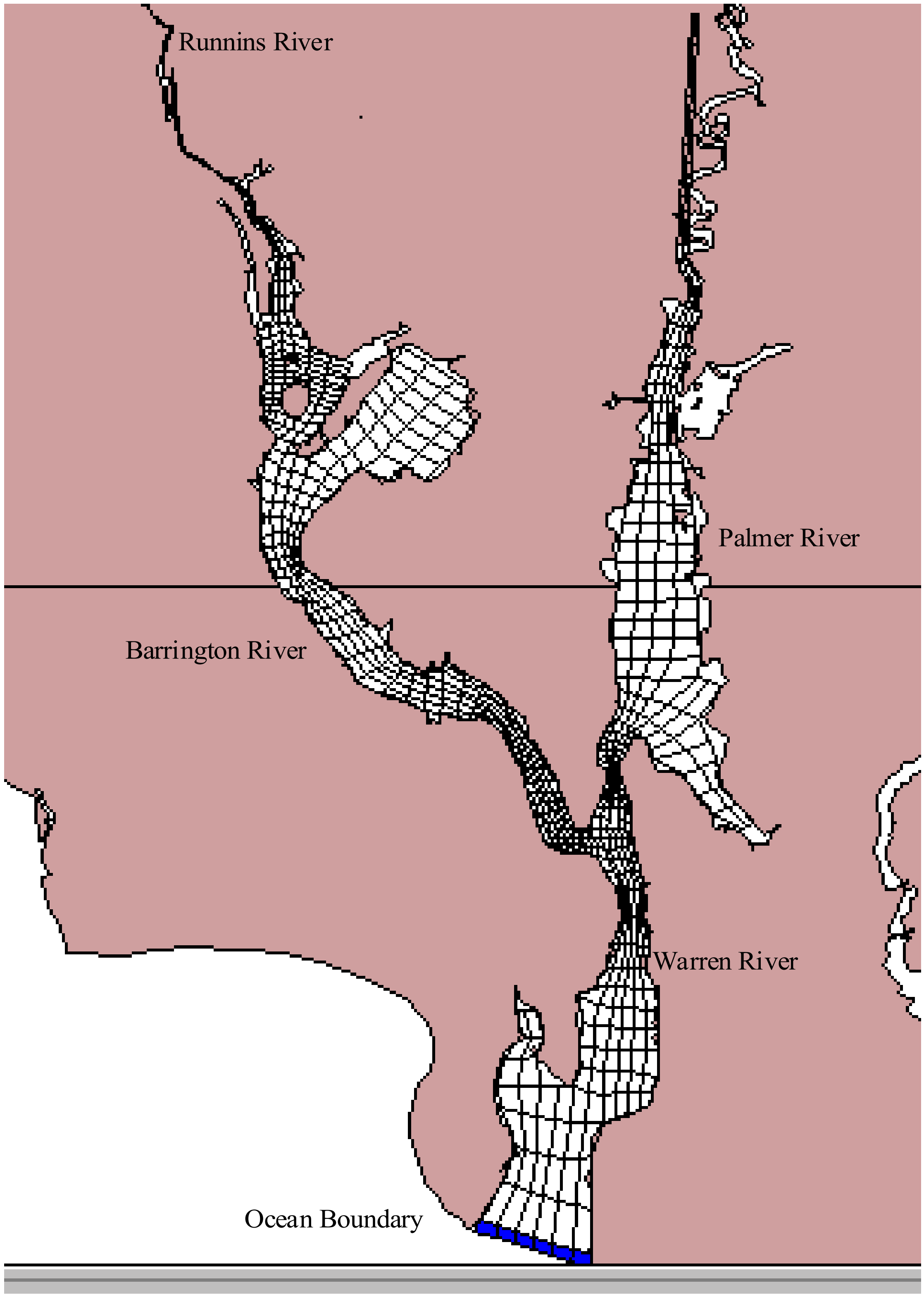


Figure 6.1 Graph of WQMAP Grid

and scaled up to the value at School Street, based on the mean difference in discharge observed during the 1996 studies (RIDEM, 1999c). Direct storm water discharges along the Barrington and Warren Rivers were not sampled during the 1998 wet weather study. When calibrating to the wet weather case, RIDEM added in the storm water loads estimated in Section 5.2 at selected locations along the Barrington and Warren Rivers.

The two RIPDES permitted discharges, Blount Seafood and the Warren WWTF, were included in the central Warren River. The seaward boundary was assumed to contribute to the fecal coliform budget of the system. The average of the high and low sample results at the seaward station, excluding outlier values, was used to represent background fecal coliform concentrations in upper Narragansett Bay.

6.3 Model application

Application and validation of the model followed the process outlined below:

Verify that the model grid works

Apply tidal forcing at the seaward boundary of the system. Adjust model grid geometry as necessary to ensure that the model predictions remain stable.

Reproduce tidal forcing

Adjust bottom friction to reproduce the observed propagation of the tidal wave through the area.

Conservative mass transport calibration

- Adjust friction, horizontal diffusivity, and dispersion to reproduce the behavior of a conservative tracer, salt, through the system using observed freshwater flows and predicted tides using continuous time series measurements at one point in the system.

- Verify that the distribution of salinity along the length of the Barrington and Palmer Rivers agrees with available data over a range of tributary inflow conditions.

Non-conservative mass transport

- Reproduce the spatial distributions of fecal coliform over the length of the Barrington and Palmer Rivers using observed loadings and instream concentrations for the conditions used in the calibration for salt.

- Validate the non-conservative model using data collected during and after a wet weather event.

6.4 Measures of calibration and validation

Comparisons between model-predicted and observed properties of a system may be divided into qualitative and quantitative categories. The most basic means of examining model performance may be made by simply overlaying the observed values by the modeled values and commenting on the “goodness” of fit. This process is useful in that it does provide the viewer with a quick but subjective assessment of the comparison. The reviewer can examine whether differences are a result in a time lag, whether the model tracks the long term trends in the data, and under what conditions the agreement is poorest.

The EPA has summarized techniques (McCutcheon et. al., 1990) that may be used to examine model performance in a quantitative manner. The techniques include relative error (RE), root mean square error (RMS), coefficient of variation (CV), and the correlation coefficient (R).

The relative error statistic is a simple means of quantifying the error when model-data differences are not uniform over space or time. It is defined as:

$$RE = (Cm_{Ave} - Cs_{Ave})/Cm_{Ave}$$

Where: Cm_{Ave} = mean of the measured data
Cs_{Ave} = mean of the simulated data

The relative error behaves poorly for small values of measurements if discrepancies are not proportional to the magnitude of the measurement. Therefore, the relative error is best for composite statistics when discrepancies are not constant as may occur when calibration over a large time or spatial range is attempted.

The root mean square term is the most widely used criterion to evaluate the agreement between the model predictions and measurements. The RMS error is defined as:

$$RMS = [\sum(Cm-Cs)^2/N]^{0.5}$$

Where: N = number of points in the series.

Concrete guidance on what levels of the above variables to assume as sufficient for a model to be calibrated is not well defined in the literature. McCutcheon et al, 1990 does suggest values that might be considered suitable, which are listed in Table 6.1.

Table 6.1 Criteria for error statistics.

Error Statistics	Criteria for Model Variables		
	Hydrodynamic	Transport	Water Quality
Relative Error, e	<30%	<25%	<45%
Coefficient of Variation, CV	<10%	<45%	<90%
Correlation coefficient, R	>0.94	>0.84	>0.60

6.5 Model calibration

Sections 6.5.1 through 6.5.3 describe calibrating WQMAP with data from two surveys conducted by RIDEM throughout the spring and summer of 1996. The surveys were conducted on March 14 and July 11 when discharge at School Street was 0.626 m^3/sec and 0.199 m^3/sec, respectively. The parameters that were needed to calibrate the model include horizontal diffusivity and die-off coefficients. While horizontal diffusivity should be the same for all surveys, it can be expected that the die-off coefficient is greater in early spring that in late spring and summer. Section 6.5.4 describes the calibration process for the wet weather condition.

6.5.1 Hydrodynamics calibration

The predicted tide based on National Ocean Service (NOS) data was used to force the system at the ocean boundary of the Warren River system. The tidal elevations at the White Church Bridge in the Barrington River calculated by the computer model were compared with the data collected by the

Environmental Studies Program at Brown University (Brown University, 1996). Changing horizontal diffusivity was found to have no impact on the results of the hydrodynamic simulation.

Error statistics for the model comparison are presented in Table 6.2. The March 14 and July 11 surveys meet guidance levels for relative error. The coefficient of variation (CV) exceeds guidance levels by not more than 5% for all surveys. The correlation coefficient (R) falls within guidance levels in March. Insufficient data were available to make a comparison for the July 1996 survey.

Table 6.2 Hydrodynamic calibration error statistics at White Church Bridge.

Date	RE (%)	RMS Error (m)	CV (%)	R
March 14, 1996	14.64	0.16	15.08	0.997
July 11, 1996	8.54	0.14	11.79	
Guidance Levels	<30		<10	>0.94

6.5.2 Mass transport: salinity calibration

The Runnins River and Palmer River freshwater inputs to the system were specified based on field measurements made the previous day by RIDEM. The seaward salinity was based on values measured outside the mouth of the Warren River.

Horizontal diffusivity and friction coefficients were adjusted to produce the best fit for mean salinity for the March 14 and July 11 using measurements made by Brown University (1996). Data-model comparison summaries presented in Table 6.3 meet the suggested guidelines based on a high to low tide salinity difference. For both cases, changes in horizontal diffusivity had minimal impact on the goodness of the fit. By studying the figures and the error statistics, the optimum horizontal diffusivity was determined to be 4 m^2/sec.

Table 6.3 Data-model comparison summary for salinity at White Church Bridge.

Date	Horizontal Diffusivity	RE (%)	RMS Error (ppt)	CV (%)	R
March 14, 1996	4	4.91	1.68	8.17	0.84
	3	5.46	1.79	8.71	0.84
	2	6.67	2.02	9.83	0.83
	1	9.65	2.59	12.59	0.78
July 11, 1996	4	0.98	0.53	2.06	0.92
	3	1.81	0.63	2.44	0.92
	2	2.72	0.79	3.06	0.91
	1	0.91	0.44	1.71	0.90
Guidance Levels		<25		<45	>0.84

6.5.3 Water quality: dry weather fecal coliform calibration

The March 14 and July 11 surveys represent a range of flow and loading conditions in the Runnins River. Four fecal coliform sources were used in the model simulations. Source flows and loadings are reported in RIDEM (1999c). The Runnins River loading was calculated from School Street flow and fecal coliform concentration at County Street. The Palmer River loading entered the river north of Rocky Run as the sum of the loads at Mason Street in Rocky Run and the Palmer River Shad Factory. The ocean boundary fecal coliform level was taken as an average of the coliform concentration at the low and high tide surveys. Due to their proximity to each other, the loading from the Warren WWTF and Blount Seafood were entered into the model as a single point source.

Each RIDEM survey consisted of a high and low tide sampling round at each station. Fecal coliform die-off coefficients were varied between 0 day^{-1} to 1 day^{-1}. The RMS error, CV, and R were calculated by comparing the modeled data to the actual data. Analysis of these parameters led to the selection of the decay coefficients of 0.95 day^{-1} and 0.2 day^{-1} for the March and July surveys, respectively.

Tables 6.4 and 6.5 summarize the RMS error, CV, and R for high and low tide conditions. During the March survey the CV and R exceeds guidance levels at high tide, however the RMS error is less than 2 fc/100 ml. These results are attributable to the low fecal coliform concentrations during the March survey and the apparently strong non-tidal forcing of transport at the time. At high tide, the July 11 survey exceeds guidance levels for the CV at high tide by over 40%, but if station 10 is not included in the CV calculation, the CV drops to 33%.

