2005

Urban Streams Nonpoint Source Assessments in Maine Final Report, Birch Stream, Trout Brook, Barberry Creek, Capisic Brook

Susan Meidel
Partnership for Environmental Technology Education

Maine Department of Environmental Protection

Recommended Citation

Meidel, Susan and Maine Department of Environmental Protection, "Urban Streams Nonpoint Source Assessments in Maine Final Report, Birch Stream, Trout Brook, Barberry Creek, Capisic Brook" (2005). *Publications*. 255.
https://digitalcommons.usm.maine.edu/cbep-publications/255

Urban Streams Nonpoint Source Assessments in Maine

Final Report

Partnership for Environmental Technology Education
Community Colleges · Government · Industry

Department of Environmental Protection
State of Maine

Birch Stream
Bangor

Trout Brook
Cape Elizabeth and South Portland

Barberry Creek
South Portland

Capisic Brook
Portland

DEPLW0699

Urban Streams Nonpoint Source Assessments in Maine

Final Report

Prepared By:

Susanne Meidel
Partnership for Environmental Technology Education (PETE)
584 Main Street
South Portland, ME 04106

and

Maine Department of Environmental Protection
Bureau of Land & Water
Division of Environmental Assessment
State House Station #17
Augusta, ME 04333

Prepared For:

U.S. Environmental Protection Agency, Region 1
1 Congress Street, Suite 1100
Boston, MA 02114-02023

Date: 2/16/2005

TABLE OF CONTENTS

EXECUTIVE SUMMARY

REPORT

Chapter 1 Introduction

Chapter 2 Methods

Chapter 3 Birch Stream in Bangor

Chapter 4 Trout Brook in Cape Elizabeth and South Portland

Chapter 5 Barberry Creek in South Portland

Chapter 6 Capisic Brook in Portland

FIGURES
See Individual Chapters for Lists of Figures.

TABLES
See Individual Chapters for Lists of Tables.

APPENDICES
Appendix A Standard Methods and Standard Operating Procedures (SOPs) used in this Study (not included here, available upon request)

Maine Department of Environmental Protection

i. Methods for Biological Sampling and Analysis of Maine's Rivers and Streams (Davies and Tsomides, 2002)
ii. SOP for Sampling Stream Fish Assemblages by Backpack Electrofishing
iii. Protocols for Sampling Benthic Algae in Rivers, Streams, and Freshwater Wetlands
iv. Protocols for Sampling Aquatic Macroinvertebrates in Freshwater Wetlands
v. Protocols for Using the Hanna Dissolved Oxygen and Specific Conductance/pH Meters in Rivers, Streams, and Freshwater Wetlands
vi. Procedure for Operation, Deployment, and Maintenance of a YSI Sonde 6920
vii. Procedure for Measuring Continuous Water Temperature Using an Optic Data Logger
viii. Protocols for Collecting Water Grab Samples in Rivers, Streams, and Freshwater Wetlands
ix. Protocols for Using the Global Flow Meter in Wadeable Rivers and Streams

State of Maine Health and Environmental Testing Laboratory (HETL)

x. Analysis of Total Kjeldahl Nitrogen in Waters
xi. Analysis of Nitrate + Nitrite in Drinking Water, Groundwater, Surface Water, and Wastewater