Table 6.4 Low tide fecal coliform concentration.

Date	RMS Error fc/100 ml	CV %	R
March 14, 1996	1.42*	67.49*	0.79*
July 11, 1996	16.91	79.38	0.98
Guidance Levels		<90	> 0.64

* This number eliminates the data from station 4.

Table 6.5 High tide fecal coliform concentration.

Date	RMS Error fc/100 ml	CV %	R
March 14, 1996	1.10*	91.92*	0.08
July 11, 1996	4.68*	133.80*	0.77*
Guidance Levels		<90	> 0.64

* Data from station 3 are not included in this number.

6.5.4 Water quality: wet weather fecal coliform simulation

The model was calibrated for wet weather using RIDEM's October 1998 wet weather survey of the Barrington, Palmer, and Warren Rivers. This is the only wet weather survey that has been conducted in the Warren River estuary. Time variable flows and concentrations were used to simulate loadings. The Runnins River load was calculated from discharge and concentration data at School Street. Due to tidal influences throughout the Palmer River, flow in the Palmer River was calculated using elevation and current meter readings under the Route 6 Bridge (RIDEM, 1999c). The bacterial loading was introduced to the river at this point. The Warren

WWTF and Blount Seafood inputs were entered as constant values throughout the storm event based on their mean values from the 1996 dry weather surveys. Fecal coliform concentrations at the ocean boundary were set constant at pre-storm conditions. Direct storm water discharges along the Barrington and Warren Rivers were not sampled during the 1998 wet weather study. When calibrating to the wet weather case, RIDEM added in the storm water loads estimated in Section 5.2 at selected locations along the Barrington and Warren Rivers.

Horizontal diffusivity was set to 4 m^2/sec. Fecal coliform die-off was varied between 0 day^{-1} and 1 day^{-1} because fecal coliform decay had been previously determined to vary with different seasonal (i.e. temperature) conditions. A die-off coefficient of 0.5 day^{-1} was chosen by overlaying the actual and modeled fecal coliform concentration levels in a concentration versus distance plot and by an analysis of relative error. Figures 6.2 through 6.6 show the comparison between the modeled and observed instream concentrations using a die-off coefficient of 0.5 day^{-1}.

Five low tide sampling surveys were conducted during and after the October 1998 wet weather survey. Table 6.6 summarizes the RMS error, CV, and R comparisons between the results of fecal coliform concentrations based on field sampling and the model-predicted values.

Table 6.6 Wet weather error statistics.

Date	Time	RMS Error fc/100 ml	CV	RMS Error fc/100 ml*	CV*	R
10/14/98	10:19	113	68.12	92.19	115.37	0.97
10/15/98	10:35	3668	252.14	89.67	66.71	0.96
10/16/98	12:02	592	249.93	106.81	72.66	0.69
10/19/98	11:19	20	75.20	15.14	254.27	0.97
10/20/98	11:06	12	64.86	5.22	58.64	0.91
Guidance Levels			<90		<90	> 0.64

* Without the Palmer River Stations.

All values for the coefficient of correlation are better than the guidance level. Using all sampling stations in the Barrington, Palmer, and Warren Rivers, the CV falls within guidance levels of 90% for three of the five days of surveys. When the Palmer River stations are eliminated from this calculation, the CV improves to within guidance limits for those two survey days. Eliminating the Palmer River stations also reduces the RMS error of the model-predicted fecal coliform concentrations.

6.6 Model confirmation

Sections 6.6.1 through 6.6.3 describe the confirmation of the WQMAP model using two surveys conducted by RIDEM on June 13 and August 8 during 1996. Section 6.5 describes the calibration process. The fecal coliform decay and dispersion values established in Section 6.5 above were used for the confirmation runs.

6.6.1 Hydrodynamics

The model hydrodynamics was confirmed using the June 13 and August 8 cases. Tidal elevations returned by the model are compared to observations by Brown University in Figures 6.7 and 6.8 for June 13 and August 8, respectively (Brown University, 1996). Error statistics presented in Table

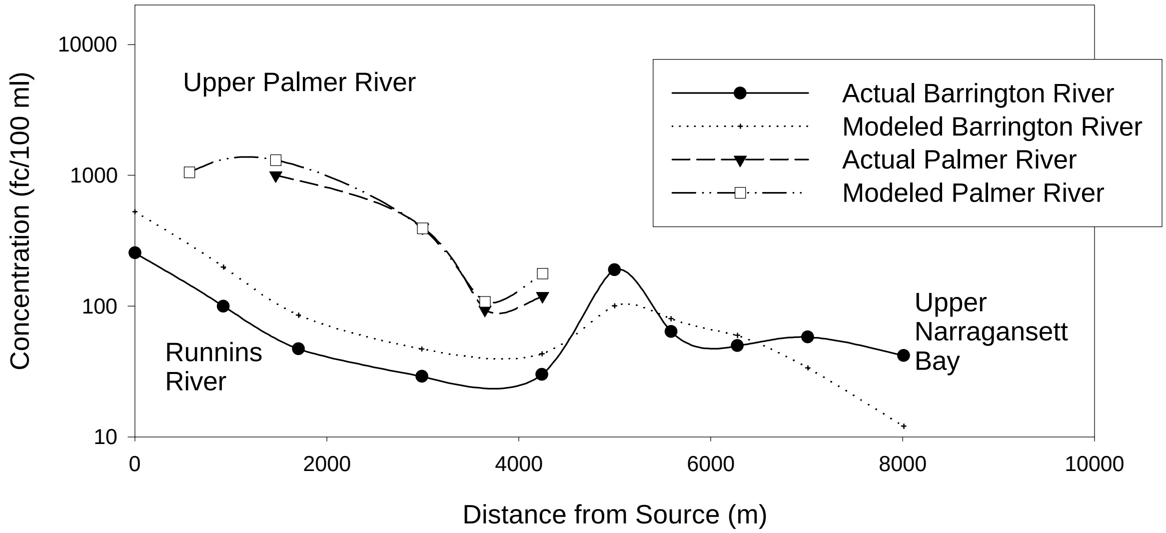


Figure 6.2 Wet Weather Pre-Storm Survey on October 14, 1998.

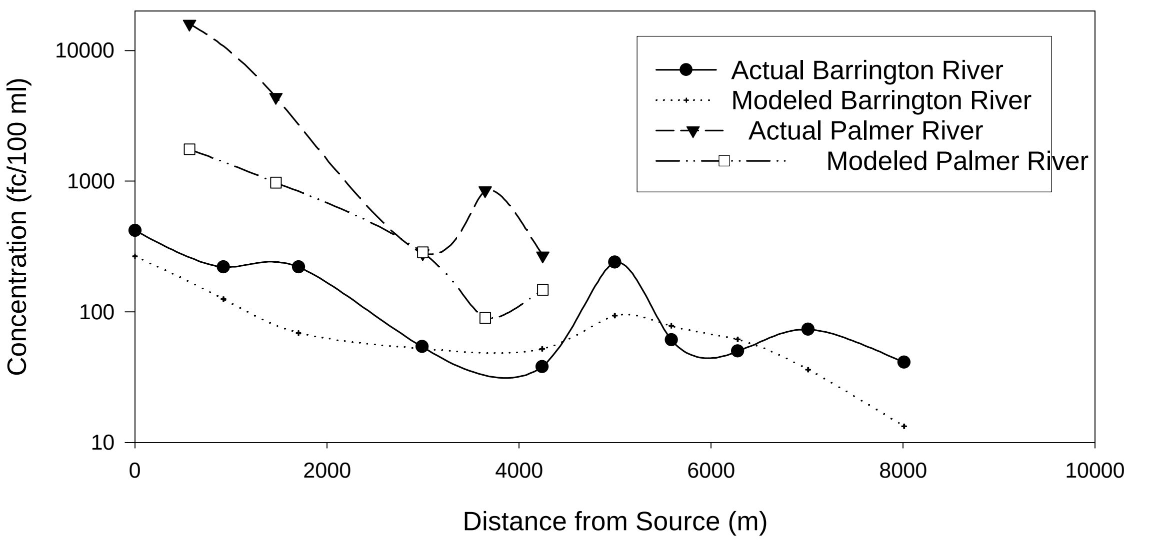


Figure 6.3 Wet Weather Storm Survey on October 15, 1998.

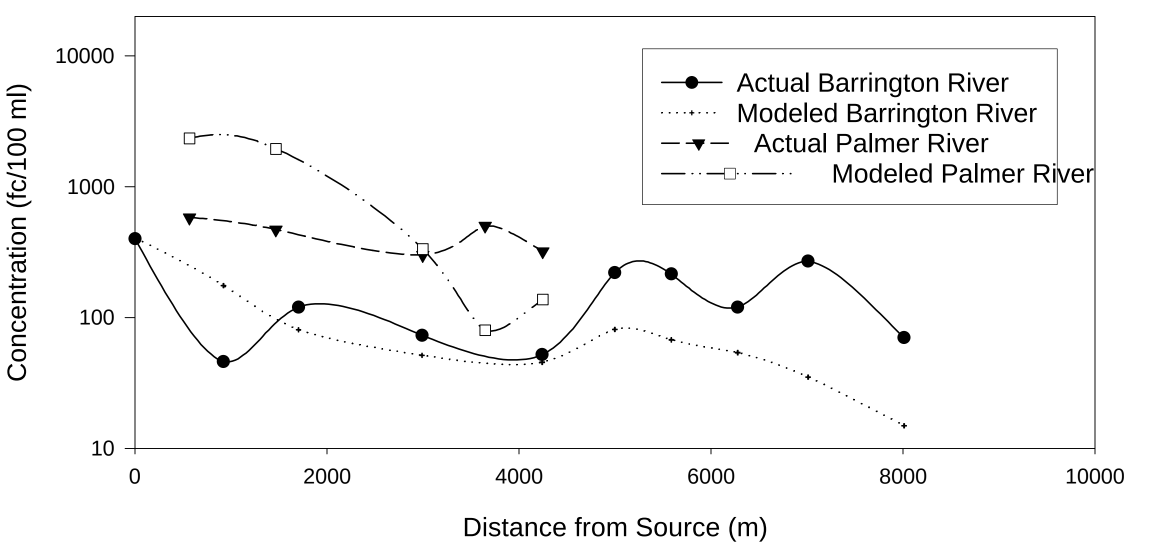


Figure 6.4 Wet Weather Post-Storm Survey on October 16, 1998.

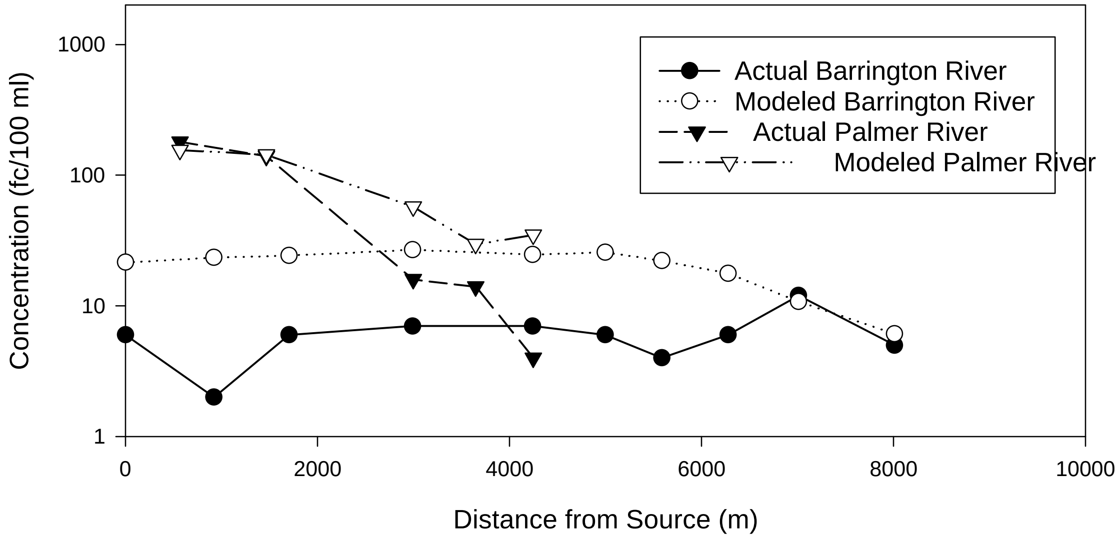


Figure 6.5 Wet Weather Post-Storm Survey on October 19, 1998.

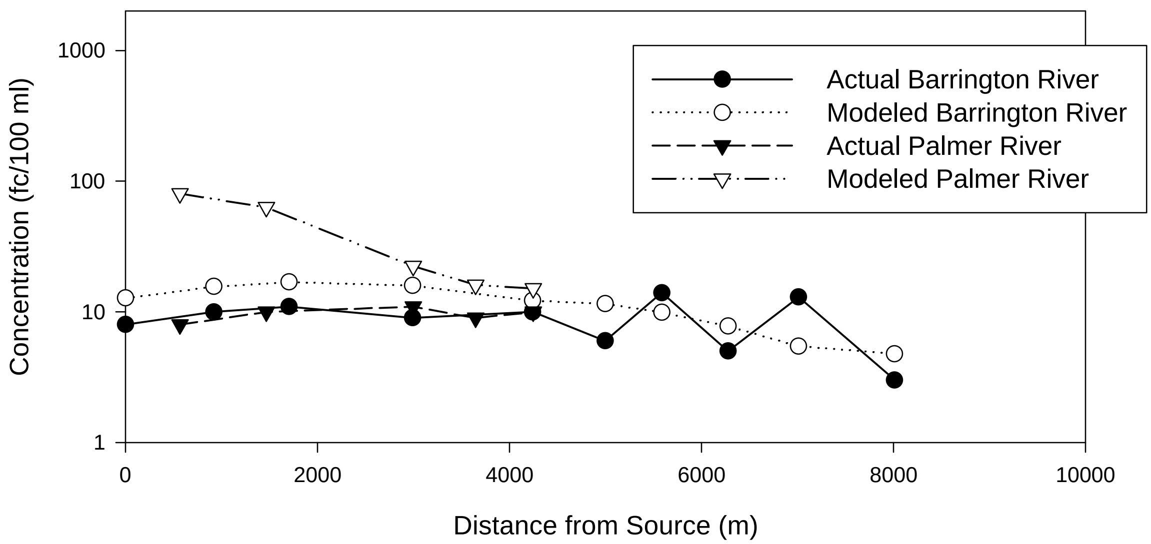


Figure 6.6 Wet Weather Post-Storm Survey on October 20, 1998.

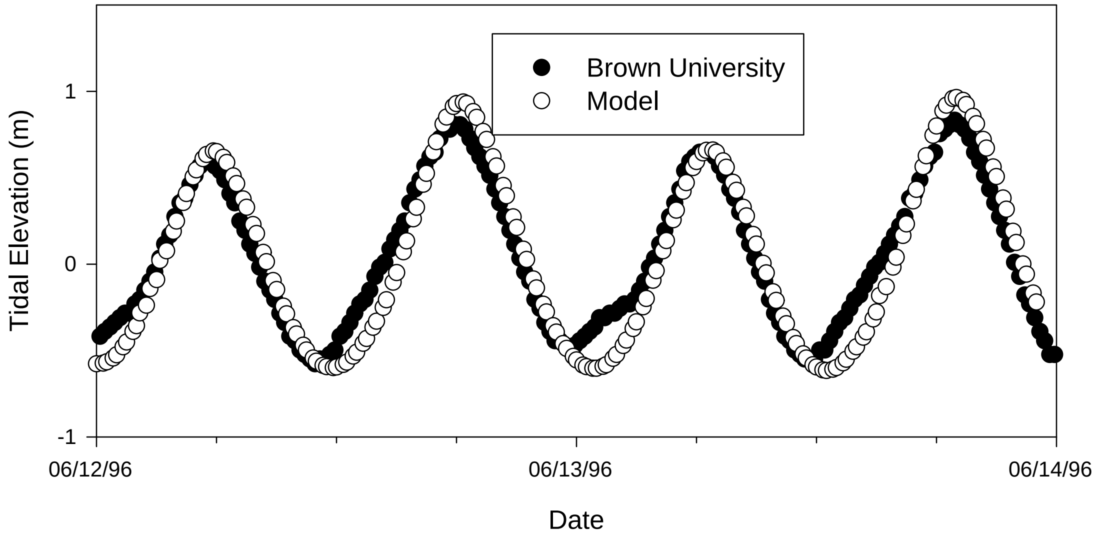


Figure 6.7 Tidal Elevation at White Church Bridge on June 13, 1996.

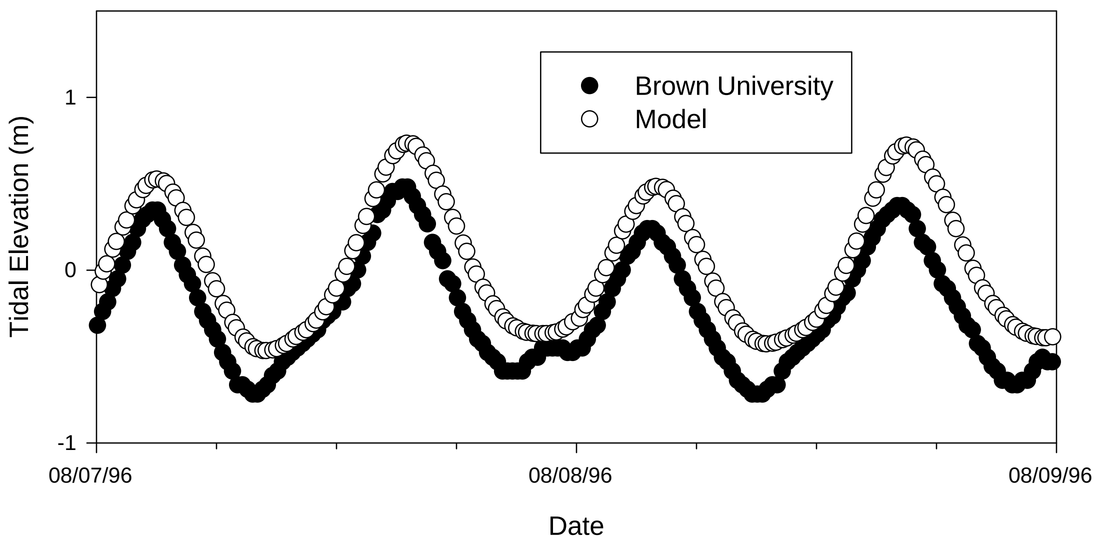


Figure 6.8 Tidal Elevation at White Church Bridge on August 8, 1996.

6.7 confirm that the model is a good fit for hydrodynamics. The June 13 and August 8 surveys meet guidance levels for relative error. The CV is slightly above guidance levels for both surveys.

Table 6.7 Hydrodynamic calibration error statistics.

Date	RE (%)	RMS Error (m)	CV (%)	R
June 13, 1996	4.08	0.12	12.16	0.862
August 8, 1996	10.25	0.16	11.49	0.932
Guidance Levels	<30		<10	>0.94

6.6.2 Mass transport: salinity

Salinity simulations for June 13 and August 8 using a horizontal diffusivity of 4 m^2/sec are presented in Figures 6.9 through 6.12. Figures 6.9 and 6.10 show the variation of salinity along the length of the Barrington River at high and low tide. The plot starts at the mouth of the Warren River, the ocean boundary for the grid, and ends in Barrington River, north of Hundred Acre Cove. The actual salinity data was collected during the RIDEM surveys. Figures 6.11 and 6.12 depict the salinity profile at White Church Bridge. Brown University (1996) collected the actual salinity data at White Church Bridge. Statistical comparisons presented in Table 6.8 meet all the suggested guidelines based on a high to low tide salinity difference.

Table 6.8 Data-model comparison summary for salinity at White Church Bridge.

Date	Horizontal Diffusivity	RE (%)	RMS Error (ppt)	CV (%)	R
June 13, 1996	4	5.03	1.31	5.40	0.94
August 8, 1996	4	1.95	0.65	2.52	0.92
Guidance Levels		<25		<45	>0.84

6.6.3 Water quality: dry weather fecal coliform

The Runnins River flow ranges from 0.199 m^3/sec to 0.616 m^3/sec on March 14 and July 11, respectively. The June 13 and August 8 flows are 0.275 m^3/sec and 0.235 m^3/sec, respectively. These flows fall into the calibration range. The August 8 discharge is close to 0.242 m^3/sec, the average Runnins River discharge. The calibration process returned two separate die-off coefficients for the March 13 and July 10 surveys because sunlight and temperature impact die-off. The June 11 and August 8 surveys were modeled with a 0.2 day^{-1} coefficient because environmental conditions in June and August are more similar to conditions in July than in March.

Tables 6.9 and 6.10 summarize for high and low tide, the RMS error, CV, and R. The CV exceeds guidance levels at low tide on June 13, while the correlation coefficient exceeds guidelines by 0.05. Other than these two violations, the data represents a good match, one better than was achieved in the calibration process.

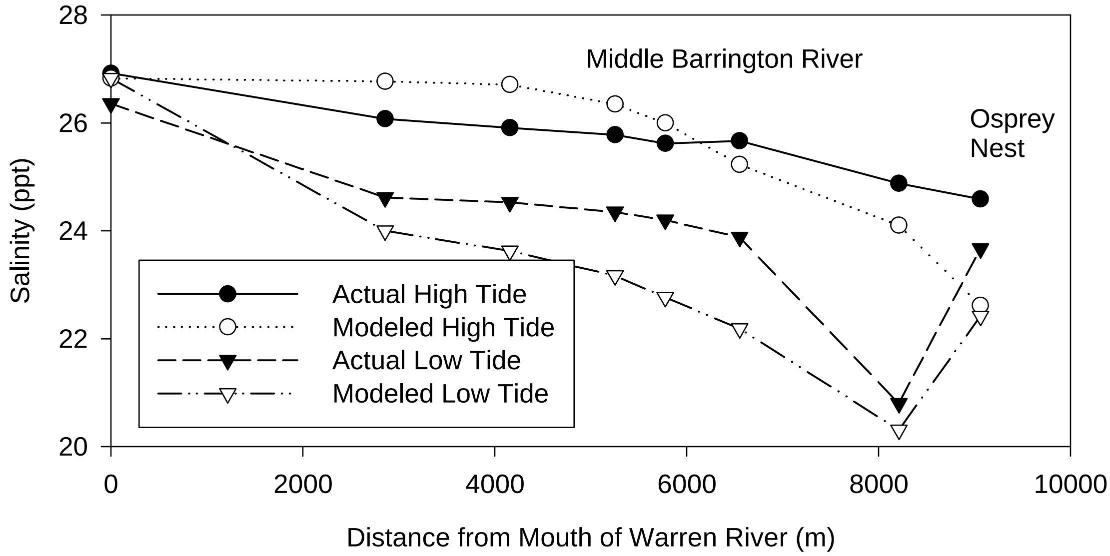


Figure 6.9 Salinity versus Distance Profile for the Barrington River on June 13, 1996.