LIST OF ACRONYMS AND ABBREVIATIONS USED

ANG	Maine Air National Guard
BIA	Bangor International Airport
BLWQ	Bureau of Land and Water Quality (MDEP)
BMP	Best Management Practice
BOD	Biochemical Oxygen Demand
BRWM	Bureau of Remediation and Waste Management (MDEP)
CCC	Criteria Chronic Concentration
Chl *a*	Chlorophyll *a*
CMC	Criteria Maximum Concentration
COD	Chemical Oxygen Demand
CSO	Combined Sewer Overflow
CWP	Center for Watershed Protection
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DRO	Diesel Range Organics
EPA	Environmental Protection Agency (also: USEPA)
EPT	Ephemeroptera, Plecoptera, Trichoptera (Mayflies, Stoneflies, Caddisflies)
GRO	Gasoline Range Organics
LEL	Lowest Effect Level
LWD	Large Woody Debris
MDEP	Maine Department of Environmental Protection
mg/L, μg/L	Milligrams per liter, Micrograms per liter
N	Nitrogen
NPS	Nonpoint Source
P	Phosphorus
PAH	Polyaromatic Hydrocarbon
PPM	Parts per million
TMDL	Total Maximum Daily Load
SEL	Severe Effect Level
SPC	Specific Conductance
SQG	Sediment Quality Guidelines
SSD	Total Suspended Solids
SVOC	Semi-Volatile Organic Compound
SWAT	Surface Water Ambient Toxics
SWD	Small Woody Debris
SWQC	(Maine) Statewide Water Quality Criteria
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TOC	Total Organic Carbon
TP	Total Phosphorus
TPH	Total Petroleum Hydrocarbon
TSS	Total Suspended Solids
USEPA	United States Environmental Protection Agency (also: EPA)
VOC	Volatile Organic Compound

ACKNOWLEDGEMENTS

The work carried out for this report, and the report itself, would not have come together without the help of many individuals, whose input of time, energy, and knowledge is greatly appreciated: Barbara Arter (BSA consulting); Jennie Bridge (EPA); Patrick Cloutier (City of South Portland); Beth Connors (MDEP); Steven Corsi (U.S. Geological Survey); Tom Danielson (MDEP); Susan Davies (MDEP); Jeff Dennis (MDEP); Mary Ellen Dennis (MDEP); Jeanne DiFranco (MDEP); Melissa Evers (MDEP); Douglas Heath (EPA New England); John Hopeck (MDEP); Ed Logue (MDEP); Dave Miller (MDEP); Paul Mitnik (MDEP); Chandler Morse (National Association of Home Builders); John Murphy (City of Bangor); David Pineo (City of South Portland); Brad Roland (City of Portland); John True (MDEP); Leon Tsomides (MDEP); Jeff Varricchione (MDEP); Dave Waddell (MDEP); Mark Whiting (MDEP).

Executive Summary

This report summarizes the findings of part 1 of the Urban Streams Non-Point Source (NPS) Assessments in Maine project, or Urban Streams Project, which investigated impacts of urban NPS pollution on four small streams in Maine, USA. The final goal (part 2) of the project is the development of NPS Total Maximum Daily Load (TMDL) plans aimed at removing or alleviating the impacts, and allowing impaired macroinvertebrate communities to recover and meet applicable water quality standards. The streams included in the project are Birch Stream in Bangor (central Maine), Trout Brook in Cape Elizabeth and South Portland, Barberry Creek in South Portland, and Capisic Brook in Portland (southern Maine). All streams are of moderate length (<1 to 2.5 miles) and watershed size (760 to 1,900 acres), and are located in highly urbanized areas. They have a fairly high percentage of impervious surfaces (13 to 33 %), and are impacted by a variety of urban stressors including high and low density residential development, commercial development, industry, and an extensive transportation infrastructure (roads, railroad, airport). Under Maine’s Water Classification Program (Title 38 MRSA Art. 4-A), Birch Stream in Bangor and the Cape Elizabeth portion of Trout Brook are Class B waterbodies, while the South Portland and Portland streams are Class C.

The four streams were chosen for inclusion in this project because existing data collected by the Maine Department of Environmental Protection (MDEP) and the University of Maine at Orono (Morse 2001) indicated that biological communities (macroinvertebrates) and water quality (dissolved oxygen, temperature, nutrient, and toxic levels) were impaired. Based on data collected by the MDEPs Biological Monitoring Program between 1996 and 2001, all streams were included in Maine's 2002 305(b) list (MDEP 2002d) because of aquatic life violations of State Water Quality Standards. So as to identify potential stressors causing the impairments, a large amount of data were collected in part 1 of the Urban Streams Project:

1) Biological data: detailed analyses of macroinvertebrate communities in the streams as well as identification of fish species present, and detailed analyses of algal communities; identification of macroinvertebrates and detailed analyses of algal communities in wetlands connected to the streams (where present).

2) Water quality data: dissolved oxygen, temperature, conductivity, pH, turbidity; nutrients (forms of nitrogen and phosphorus), Chlorophyll *a*, total and dissolved organic carbon, total dissolved and suspended sediment, toxicants (metals, chloride, diesel range organics), and ions.

3) Habitat assessments: stream width and depth, flow velocities; large woody debris analyses; channel, watershed and stream habitat assessments; fluvial geomorphology study; determination of spill and combined sewer overflow (CSO) event occurrence.

Most of the data were collected at distinct locations (stations) on each stream, and not all data were collected at each station. There were two main stations on Birch Stream (middle and downstream), two on Trout Brook (upstream and downstream), one on Barberry Creek (middle), and two on Capisic Brook (upstream and downstream). Following data collection, the EPA Stressor Identification (SI) protocol (USEPA 2000a) was applied to each data set to identify stressors affecting each stream. Ratings assigned to each stressor considered in each stream are shown in Table 1. An assessment of the utility of the SI process is presented in App. H of the report.

Table 1. Ratings for urban stressors at stream stations. "High importance" ratings are highlighted. Note that ratings reflect situation in each stream, i.e., are not necessarily consistent among streams.

Stressor	**Birch Stream (both stations)**	**Trout Brook (both stations)**	**Barberry Creek (single station)**	**Capisic Brook (downstream)**
Toxicants	H (7 +)	U, D: H (7 +)	H (10 +)	M (3 +)
Propylene Glycol	H (7 +)	--	--	--
Degraded habitat – in-stream	--	U: M (5 +) D: 0 (0 +)	H (9 +)	H (5 +)
Degraded habitat – riparian	--	U: 0 (0 +) D: M/L (3 +)	--	--
Increased sedimentation	--	U, D: 0 (0 +)	H (7 +)	--
Altered Hydrology	M (5 +) (peak flow only)	U: M/L (4 +) D: L (2 +)	L (3 +) (low flow only)	H (5 +)
Low dissolved oxygen	0 (1 +)	U: M/L (4 +) D: 0 (0 +)	--	L (2 +)
Elevated water temperature	M (5 +)	--	--	M (3 +)
Elevated nutrients	M (5 +)	--	--	M (3 +)

H, high importance; M, medium importance; L, low importance; 0, not important; --, not rated because not considered a stressor. Number in brackets gives the number of "+" assigned during SI process, i.e., positive evidence that stressor is affecting macroinvertebrate community.
Trout Brook: U, upstream; D, downstream.

Toxicants were rated as the top stressor in three out of the four streams, and as a major stressor in the fourth. Other stressors receiving high ratings in individual streams were propylene glycol (deicer used at Birch Stream), degraded in-stream habitat, increased sedimentation, and altered hydrology. Although the stressors are ranked in their importance, all stressors are linked to a certain extent and their effects connected, making it difficult to apply a ranking scale. Nearly all sources for the stressors (e.g., high percent of impervious surfaces, railroad/airport operations, road runoff, input of winter road sand/road dirt, spills and dumping, CSO input, channelization) were linked to urbanization although a few natural sources of stressors were detected also (e.g., saltwater intrusion into stream channel, low gradient, low-DO groundwater input, naturally sandy/silty substrate).

Recommendations made in the report for Best Management Practices (BMPs) and remedial actions aimed at removing stressors, or alleviating their effects, included both structural (e.g., dry/wet ponds, infiltration trenches/beds/basins, driveway drainage strips, oil/water separators) and non-structural (general "good housekeeping" practices) measures as well as activities such as replanting of the riparian zone, channel restoration, CSO separation, and outreach efforts. A summary of the identified stressors, BMP goals, and recommended structural/non-structural BMPs is presented in App. I of the report. The TMDLs to be developed in part 2 of the project will take the recommendations into account, and determine actions necessary for restoring water and habitat quality in these streams to a level that promotes Class B or C macroinvertebrate communities.