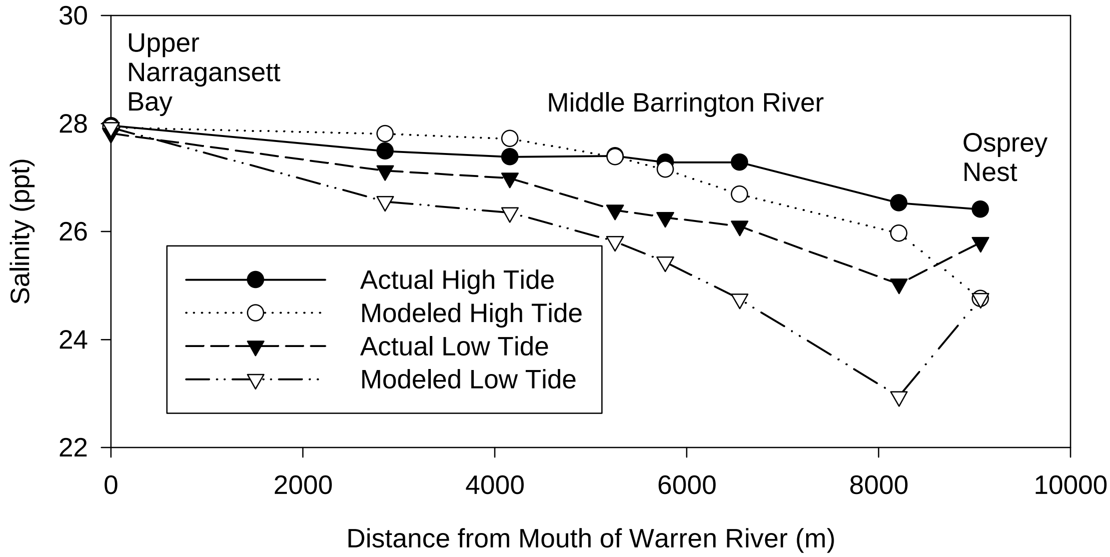


Figure 6.10 Salinity versus Distance Profile for the Barrington River on August 8, 1996.

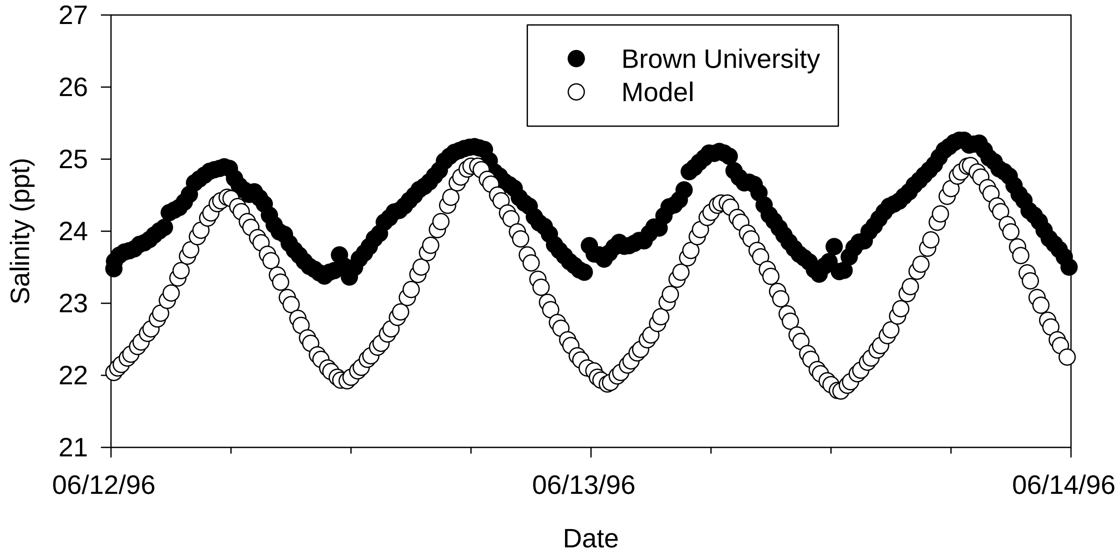


Figure 6.11 Salinity Profile at White Church Bridge on June 13, 1996.

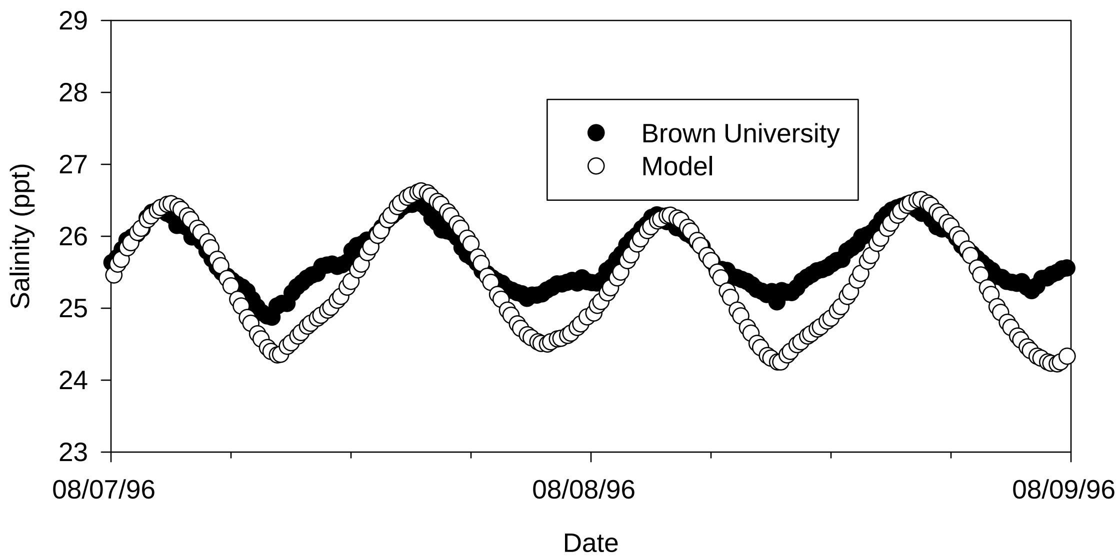


Figure 6.12 Salinity Profile at White Church Bridge on August 8, 1996.

Table 6.9 Low tide fecal coliform concentrations.

Date	RMS Error fc/100 ml	CV %	R
June 13, 1996	25.66*	111.93*	0.86
August 8, 1996	6.74	76.41	0.95
Guidance Levels		<90	> 0.64

* This number eliminates the data from station 9.

Table 6.10 High tide fecal coliform concentrations.

Date	RMS Error fc/100 ml	CV %	R
June 13, 1996	3.82	62.81	0.80
August 8, 1996	4.53	58.52	0.59
Guidance Levels		<90	> 0.64

Figures 6.13 and 6.14 show a distance versus fecal coliform plot for June 13 and August 8 at high and low tide.

At this point the model was considered to be calibrated and validated.

6.7 Model exercises: determining existing water quality

6.7.1 Dry Weather

Data from RIDEM's 1996 dry weather surveys of the Barrington, Palmer, Warren River estuary were used to calibrate and validate the model. During these surveys, the Barrington River met water quality standards. The computer model was used to determine existing water quality in the Barrington River for the design dry weather contributions using average summer flow and characteristic summer season source concentration values for the Runnins and Palmer Rivers (RIDEM, 2002a; RIDEM 2002b). Tables 6.11 and 9.1 detail the existing loads entered into the computer during dry weather. Table 7.1 summarizes the model-predicted geometric mean and 90th percentile values at each shellfish station in the Barrington River. The model predicted fecal coliform concentrations at each water quality station in the river at ten-minute intervals over an eight-day spring to neap period.

6.7.2 Wet Weather

Data from RIDEM's 1998 wet weather survey of the Barrington, Palmer, Warren River estuary were used in the model's simulation of existing wet weather conditions in the Barrington River (see Section 6.5.4). Tables 6.11 and 9.1 detail the strength of the sources entered into the computer model. As described in Section 5.2, direct storm water loadings to the Barrington and Warren Rivers were estimated. Table 7.1 summarizes the model-predicted geometric mean and 90th percentile values at each shellfish station in the Barrington River. The model predicted fecal coliform concentrations at each water quality station in the river at ten-minute intervals over the four-day period of increased flow.

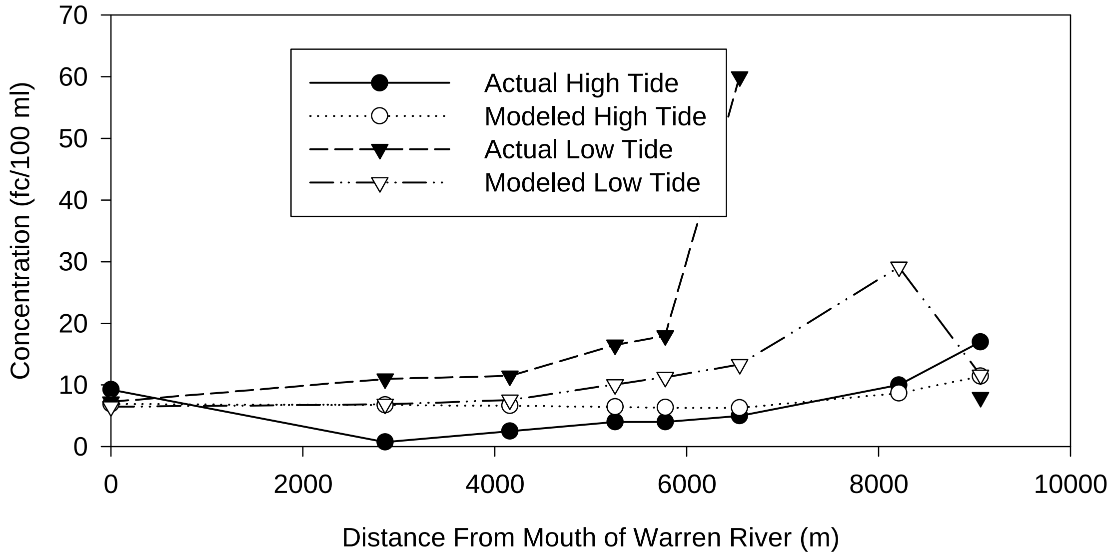


Figure 6.13 Fecal Coliform versus Distance for June 13, 1996.

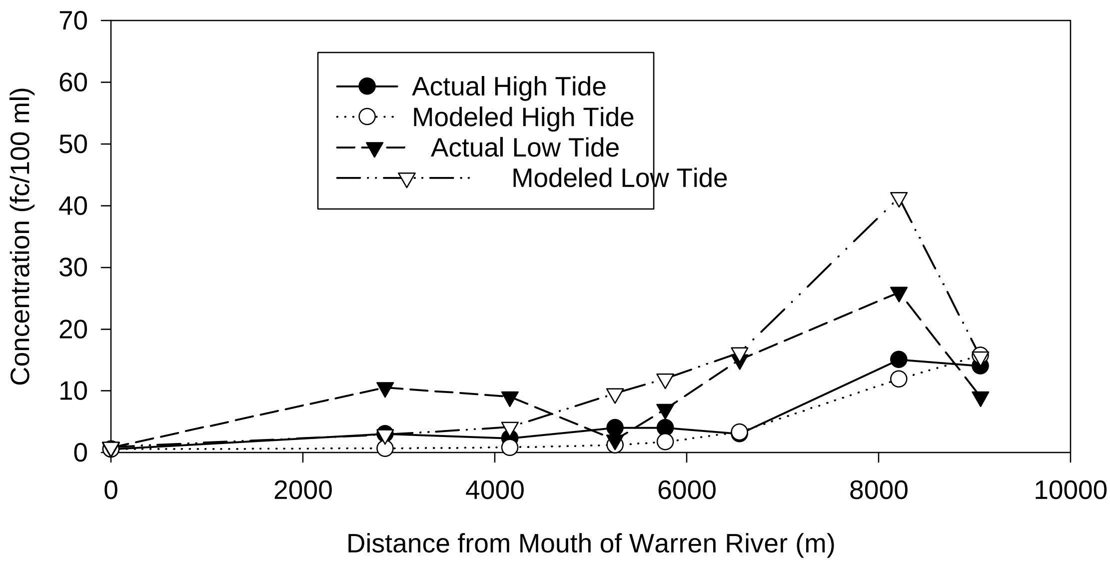


Figure 6.14 Fecal Coliform versus Distance for August 8, 1996.