Copies of the full report including appendices can be found on the MDEP website (www.state.me.us/dep/blwq/docmonitoring/stream/index.htm). The report is broken down into individual chapters (Ch. 1 Introduction, Ch. 2 Methods, Ch. 3 Birch Stream, Ch. 4 Trout Brook, Ch. 5 Barberry Creek, Ch. 6 Capisic Brook) and a series of appendices, which can be downloaded individually. Note that documents included in Appendix A are available on request from biome@maine.gov or 207/287-3901.

Chapter 1: Introduction

Non-urban Stream
(Lambert Brook, Skowhegan)

Urban Stream
(Birch Stream, Bangor)

INTRODUCTION

Rivers and Streams in Maine

The Federal Clean Water Act of 1972 requires that states protect and maintain the chemical, physical, and biological integrity of the nation's waters. In pursuit of this directive, the Maine State Legislature in 1986 created the Water Classification Program (Title 38 MRSA Art. 4-A) so as to "restore and maintain the chemical, physical and biological integrity of the State's waters and to preserve certain pristine State waters." Recognizing that it was unrealistic to assign the same environmental goals to all of the State's surface waters, the Legislature adopted the following four classes of fresh surface waters, excluding great ponds:

- Class AA Waters. Class AA is the highest classification and is applied to waters that are outstanding natural resources which should be preserved because of the ecological, social, scenic or recreational importance.
- Class A Waters. Class A is the second highest classification.
- Class B Waters. Class B is the third highest classification.
- Class C Waters. Class C is the fourth highest classification, and establishes the State's minimum environmental goals.

The classification system is based on water quality standards that designate uses for each of the four water classes. For example, "Class C waters shall be of such quality that they are suitable for the designated uses of drinking water supply after treatment; fishing; recreation in and on the water; industrial process and cooling water supply; hydroelectric power generation, except as prohibited under Title 12, section 403; and navigation; and as habitat for fish and other aquatic life."[1] To ensure that water quality was sufficient to protect the designated uses, the Legislature established narrative criteria (for habitat and aquatic life) as well as numeric criteria (for bacteria and dissolved oxygen). Table 1 lists the criteria for each of the four water classes. Classification for the four streams included in the Urban Stream NPS TMDL project (see below) is as follows:

- Birch Stream: Class B;
- Trout Brook: Class B in Cape Elizabeth, and Class C in South Portland;
- Barberry Creek: Class C; and
- Capisic Brook: Class C.

---

[1] Class C was chosen as an example here because three of the four Urban Streams are partially or entirely Class C.

Table 1. Maine Water Quality Criteria for Classification of Fresh Surface Waters (Title 38 MRSA §465)

	Numeric Criteria		**Narrative Criteria**	
	Dissolved Oxygen	**Bacteria (*E. coli*)**	**Habitat**	**Aquatic Life (Biological)**
Class AA	as naturally occurs	as naturally occurs	free flowing and natural	No direct discharge of pollutants; as naturally occurs
Class A	7 ppm; 75% saturation	as naturally occurs	natural	as naturally occurs
Class B	7 ppm; 75% saturation	64/100 ml (g.m.*) or 427/100 ml (inst.*)	unimpaired	Discharges shall not cause adverse impact to aquatic life in that the receiving waters shall be of sufficient quality to support all aquatic species indigenous to the receiving water without detrimental changes to the resident biological community.
Class C	5 ppm; 60% saturation	142/100 ml (g.m.*) or 949/100 ml (inst.*)	habitat for fish and other aquatic life	Discharges may cause some changes to aquatic life, provided that the receiving waters shall be of sufficient quality to support all species of fish indigenous to the receiving waters and maintain the structure and function of the resident biological community.