Table 6.11 Existing sources of fecal coliform by subwatershed.

Source	Dry Weather			Wet Weather		
	Discharge (m^3/sec)	Existing GMC[1] (fc/100 ml)	Existing Load (fc/day)	Discharge[2]	Existing EMC[3] (fc/100 ml)	Existing Load[2]
Runnins River	0.242	1576	3.3×10^{11}	0.54 m^3/sec	3211	1.50×10^{12}
Palmer River	0.224	714	1.4×10^{11}	1.32 m^3/sec	5480	5.23×10^{12}
Barrington River	0.001	418	3.6×10^{8}	1.7×10^{4} m^3	2000	3.40×10^{11}
Warren River	0	0	0	3.2×10^{3} m^3	2000	6.40×10^{10}
Upper Narragansett Bay	NA	0.5	NA	NA	5	NA

[1]GMC is the geometric mean concentration.
[2]Wet weather discharge for the Runnins and Palmer Rivers is the average storm discharge during the period of increased flow, from October 14-18, 1998. Existing load is in fc/day for the period from October 14-18, 1998. For the Barrington and Warren Rivers, discharge and existing load is the total estimated for the storm event in m^3 and fc, respectively.
[3]EMC is the event mean concentration.

7.0 WATER QUALITY IMPAIRMENT

This section characterizes the fecal coliform impairments to the Barrington River, waterbody RI007021, and specifies violations of designated uses and water quality criteria found in the state's Water Quality Regulations

7.1 Barrington River

The Barrington River is designated a Class SA waterbody by the State of Rhode Island. The River violates the Class SA water quality standard for fecal coliform. The entire river has been closed to shellfishing since 1998.

Dry weather fecal coliform concentrations in the Barrington River are highest at the stations closest to the Runnins River. Seasonal data from the Runnins River show that fecal coliform concentrations begin their rise in July and reach their peak in August. The levels remain elevated until the end of October. Loads from the Palmer River, the Warren WWTF, and Blount Seafood apparently have a minor effect on the Barrington River in dry weather.

The entire Barrington fails to meet water quality standards in wet weather. Sampling data and the water quality model analysis indicate that the Runnins and Palmer Rivers impact the Barrington River. Direct storm water sources along the Barrington River were never sampled during wet weather. RIDEM added in the storm water loads estimated in Section 5.2 at selected locations along the Barrington and Warren Rivers when evaluating water quality in the river. The point sources, Blount Seafood and the Warren WWTF are not a significant wet weather source to the Barrington River because their fecal coliform are relatively small and are diluted before reaching the Barrington River.

Table 7.1 characterizes the dry and wet weather water quality conditions in fecal coliforms per 100 milliliters (fc/100 ml) at shellfish growing area stations. The existing conditions were determined by using the computer model as described in Section 6.7 of this report. See Figuer 3.1 for station locations.

Table 7.1 Current water quality characterization in the Barrington River [1].

Station[2]	Dry Weather (fc/100 ml)		Wet Weather (fc/100 ml)	
	Geometric Mean	90th Percentile Value	Event Mean Concentration	90th Percentile Value
GA2-1 (Tongue)	93.1	173.0	155.1	348.85
GA2-1A	40.7	84.6	81.6	150.0
GA2-2 (Hundred Acre Cove)	40.6	42.5	50.9	66.8
GA2-3 (White Church Bridge)	23.9	52.1	65.8	94.5
GA2-4	12.3	37.7	55.7	98.2
GA2-5 (Bike Path Bridge)	6.9	26.2	43.4	95.2

[1] Values were derived using a water quality computer model.
[2] Stations are listed from upstream to downstream. Locations are shown in Figure 3.1.

7.2 Fecal coliform sources to the Barrington River

7.2.1 Direct sources to the Barrington and Warren Rivers

RIDEM has identified the locations of direct storm water discharges along the Barrington and Warren Rivers. Direct storm water inputs along the Barrington and Warren Rivers were not measured during wet weather. Their strength was estimated using the modified form of the Rational Method described in Section 5.2. The bacterial loading to the Barrington and Warren Rivers was calculated as the product of the rainfall amount, the watershed area, the runoff coefficient, and the assumed event mean concentration. Estimates were determined based on storm characteristics seen in Runnins River during the October 1998 storm. The estimated Barrington River loading was divided equally between ten sources along both banks of the Barrington River. The estimated Warren River loading was entered as a source located north of the Warren Wastewater Treatment Facility.

In dry weather, sources along the Barrington River would contribute less than 0.01 fc/100 ml to elevated fecal coliform levels in Hundred Acre Cove, located in the upper Barrington River (see Appendix A). The Warren River point sources, Blount Seafood and the Warren WWTF are not a significant source in wet or dry weather because their fecal coliform loads are relatively small and are diluted before reaching the Barrington River. Based on available information, there are no other direct discharges to the Warren River in dry weather.

7.2.2 Palmer River

Loadings from the Palmer River enter the Barrington River at its mouth during and after wet weather, impacting the lower Barrington River. Agricultural landuses make up a significant portion of practices in the Palmer River watershed. It is believed that agricultural sources are the primary contributors to elevated fecal coliform levels. A TMDL has been developed by RIDEM for the Palmer River to document impacts of known pollution sources in the watershed (RIDEM, 2002a).

7.2.3 Runnins River

Investigations performed in the Barrington River watershed (RIDEM, 1999c; RIDEM, 2002b) document that the Runnins River is the principal cause of fecal coliform standard violations in the Barrington River during dry weather and is one of two major sources of fecal coliform in wet weather.

8.0 ALLOCATIONS TO THE BARRINGTON RIVER

A TMDL identifies the amount of a pollutant that can be assimilated by a waterbody while still achieving water quality standards. The TMDL is defined as the sum of loads allocated to point sources (i.e. waste load allocation, WLA), loads allotted to nonpoint sources, including natural background sources (i.e. load allocation, LA), and a margin of safety (MOS).

TMDLs can be expressed as a mass loading (mass unit per time) or any other appropriate measures. For the allocation of fecal coliform sources, USEPA Region 1 has stated that the TMDL may alternatively be expressed in concentration units (mass per unit volume).

8.1 Margin of safety (MOS)

There are two basic methods for incorporating the MOS into the TMDL. One can implicitly incorporate the MOS using conservative assumptions to develop the allocations or explicitly specify a portion of the TMDL as a portion of the final TMDL allocation. The TMDL uses both these methods to establish a MOS. To account for any conditions that may cause concentrations to exceed the water quality standards, a 10% explicit margin of safety was incorporated into the endpoint concentrations, setting the target geometric mean concentration to 12.6 fc/100 ml. The inclusion of an explicit MOS provides an additional buffer to allow for data variability and the presence of unknown sources.

Several conservative assumptions were used when determining the required percent reductions. The observed dry and wet weather fecal coliform concentrations were obtained by using the computer model to simulate dry and wet weather conditions. The dry weather loads for the Palmer and Runnins Rivers were composed of the average flow and the geometric mean of the fecal coliform data. Instream concentrations predicted by the computer model at the water quality station locations were analyzed over a spring to neap tidal cycle to characterize the dry weather condition. In wet weather, fecal coliform concentrations from the 1998 0.93-inch storm were used to fecal coliform conditions at the instream stations. In both wet and dry weather, the modeled geometric mean and 90^{th} percentile concentration at each shellfish station were higher than the observed values.. In addition, the design conditions occur in the critical summer month time period when bacteria concentrations are highest in the Runnins River and Barrington River. The loading reductions specified in this TMDL will therefore ensure compliance with the water quality standards during other times of the year.

8.2 Seasonality

Due to its proximity to the Barrington River, its discharge volume, and its source strength, the Runnins River constitutes the principal influence on fecal coliform conditions in the Barrington River. The data collected by Mr. Rayner, the volunteer monitor, shows that the loads from the Runnins River are low in the winter, spring, and early summer. Concentrations and loads in the Runnins River are at their highest levels between July 1 and October 31 (RIDEM, 2002b). The endpoints determined in this TMDL ensure that the Barrington River will meet water quality standards during this critical time period.

8.3 Receiving Water Reductions

The goal of this TMDL is to specify the percent reduction in existing instream bacterial concentrations needed to meet both the geometric mean and the 90^{th} percentile parts of the water quality standard in both wet and dry weather at all monitored stations in the Barrington River. The percent reduction required at each station is expressed as the difference between the present geometric mean concentration (GM) and the water quality goal (WQ Goal), divided by the GM:

% Reduction = (GM - WQ Goal)/ GM

The geometric mean water quality goal is the State's Class SA fecal coliform standard of 14 fc/100 ml minus a 10% explicit MOS:

WQ Goal = 14 fc/100 ml – 10% MOS = 12.6 fc/100 ml

The reductions required to meet the water quality goal are presented in Table 8.1. These reductions ensure that each receiving water station will meet both the geometric mean and 90th percentile portions of the water quality standard. They represent a reduction goal that is applicable to the composite of all tributary, point and nonpoint sources contributing to the water quality impairment.

Table 8.1 Required Barrington River Reductions.

Station[1]	Geometric Mean fc/100 ml			90th Percentile Value fc/100 ml			Reduction Required to meet both parts of Standard
	Target	Dry Observed	Wet Observed	Target	Dry Observed	Wet Observed	
GA2-1 (Tongue)	12.6	93.1	155.1	49	173.0	348.9	93 %
GA2-1A	12.6	40.7	81.6	49	84.6	150.0	85 %
GA2-2 (Hundred Acre Cove)	12.6	40.6	50.9	49	42.5	66.8	75 %
GA2-3 (White Church Bridge)	12.6	23.9	65.8	49	52.1	94.5	81 %
GA2-4	12.6	12.3	55.7	49	37.9	98.2	77 %
GA2-5 (Bike Path Bridge)	12.6	6.9	43.4	49	26.2	95.2	74 %

[1] Stations are listed from upstream to downstream. Locations are shown in Figure 3.1.

8.4 Tributary Reductions

The Runnins River, a Class B stream, is the largest fecal coliform source to the Barrington River. Class SA water quality standards must be met at the Runnins River point of entry to the Barrington River (RIDEM, 2002b). In the absence of site specific data to indicate that the Barrington River water quality goals could be met if each tributary discharges at the Class B standard, this TMDL requires that the Runnins River and other freshwater streams entering the Barrington River must meet the Class SA standard at its point of entry. A geometric mean of 14 fc/100 ml and a 90th percentile value of less than 49 fc/100 ml are set as numeric targets for downstream stations in each of the tributaries.

As specified in the Palmer River TMDL, the Palmer River is a Class B waterbody (RIDEM, 2002a) that must also meet the Class SA water quality standards at its point of entry to the Barrington River. This ensures that water quality standards in the Barrington River are met, particularly in wet weather.

9.0 RECOMMENDED MITIGATION MEASURES

Fecal coliform bacteria levels in the Barrington River are related principally to conditions and loadings introduced by the Runnins River. The Palmer River watershed is a source during wet weather. Sources along the Barrington River shoreline were considered negligible in dry weather (RIDEM, 1996a) and were only estimated for wet weather conditions. These point and nonpoint bacteria sources were found to be smaller contributors to fecal coliform concentrations in the Barrington River.