* g.m., geometric mean; inst., instantaneous level

The task of determining whether a river or stream meets its assigned water quality class rests with the Maine Department of Environmental Protection (MDEP). Depending on the situation, various MDEP programs may be asked to assess water quality, and determine whether water quality standards are met. In the case of aquatic life criteria, assessments are performed by the MDEP Biological Monitoring Program. The program began evaluating biological communities in rivers and streams in 1983, and by late summer 2004 had established ~760 monitoring stations on ~260 rivers and streams throughout Maine. Biological data are collected in accordance with a standardized sampling protocol developed by the program, and are analyzed using statistical models. These models estimate the association of a biological sample to the four water quality classes defined by Maine's Water Classification Program (see above), thus indicating attainment or non-attainment of aquatic life standards. Findings of the Biological Monitoring Program are used to document existing conditions, identify problems, set water management goals, assess the progress of water resource management measures, and trigger needed remedial actions. More information on the Biological Monitoring Program can be found in Davies et al. 1999, MDEP 2002c, or on the following website: www.state.me.us/dep/blwq/docmonitoring/biomonitoring.

Biological Assessments of Impacts of Urbanization on Streams

During the first fifteen years of its existence, the Biological Monitoring Program primarily monitored the water quality of rivers and streams impacted by point source discharges, which predominantly affected larger waterbodies such as the Penobscot and Androscoggin rivers. Point source discharges are those that can be attributed to a distinct entity such as a wastewater treatment plant, pulp and paper mill, or heavy industry operation. More recently, biological monitoring has expanded to include streams impacted by nonpoint source (NPS) pollution that has led to a focus on smaller waterbodies or waterbodies where it is presumed that nonpoint sources are the major cause of water quality impairment.

Nonpoint source pollution is defined as pollution that originates from a number of diffuse sources as opposed to a distinct entity. Land use activities related to development (urbanization), agriculture, forestry activities, and transportation, as well as atmospheric deposition all may lead to NPS pollution. This type of pollution affects waterbodies in two main ways: first, changes in land use patterns alter the local watershed hydrology; and second, runoff from the land carries increased pollutant loads into waterbodies. The combined effects of NPS pollution can lead to habitat alterations, changes in water quality, and ultimately to ecosystem changes.

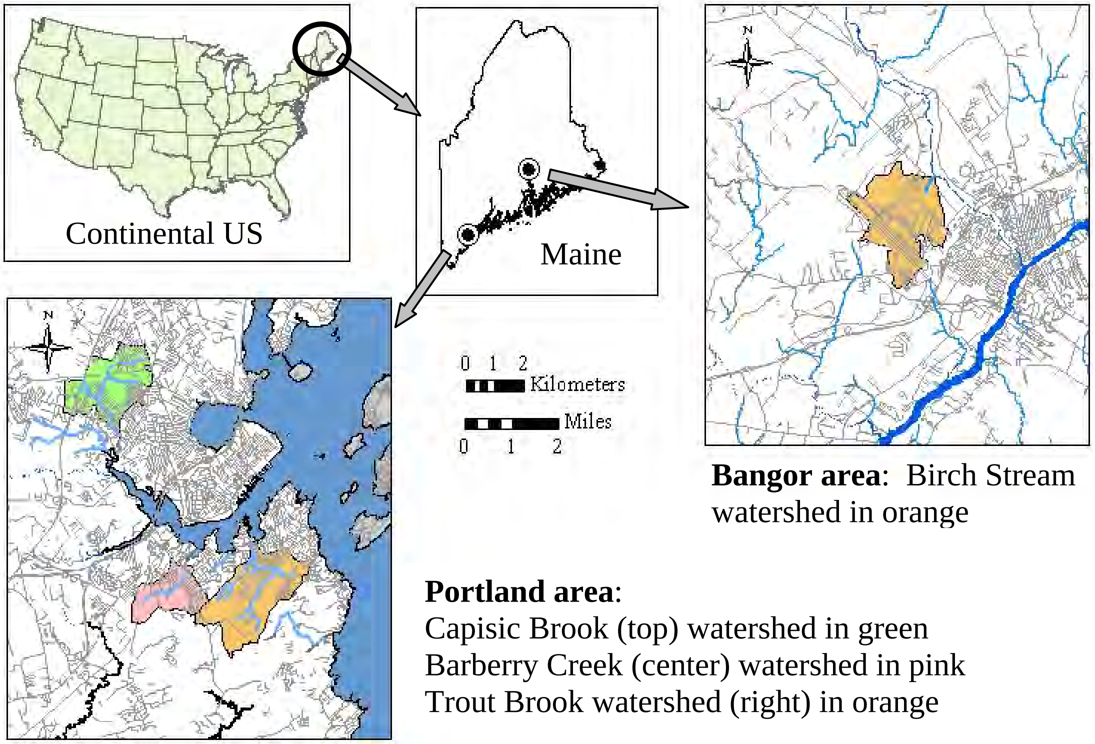
The specific effects of land use activities on a waterbody depend on the types of land uses occurring in a watershed and their extent. Currently, development associated with urbanization is the greatest threat to water quality since it entails the most dramatic changes and is rapidly expanding while other types of land uses tend to be stable or declining. It is also typically an irreversible type of land use change. In terms of the impact on aquatic systems, the most important feature of urbanization is an increase in watershed imperviousness, that is an increase in the amount of impermeable surfaces such as roads, rooftops, and parking lots. Wide-ranging effects of an increase in impervious cover on stream hydrology, morphology, water quality, and biota were first summarized by Schueler (1994), and later documented in a more comprehensive manner by the Center for Watershed Protection (CWP 2003). On a more local scale, a recent USGS publication (Coles et al. 2004) investigated effects of urbanization on New England streams. Briefly, the following effects have been observed. At the most basic level, an increase in imperviousness causes an increase in stormwater runoff, usually in direct proportion to the extent of watershed imperviousness. At the same time, reduced water infiltration into the ground causes lower baseflows, sometimes causing streams to entirely dry up during the dryest part of the year. The combination of increased stormwater runoff and reduced baseflow means that, in contrast to waterbodies in non-urbanized watersheds, waterbodies in urbanized watersheds tend to receive a proportionally greater amount of their flow from surface runoff than from groundwater. Elevated levels of surface runoff cause more frequent and extreme high flow events which can cause severe bank erosion and channel scouring to the extent that the morphology of a stream will change. Typically, a stream will become wider and shallower, and sediment loading from bank erosion and watershed sources increases. In addition to altering stream flow patterns, stormwater runoff can impair water quality as it carries with it elevated concentrations of pollutants, for example toxics like metals or oil from vehicular traffic or gas stations, nutrients from fertilizers, bacteria from pet waste, or sediment from construction sites or roads. Finally, runoff from hot pavements can increase stream water temperature to levels that are unhealthy for biological communities, an effect that can be exacerbated by the absence of shade-providing vegetation in the riparian zone.

The combined effects of land use changes associated with urbanization can severely stress aquatic resources such as fish and macroinvertebrates, leading to predictable changes in the instream biological community. Biological communities thus function as useful indicators of the health of a waterbody, and can be monitored to determine the effects of human influences upon freshwater resources.

MDEP Urban Streams Project

The MDEP Biological Monitoring Program has identified a number of rivers and streams in Maine which are impacted by various types of land use changes. The Clean Water Act requires states to improve the quality of impacted streams by developing Total Maximum Daily Load (TMDL) plans aimed at removing or alleviating stressors that have been identified as causing an impairment. While traditional TMDL plans address pollutants that typically originate from point sources of pollution, pollutants originating from nonpoint sources are more difficult to identify because of the absence of a distinct “polluter” and the multitude of effects on biological communities, water quality and watershed hydrology. To address this problem, the Biological Monitoring Program in early 2003 launched a pilot project to develop TMDLs dealing with NPS pollutants and the impairments they create. Under the Urban Streams NPS Assessments in Maine project, or Urban Streams Project, biological, physical, and chemical data were collected (see Ch. 2 for Methods) in four urban streams, namely Birch Stream in Bangor, Trout Brook in Cape Elizabeth and South Portland, Barberry Creek in South Portland, and Capisic Brook in Portland (Fig. 1; see also Fig. 1 in Ch. 3 - 6). The findings of data collection and analysis efforts are summarized and discussed in Ch. 3 - 6 of this report. Using the data summarized in a preliminary report, a group of biologists and engineers held a series of Stressor Identification (SI) workshops (USEPA 2000) to identify the particular stressors causing the impairments detected in each waterbody. Results from the SI process led to the development of recommendations for Best Management Practices and remedial actions aimed at removing or alleviating the stressors. Information regarding the SI process and the resulting recommendations are presented in the last two sections of each stream chapter as well as in Apps. H and I. The recommendations will form the basis for stream-specific TMDL plans to be developed in 2005. It is anticipated that implementation of the TMDL plans will restore the streams and their biota to functioning systems.