Mitigation measures designed to bring about water quality improvements to the Barrington River are outlined below. In all cases, the significant sources are nonpoint in nature, and the improvements achieved by implementing the measures outlined below cannot be quantified. Section 10 therefore contains recommendations for the continued monitoring of the Runnins, Barrington, and Palmer Rivers to ensure that the instream numeric targets are met.

9.1 Barrington River

Areas of the Barrington River below the White Church Bridge that have historically been used as shellfishing areas are directly adjacent to the heavily developed commercial area of Barrington. Sources along this area were sampled in dry weather by RIDEM as part of the upper Barrington River surveys (RIDEM, 2000). The RIDEM Shellfish Program (RIDEM, 1999a) also sampled pipes in this area during 1994, 1996, and 1999. These studies found that loadings from sources below the Runnins River are negligibly small in dry weather.

When designing a wet weather monitoring plan for the Barrington, Palmer, and Warren Rivers, RIDEM personnel sampled only the largest bacteria sources to the watershed. These sources included the Runnins River, RIPDES sources in the Warren River, and several freshwater streams within the Palmer River watershed. RIDEM did not sample direct storm water discharges along the Barrington River because it was believed that these sources were significantly smaller in their water quality impact than the sampled sources. In other words, the much larger loads from the sampled sources would *mask* any impact from the Barrington River direct storm water sources.

The modeling calibration and validation exercises supported the decision to not sample direct storm water discharges along the Barrington River. As shown in the RIDEM Shellfish Program's Shoreline Surveys, several pipes may potentially discharge storm water to the Barrington River. After reviewing draft copies of this report, EPA requested that RIDEM examine the potential impact of these sources. Section 5.2, describes the methodology used by RIDEM to estimate direct storm water loadings to the Barrington River. After estimating the direct storm water loading, RIDEM added these sources to the calibration storm event simulation in the water quality model. The loading was divided equally between ten sources that were placed along the Barrington River shoreline. These sources did not improve the model-data agreement. A reexamination of the available water quality data collected following the storm event did not reveal any reliable evidence of direct storm water impacts. Although these outfalls are sources of bacteria, any impact from these sources could not be seen due to the much larger impact of other sources.

9.1.1 Storm Water Phase II Permit Program

RIDEM has amended the existing Rhode Island Pollution Discharge Elimination System (RIPDES) regulations to include the requirements of the EPA Phase II Storm Water Regulations. The new regulations became effective in March 2002. As designated by the regulations, certain 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:

- Public education and outreach program to inform the public about the impacts storm water on surface water bodies.
- Public involvement/participation program.
- Illicit discharge detection and elimination program.
- Construction site storm water runoff control program for sites disturbing one or more acres.
- Post construction storm water runoff control program for new development and redevelopment sites disturbing one or more acres.
- Municipal pollution prevention/good housekeeping operation and maintenance program.

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

Operators of municipal separate storm sewer systems (MS4s) within urbanized areas (UAs) will be required to develop a SWMPP and obtain a permit (for those portions within the UA) by March 10, 2003. The Director will require permits for areas 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 the Barrington River are owned and operated by the Town of Barrington and the Rhode Island Department of Transportation (RIDOT). Areas within Rhode Island adjacent to the Barrington River are in a UA. Accordingly, the Town of Barrington and RIDOT will be required to apply for RIPDES permits by March 10, 2003.

RIDEM will continue to work with the Coastal Resources Management Council (CRMC), RIDOT, and the town of Barrington to identify funding sources and to evaluate locations and designs for storm water control BMPs throughout the watershed. In accordance with the requirements of this phased TMDL, monitoring of the Barrington River will continue so that the effectiveness of ongoing remedial activities can be gauged.

9.1.2 Woods Pond

Based on information gathered by scientists at the University of Rhode Island and additional RIDEM sampling, detailed in Section 11, RIDEM believes that the Town of Barrington and the Rhode Island Department of Transportation (RIDOT) should consider a structural BMP to pre-treat storm water prior to discharge into Woods Pond. Woods Pond, located behind the Barrington Town Hall was constructed to handle storm water runoff from Route 114 and Maple Avenue. Woods Pond discharges to an unnamed cove in the Barrington River. The outlet of the pond, source 5 in Figure 5.7, was not flowing in 1999 during the Shellfish Growing Area Water Quality Monitoring Program's shoreline survey. In 1996 this tributary showed elevated levels of fecal coliform. The pond acts as a detention pond by reducing peak flows during storms, providing some detention time, and allowing for greater fecal coliform decay. As sediments common in storm water accumulate in the pond, the pond's effectiveness as a stormwtaer BMP would be reduced. As with all storm water BMPs, routine maintenance, including periodic removal of accumulated sediment, is recommended.

9.2 Palmer River

The TMDL written by RIDEM for the Palmer River requires the upper Palmer River to meet the fecal coliform criteria for Class SA waters at its point of entry to Rhode Island waters (RIDEM, 2002a). The upper Palmer River is located in Massachusetts. Studies in this upper portion of the Palmer River watershed determined that significant loads were associated with agricultural operations adjacent to both the Palmer River and its freshwater tributary, Rocky Run (RIDEM, 1999c). Tributary streams to Belcher Cove represented significant sources to the system during dry and wet weather. The causes were traced to disposal of dog waste and urban runoff in one stream and to a potential range of problems, including a small cattle farm and urban storm runoff, in the second stream.

9.3 Runnins River

The draft TMDL written by RIDEM for the Runnins River requires the river to meet the fecal coliform criteria for Class SA waters at its point of entry to the Barrington River (RIDEM, 2002b). Possible dry weather sources to the Runnins River include regrowth and accumulation of bacteria in areas of dense *phragmites* growth. In wet weather, several direct storm water discharges have been identified throughout the waterbody.

9.4 RIPDES Sources

The impacts of point sources adjacent to the Barrington River were determined to be negligible in their impact on instream fecal coliform levels. The point sources are the Warren WWTF and Blount Seafood with Rhode Island Pollutant Discharge Elimination System (RIPDES) permit numbers RI0100056 and RI0001121, respectively.

The Warren WWTF experiences occasional exceedences of the daily maximum fecal coliform concentration limit. Investigation thus far has not found the cause, however equipment failures have been ruled out. The timing of the exceedences suggests that the problem may be tied to excessive infiltration and inflow (I/I) in its collection system. The Warren WWTF has been issued a Compliance Order to address excessive I/I, and the plant has completed implementation of corrective actions for inflow sources. The plant also recently submitted the results of an infiltration identification study along with a schedule for implementing corrective actions.

Allocations for the point sources are the same in dry and wet weather and have been set to their current permit limits, as listed in Table 9.1. Dye dilution studies have been used to establish mixing zones and effluent concentration limits for RIPDES permits at the Warren WWTF and Blount Seafood. From examining the dye study data, RIDEM has concluded that increasing or decreasing the loadings from these sources has very little impact on water quality in the Barrington River.

Table 9.1 Waste load allocations based on permit limits.

Point Source	Permitted Discharge[1] (MGD)	Permitted Concentration[2] (fc/100 ml)	Actual Concentration[3] (fc/100 ml	Percent Reduction
Warren WWTF	2.01	200	10.1	0 %
Blount Seafood	0.2	200/3100	29.3	0 %

[1] Warren WWTF permitted discharge is the average monthly limit while the Blount Seafood discharge is the maximum daily discharge.
[2]The permitted concentration is the average monthly limit. Blount has different concentration limits in the winter and summer. See above for explanation.
[3]Actual concentration data is from 1998-2000 plant data.

The 1994 RIPDES development document for Blount Seafood (RIDEM, 1994b) used EPA guidance to establish an acute mixing zone radius of ten feet and a chronic mixing zone radius of 100 feet. The minimum dye dilution observed in the acute zone (i.e. minimum of observed raw values in the top two meters of the water column at the boil) during a dye study performed at the outfall was 290:1 in the outfall boil. The minimum dilution 100 feet from the outfall was 370:1.

The RIPDES permit issued to Blount Seafood on June 14, 1994 included seasonal permit limits for fecal coliform. Summer limits (April 1 - October 31) for Blount Seafood were established at the state treatment performance standard of 200 MPN/100 ml. Since the state applies performance standards statewide for secondary sanitary facilities and Blount does not discharge sanitary waste, the permit included higher winter limits. Blount was assigned a winter limit (November 1 - May 31) of 3,100 MPN/100 ml. Other factors that contributed to the determination that the winter limit would not impact existing or designated uses included that Blount does not discharge treated sanitary waste and that large amounts of chlorine were being utilized to meet the limit of 200 MPN/100 ml. In November 1998 Blount Corporation received approval to eliminate the use of chlorine and at that time switched to pasteurization to disinfect their effluent.

The dye studies demonstrated that the monthly average fecal coliform discharge limits of 3100 fc/100 ml in the winter for Blount Seafood would be reduced to a maximum observable value of 10.7 fc/100 ml above background within its boil. The corresponding summer acute zone elevation for Blount at the 200 MPN/100 ml summer limit would be 0.7 fc/100 ml. The maximum impact area associated with these elevations for Blount is within ten feet of its outfall. Assuming an ambient concentration of 6 fc/100 ml for the Warren River (RIDEM, 2002a), the maximum local concentration in the vicinity of the outfall would be 17 fc/100 ml at Blount Seafood, well below the SB limit.

The Warren WWTF dye study established the size of the acute zone as a circle with a radius of 50 feet. The minimum observed dilution in this zone was 35:1. The chronic zone was assigned a lateral dimension of 300 feet and a longitudinal dimension of 500 feet centered on the outfall. The minimum dilution factor for this zone was 100:1. The permit includes year round fecal coliform limits of 200 MPN/100 ml. When the plant discharges at its maximum allowable value for mean fecal coliform concentration, the elevation in concentration would be 5.7 fc/100 ml, and the local concentration would be 11.7 fc/100 ml. RIDEM will be proposing a change in the fecal coliform standard for SB1 waters, which would include that stretch of the Warren River. The change would raise the SB1 fecal coliform standard from a geometric mean of 50 fc/100 ml to 200 MPN/100 ml.

At both facilities, additional dilution occurs in the approximately 1800 meters between the boundary of each mixing zone and the mouth of the Barrington River. Both of these point sources are diluted to a sufficient degree that their contribution to fecal coliform concentrations in the Barrington River may be neglected.

10.0 RECOMMENDATIONS FOR MONITORING OF THE AREA

Follow-up monitoring of the Barrington, Runnins, and Palmer River will confirm whether the desired water quality standards will be achieved. The monitoring conducted by volunteers, such as those in the Pokanoket Watershed Alliance, will be valuable in the monitoring the effectiveness of the proposed BMPs and in keeping water quality issues in the public eye.

RIDEM recruited volunteers through the Pokanoket Watershed Alliance to continue sampling at three stations in the Runnins Rivers. The stations are located below the Burrs Pond Dam, Mink Street, and at School Street in the Runnins River. At these stations, volunteers would collect fecal coliform samples and record instream temperatures on a monthly basis from July through October. In addition, stage should be recorded at School Street.

The Shellfish Growing Area Water Quality Monitoring Program samples the Barrington and Palmer Rivers bimonthly. At the present time, all stations in the Barrington River exceed water quality standards. If BMPs are effective in reducing the Runnins River loading to the extent projected in this study, these stations will meet standards. At the time that these stations begin to meet water quality standards, supplemental monitoring may be required for the northernmost shellfish stations. This monitoring may involve sampling this station at high and low tide on the same day along with the School Street station in the Runnins River.

11.0 OTHER CONCERNS IN THE BARRINGTON RIVER WATERSHED

During 1998, two researchers at the University of Rhode Island Graduate School of Oceanography sampled surface sediments and shellfish samples at more than 40 sites in Narragansett Bay, including in an unnamed cove directly behind the Barrington Town Hall (sometimes referred to as Town Hall Cove). Analyses of the sample revealed high concentrations of organic compounds: PAHs, PCBs, TPH, and DDTs, and several metals, including lead (Quinn and King, personal communication). The area was subsequently re-sampled by RIDEM. RIDEM collected two sediment samples in the cove, and a sample each in an unnamed tributary stream and Woods Pond that drain to the cove. RIDEM Fish and Wildlife personnel collected quahog samples from the Barrington River adjacent to the cove and from three other areas that included Hundred Acre Cove. The RIDEM sampling yielded lower, but similar results in the sediment samples. The quahog meat analyses yielded low pollutant levels that were characterized as typical of upper Narragansett Bay. The follow-up sampling by RIDEM suggests that the elevated contaminant levels in the sediment are limited to the Cove area.

After examining the sediment data, the Rhode Island Department of Health (HEALTH) concluded that occasional contact with this contamination does not pose a risk to public health. HEALTH advised residents to take a precautions to avoid exposure, including avoid wading or swimming near the shore in the contaminated areas, wash yourself, children, or pets if they are exposed to these sediments. HEALTH has also reminded residents of general advisories for fish and shellfish consumption. Due to elevated bacterial levels, there should be no harvesting of shellfish. In addition, the consumption of bluefish and striped bass should be limited to one meal per month because of elevated PCB levels in these species that are caused by regional (East Coast of the United States) PCB levels.

Continued investigations by RIDEM led to the conclusion that the sources could be characterized as nonpoint in nature. The sources are associated with the historic use of DDT to control mosquitoes. The PAH and the metal levels are associated with the intensive traffic and commercial use of the Barrington area. Runoff carries the DDT, PAHs, and metal to the Pond and Cove. Fecal coliform bacteria have historically been associated with urban runoff. RIDEM supports efforts by the Town of Barrington and the RIDOT to mitigate loadings from roadway and commercial areas that act as suspended solids and potential bacterial sources to the Barrington River.

12.0 PUBLIC PARTICIPATION

The New England Interstate Water Pollution Control Federation (NEIWPCC) established the Runnins River Steering Committee in 1993. This group of stakeholders includes participants from municipalities, states, EPA, and volunteer monitoring groups. The group was formed to facilitate communication among interested parties in the Runnins River watershed, which is part of the Barrington River watershed. The group has bimonthly meetings that are open to the public. The Runnins River Steering Committee participated in the 1995 wet weather study of the Runnins River and has contributed actively to the content of the ongoing work by RIDEM. The committee has ensured that improvements to the water quality of the Runnins and Barrington Rivers have remained on the agendas of the state and federal agency agendas.

RIDEM has been involved with the Runnins River Steering Committee from its creation. RIDEM routinely presents information on its activities in the watershed at the bimonthly meetings. The members of the committee help shape RIDEM's activities in the watershed by identifying areas that need more study. Members of the Pokanoket Watershed Alliance, a volunteer monitoring group, present information on routine water quality monitoring at stations in the Runnins and Barrington Rivers. RIDEM used this information in the development of the TMDL endpoints.

Public meetings and comment are an important component of the TMDL process. In addition to participating in the Runnins River Steering Committee meetings, RIDEM held an initial public meeting in July 1999 prior to TMDL development, which included all interested public, private, and government entities. The goal of the meeting was to provide information regarding the TMDL issues in the watershed and to solicit input regarding pollution sources and/or other concerns. Initial draft TMDL documents were presented for the Runnins and Barrington Rivers for public comment in June 2000. Public comment was solicited for a thirty-day period during and after the meeting. EPA comments on the draft Barrington River TMDL made it necessary to hold a final public meeting and notice period for both TMDLs in July - August 2002. Stakeholders were again given thirty days to review and submit comments on the draft Runnins and Barrington River TMDLs. RIDEM's response to comments made during the 2000 and 2002 comment periods are contained in Appendix C to this document.

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APPENDIX A ANALYSIS OF SOURCES ON THE BARRINGTON RIVER

The Shellfish Growing Area Surface Water Monitoring Program surveys all pipes, storm drains, and streams in the Warren River Estuary triennially. RIDEM concluded that the summed concentrations of all source loadings detected in 1994 would increase the mean fecal coliform loading by less than 0.01 fc/100 ml.

Assumptions

- Loadings are mixed into the volume of water that enters HAC during a tidal flood cycle.
- 1994 RIDEM Shoreline Survey data used to calculate other source impacts.
- Runnins River loading based on mean values for dry weather.

Source ID (Shoreline Inputs)	**Fecal Coliform Concentration (fc/100 ml)**	**Flow Rate (gal/min)**	**Tidal Cycle Input (fc/tidal cycle)**
6	930	1	2.62E+07
10	93	0.2	5.25E+05
13	23	3	1.95E+06
14	2300	3	1.95E+08
17	43	1.7	2.06E+06
19	4	9	1.02E+06
20	75	1.6	3.38E+06

Sum of Shoreline Inputs			2.30E+08
Runnins River	1576	0.242 m^3/sec	1.71E+11
Net Input			1.71E+11

Mean tidal prism volume	2.50E+06 m^3

Source	**Elevation of Hundred Acre Cove Fecal Coliform Concentrations (fc/100 ml)**
Shoreline Inputs	0.009
Shoreline Inputs and Runnins River	6.89

APPENDIX B   CALCULATION OF WET WEATHER LOADS

The 1998 wet weather event produced 0.93 inches of rain. The following tables detail the calculation of the average discharge and load and the event mean concentration produced by this storm.

Palmer River

The Palmer River discharge was determined using current direction and speed to calculate the instantaneous volumetric flow rate at the Route 6 Bridge. Fecal coliform concentration samples were collected at the Bungtown Bridge.

Date	Time	Discharge (m^3/sec)	Concentration (fc/100 ml)	Load (fc/day)
10/14/98	19:30	2.85	490	1.21E+12
10/14/98	21:00	2.85	1300	3.20E+12
10/15/98	1:00	1.22	7200	7.59E+12
10/15/98	3:00	1.22	4300	4.53E+12
10/15/98	5:00	1.22	430	4.53E+11
10/15/98	7:00	1.22	1100	1.16E+12
10/15/98	9:00	1.22	7900	8.33E+12
10/15/98	10:45	1.22	14000	1.48E+13
10/15/98	13:00	0.989	9700	8.29E+12
10/15/98	15:00	0.989	5200	4.44E+12
10/15/98	20:42	0.989	6700	5.73E+12
10/16/98	2:42	0.85	8800	6.46E+12
10/16/98	8:42	0.85	6100	4.48E+12
10/16/98	15:42	0.85	3500	2.57E+12
	Mean	1.32	5480*	5.23E+12

*This value is a geometric mean. It is the event mean concentration (EMC).

Runnins River

Discharge and concentration measurements were taken at School Street.

Date	Time	Discharge (m^3/sec)	Concentration (fc/100 ml)	Load (fc/day)
10/14/98	20:50	0.410	5800	2.06E+12
10/14/98	21:50	0.431	4900	1.83E+12
10/14/98	22:50	0.452	3700	1.44E+12
10/14/98	23:50	0.467	3400	1.37E+12
10/15/98	3:50	0.639	6900	3.81E+12
10/15/98	5:00	0.665	4200	2.41E+12
10/15/98	6:50	0.688	6700	3.98E+12
10/15/98	9:50	0.648	3800	2.13E+12
10/15/98	12:00	0.657	2500	1.42E+12
10/15/98	15:00	0.603	2800	1.46E+12
10/15/98	21:00	0.504	1900	8.27E+11
10/16/98	3:00	0.444	1000	3.84E+11
10/16/98	9:00	0.401	1100	3.81E+11
	Mean	0.54	3211*	1.47E+12

*This value is the geometric mean of the concentration measurements. It is the event mean concentration (EMC).

APPENDIX C COMMENT RESPONSE SUMMARY
Response Summary for the July 16, 2002 Public Meeting

July 16, 2002 Public Meeting for the Barrington and Runnins River TMDLs held at the Barrington Public Library Auditorium in Barrington.

Chris Turner presentation:

1. Purpose of tonight's meeting
- The water quality goals for the Runnins and Barrington Rivers submitted for public comment in June 2000 have been revised.

Provide an update on progress toward reducing pollutant sources and explain activities required by the Phase II Stormwater Program

2. Went over basic information on the TMDL and the process.

3. Discussed state water quality standards for fecal coliform in the waters of the Runnins and Barrington Rivers:

4. Overview of the Barrington and Runnins River system
- Runnins River Dry Weather Impairment:
  - Dry weather concentration increases as approach School Street.
  - General doubling of concentration between Mink and School Streets

- Runnins River Dry Weather Sources
  - Rte. 195 stream is major dry weather source
  - Tributary streams between Mink and School Streets are not significant because concentrations are lower than in-stream.
  - DEM investigation of Seekonk in-ground systems did not yield a link to in-stream elevations. DEM concluded that in-stream growth of bacteria was likely.

- Runnins River Wet Weather Impairment
  - Fecal coliform concentrations measured along length of river in 1995. Peaks occurred at County Street and School Street.

- Runnins River Wet Weather Sources
  - 1995 study pointed to four major sources: County Street, Rte 195 stream, OJ Creek, and Rte. 6 Stream #2.

- Barrington River Condition
  - In dry and wet weather, concentrations are highest at the osprey nest where the river tapers.
  - In wet weather, impairment is principally caused by the Runnins River, but also the Palmer River.

- Change to Barrington River water quality goal

- Revised goal: 12.6 fc/100 ml, less than <10% of samples exceeding 49 fc/100 ml at The Tongue
- Between the Tongue and the Mobil Dam, Barrington River must meet 14 fc/100 ml, with <10% of samples exceeding 49 fc/100 ml.

- Change to Runnins River water quality goal: Runnins must now meet 14 at the dam in both dry and wet weather.

Draft TMDL (June 2000) goal:

- Revised reduction targets:
  - Runnins at School Street is 99.1% dry weather, 99.6% wet weather.
  - Barrington combined wet and dry reduction ranges from 93% at the Tongue (GA2-1) to 74% at the mouth of the river.

- Restoration Measures: Underway/Completed in Rhode Island
  - County Street: storm water treatment structure (RIDOT, 2003)
  - I-195 stream: Discourage pigeon roosting (RIDOT, 2003)
  - Route 6: Storm water treatment structure (RIDOT, 2003)
  - OJ Creek (E. Providence, Ongoing)
    - Stop overflows at Wannamoisett pump station - overflow has been plugged.
    - Pump operation was improved at Wannamoisett station.
    - Interceptor line was cleaned to increase capacity.
    - Illicit connection detection.
    - Reduce infiltration and inflow in sanitary system.

- Phase II stormwater program: Barrington, East Providence, and RIDOT must submit Stormwater Management Program Plans (SWMPPs) for their systems in the Runnins and Barrington watersheds, under the Stormwater Phase II Program.

- Phase II SWMPP elements:
  - Six minimum measures:
  - SWMPPs must include plans to achieve reductions at locations identified in the TMDLs.
  - Plans for reductions must be consistent with the goals of this TMDL, focusing on methods to reduce peak stormwater flows through improved detention and infiltration
    - SWMPPs are to be submitted for DEM approval by March 10, 2003.

- Runnins River Restoration Measures For Massachusetts
  - Route 6 Stream #2: Design and construct stormwater.BMP
  - Mink-School area
    - Restore habitat of area, minimize growth of *phragmites* vegetation.
    - Evaluate/eliminate Seekonk septic systems as a coliform source.
  - Reduce upstream sources

- RIDEM will continue to be involved in the area:
  - Pursue restoration issues in the Runnins River
  - Palmer River: Implementation of bacteria TMDL is in progress.

- Complete Barrington and Runnins Rivers TMDL Reports at www.state.ri.us/dem/

Questions and comments on the presentation:
Comment: J.D. Anthony is pursuing a 37 acre development upstream of the RI border near Burrs pond. Mr. Anthony is reportedly also developing a storage facility at his property in the Route 2 stream area.

Comment: The commenter had recently visited the SW runoff ponds for Ann &Hope property. The first pond was unlined and had not been recently maintained. The second pond, which was lined, was full of gray water and had nothing living in it.
DEM Response: DEM can contact the MA watershed coordinator to see what options are available to promote stormwater structure maintenance

Question: What progress has occurred on Woods Pond?
Answer: DOT is presently scheduled to maintenance dredge the pond after Labor Day. The Town's proposal to have an inlet treatment structure (Vortex separator) installed was not approved for TEAC funding.

Question: Why is the Palmer River polluted for bacteria?
Answer: DEM recently completed the Palmer River Bacteria TMDL that concluded that bacterial pollution in the Palmer River is affected by agricultural and urban uses in the watershed. The TMDL identified farms in MA where cattle had access to the river and its tributaries. Similar conditions were found in the tributaries to Belcher Cove in RI.

Storm runoff from urban areas in RI was also a problem. The TMDL identified streets whose storm drains discharged directly to tributary streams that had high wet weather concentrations. DEM also found that dog waste was a significant problem in the Belcher Cove area, both at Jamiel Park, where residents walk their dogs, and at an auto body facility, where a dog was fenced in an area directly on a steam.

Response Summary for the Barrington River TMDL

On June 15, 2000 and again on July 16, 2002, the Rhode Island Department of Environmental Management (RIDEM) requested public comment on proposed Total Maximum Daily Loads (TMDL) that would limit bacteria loadings to the Barrington and Runnins Rivers. The first public comment period lasted from June 15, 2000 to July 14, 2000. After comments were received, RIDEM made changes to the TMDL documents, which necessitated another public comment period. The second public comment period lasted from July 16, 2002 to August 14, 2002. RIDEM also held an earlier public meeting on the topic. These meeting took place at the following dates and locations:

Location	Date
East Providence City Hall	July 14, 1999
Barrington Public Library	June 15, 2000
Barrington Public Library	July 16, 2002

While no comments were received during the second public comment period, RIDEM did receive both verbal and written comments submitted during the first comment period. The responses reflect the changes in the July 2002 Barrington River TMDL document.

Comments from Mr. Dennis Dunn, MA DEP

Although we believe that RI DEM did a very good job developing a hydrodynamic and water quality model for the reach of concern we are concerned that the model was not verified in any way with a second set of data. Although we recognize that there wasn't sufficient time to collect an additional data set we see no recommendation that indicates intent to validate the model as a follow-up action. MA DEP suggests that this activity be added to ensure that the proposed reduction in coliform loadings are verified before potentially costly efforts are undertaken to identify and eliminate additional sources. It should be noted however that DEP does support the implementation of a number of the actions identified without awaiting this verification step.

> The computer model was validated with an independent data set. Half of the data collected from the Barrington River surveys were used to calibrate the model with the other half being used to validate the model. In addition, the computer model is now being used to determine current conditions in the Barrington River.

It is unclear to MA DEP why RI DEM chose not to address the Barrington River between the Mobil Dam and the Shellfish Closure Line. It appears that there was concern that the model representation was uncertain in this area due to its variable mixing properties. From a modeling perspective this is understandable however there was no discussion as to what sources or potential sources, if any, were identified that contributed to this problem area and, if present, what implementation measures are proposed to reduce those loadings. This issue should be addresses or at a minimum discussed in the final TMDL.

> In response to this comment and input from EPA, the Barrington River between the Mobil Dam and the Shellfish Closure Line is now included in the Barrington River TMDL document.

Several of the references in the Jurisdiction column in Tables 6 and 8.1 (in the Runnins River TMDL document) and Tables 7 and 9.1(in the Barrington River document) incorrectly list MADEP as having jurisdiction. The following corrections should be made:

Abatement Measure	***Jurisdiction***
Map Storm-drain network	*City or Town or that owns the System*
ISDS investigations and repairs	*City or Town Board of Health*

The following are not under the jurisdiction of MADEP, and are assumed to be under the jurisdiction of the entities noted; however, this information needs to be verified.

Abatement Measure	***Jurisdiction***
Remove Phragmites	*Town of City DPW assuming appropriate environmental permits/clearances are obtained.*
Remove/deter waterfowl from pond	*Town animal control office*

Changes to these tables have been made in the Runnins River TMDL document. These tables are no longer in the Barrington River TMDL document.

In addition to the items identified above, Tables 7 and 9.1 suggest that MADEP implement a groundwater monitoring network in the vicinity of Mink, School, and Leavitt Streets to identify potential sources of fecal coliform in the groundwater contributing to the river loadings. There are a couple of issues of concern for DEP relative to this recommendation. The first is related to our legal authority and ability to require groundwater monitoring on private property and the second is the technical validity to identify the source through this type of effort. As to the legal authority DEP clearly has the legal authority to require groundwater monitoring to <u>regulated entities</u> such as a permitted groundwater or surface water facilities. In this case however neither of those two situations appears to be present, in fact, it is likely that DEP would have to enter onto private property to conduct such an investigation. The only historical examples of this happening are site investigations under our Hazardous Waste Site program. In any regard such an action would certainly be precedent setting and DEP would have to make sure we had legal standing and the activities were completely necessary before taking such an action.

Second, there are many technical challenges of conducting the field operations and interpreting the data. Past experience has told us that there could be a need to install numerous monitoring wells with varying well screen lengths to obtain a sufficient amount of information about the groundwater hydrology in the area to narrow the field of potential sources of contamination. Not only would this be difficult to do on private property but could be extremely expensive as well. To this end, the Department believes that taking such an action should be a last resort and only considered after all other options have been exhausted. Given this, the MADEP recommends that this requirement be removed from the TMDL and emphasis be placed on individual septic system disposal inspections and dye testing where appropriate by the local Board of Health as well as testing of the storm water systems in that area to identify possible sources. MADEP believes that such an approach is a much more effective, efficient, and less costly way of determining whether failures are occurring. This information can be used to require upgrades to failed systems or other necessary corrections.

Changes to these tables have been made in the Runnins River TMDL document. These tables are no longer in the Barrington River TMDL document.

Comments from Mr. Al Basile, US EPA
The Warren River is identified as a contributing source of bacteria to the Barrington River, but there is no estimate of loading. Assuming that the loading from the Warren River is part of the natural background is not appropriate. We recommend proving more information. Please call with questions.

The Warren River is now listed as a subwatershed with nonpoint sources of fecal coliform pollution. In dry weather, the are no fecal sources to the Warren River. In wet weather, the fecal coliform strength of direct storm water input along the River was estimated. The methodology is described in the ***Pollutant Sources*** section of the Executive Summary.

Loading Capacity (recommended language) **-** *As described in EPA guidance, a TMDL identifies the loading capacity of a waterbody for a particular pollutant. EPA regulations define loading capacity as the greatest amount of loading that a water can receive without violating water quality standards (40 C.F.R. 130.2(f). The loadings are required to be expressed as either mass-per-time, toxicity or other appropriate measure (40 C.F.R. 130.2(i)). The loading capacity for this TMDL is expressed as a concentration set equal to the state water quality standard. In the case of this TMDL, estimation of total maximum daily loads was not possible for all of the major contributing sources due to a lack of extensive site specific data. For bacteria TMDLs, it is appropriate and justifiable to set the loading capacity as a concentration. Rationale for such an approach is provided below:*

1. *Expressing a pathogen TMDL in terms of concentration provides a direct link between existing water quality and the numeric target.*
2. *Using concentration in a pathogen TMDL is more relevant and consistent with the water quality standards, which apply for a range of flow and environmental conditions.*
3. *Expressing a bacteria TMDL in terms of daily loads can be confusing to the public and difficult to interpret, especially considering that the magnitude of allowable loads are highly dependent upon flow conditions, and will therefore vary as flow rates change.*
4. *Follow-up monitoring will compare concentrations, not loadings, to water quality standards.*

This suggestion has been incorporated into the Barrington River TMDL document.

Natural Background (recommended language) - Natural background was not separated from the total nonpoint source load because of a lack of detailed site specific information. Without detailed site specific information on fecal coliform contributions from wildlife, it is difficult to meaningfully separate natural background from the total nonpoint source load.

The text above has been included in the final document.

Load Allocation Section – Barrington River flow used to calculate wet weather loading seems low. According to Appendix A, approximately 7 sources (pipes?) were flowing during dry weather with an approximate flow of 0.0001 m^3/sec. During wet weather the flow estimate was only 0.002 m^3/sec. According to Figure 5.7, more than 20 sources (pipes?) could be flowing during wet weather. Please provide justification for using this flow value.

The methodology for estimating Barrington River storm water flow was changed. The methodology is described in the ***Pollutant Sources*** section of the Executive Summary.

Page xii, 2nd paragraph, last sentence – "It is considered to be the natural background condition for the watershed" – Recommend deleting.

Deleted.

Beginning on page 8 of the report, water quality data for the Warren River is documented, both for dry and wet weather. Please don't forget this data when determining loading for the Warren.

The Warren River is now listed as a subwatershed with nonpoint sources of fecal coliform pollution.

Page xiii-,Table 5 - Runnins River flow value should be 0.529 and not 0.54. May also need to correct in other tables.

The flow should be 0.54 m^3/sec. The Runnins River TMDL document has been changed to reflect this change.

Comments from Mr. Dave Turin, US EPA

DEM appropriately describes the Class B water quality standards in terms of a geometric mean and a measure of variability (i.e. a geometric mean may not exceed 200 cfu/100ml (mean) and no more than 20% of samples shall exceed 500 cfu/100ml). Under the discussion of Numeric Water Quality Targets, DEM describes a numeric target, based on water quality modeling, to meet a more stringent geometric mean criteria downstream in the Barrington River (RES, pp. 12-13). EPA believes that a numeric target to meet the variability counterpart in the Barrington of no more than 10% of samples shall exceed 49 cfu/100ml is also warranted. EPA recommends that the DEM either provide additional justification that the selected water quality targets are sufficient to meet both parts of the Barrington River standard, or alternatively, include an additional numeric water quality target, such as "not more than 10% of the samples shall exceed a value of 394 cfu/100ml" to assure compliance with the 2nd part of the bacteria criteria in the Barrington River. The target of 394 cfu/100ml is the concentration identified in the Barrington River draft TMDL as protective of the variability part of the standard during wet weather (Barrington River draft TMDL, p. 45, 6/13/00). EPA expects that this value would also be *protective during dry weather. DEM could also utilize its water quality model to develop a target concentration specifically for dry weather.*

> The Runnins River and Barrington River documents now set water quality limits at School Street of a geometric mean of 14 fc/100ml (mean) and no more than 10% of samples shall exceed 49 fc/100ml. These goals ensure that water quality is sufficient to meet the designated uses of the Barrington River.

<u>Wet Weather</u>: The Barrington River draft TMDL indicates that an event mean concentration of 394 cfu/100ml must be attained at School St. in the Runnins River to meet the variability portion of the Barrington criteria (not more than 10% of samples exceeding 49 cfu/100ml) during wet weather. EPA believes that further information is necessary to support DEM's decision to use an event mean concentration of 394 fc/100ml instead of a 90th percentile value to calculate the reductions necessary to meet the variability portion of the criteria.

> The Runnins River and Barrington River documents now set water quality limits at School Street of a geometric mean of 14 fc/100ml (mean) and no more than 10% of samples shall exceed 49 fc/100ml. These goals ensure that water quality is sufficient to meet the designated uses of the Barrington River.