Fig. 1. Maps of Continental US, Maine, and Bangor and Portland study areas



Bangor area: Birch Stream watershed in orange

Portland area:
Capisic Brook (top) watershed in green
Barberry Creek (center) watershed in pink
Trout Brook watershed (right) in orange

Chapter 2: Methods

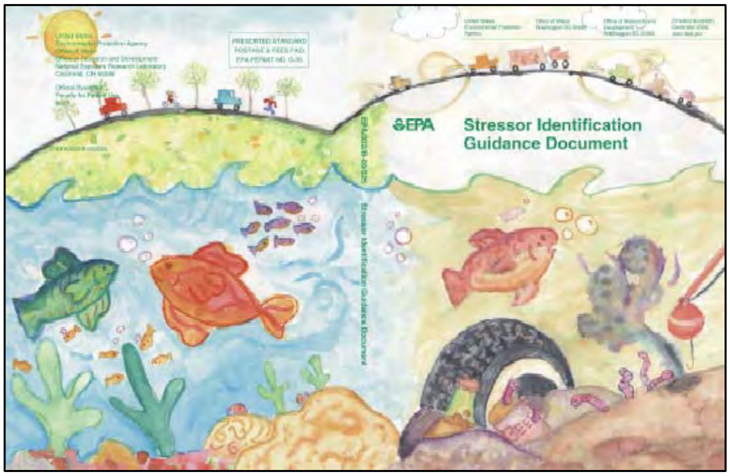
Rock bag before
deployment

Macroinvertebrates in
sieve bucket

Temperature loggers
after retrieval

Stream substrate

Measuring dissolved oxygen



Stressor Identification Document

SAMPLING METHODS

Sampling Stations

Following is a list of the 2003 sampling stations, and how and why these differed from previous years (where applicable). Sampling stations are summarized in Table 1.

Birch Stream (Fig. 1 in Ch. 3): sampling concentrated on the middle station (S312), but some data also were collected at the downstream station (S682). A previously established upstream station below the Airport Mall (S384) had become ponded since the previous sampling event in 2001 due to the construction of a beaver dam (which was removed in the fall of 2003) and was therefore not resampled. Periphyton was sampled in an open area of Birch Stream above the Ohio Street crossing (S691)

Trout Brook (Fig. 1 in Ch. 4): sampling concentrated on the upstream and downstream stations (S675 and S302, respectively). It was decided not to resample the previously established middle station (S454) because of its proximity, and similarity in results, to the downstream station. Instead, a new station was established further upstream in the hope that this might provide more insight into potential stressors. Because the new station (S675) was initially set up in a section of stream that began to dry out in early July, the station was moved ~50 m downstream in mid-July to avoid sampling problems. In the Results section in the chapter on Trout Brook, data from this station are graphed and discussed in terms of "early" and "late" to indicate this change in sampling location. The late station was located below an area where a significant amount of spring water entered the stream, causing a significant change in some sampling parameters. A limited amount of sampling occurred in a wetland area ~400 m above Sawyer Street (W-093).

Barberry Creek (Fig. 1 in Ch. 5): as in previous years, sampling concentrated on one station in the middle part of the watershed (middle station, S387). Algae were sampled in an open area of Barberry Creek ~550 m upstream of the regular sampling station (upstream station, S672); in 1998 and 1999, samples were collected from a wetland station in the lower part of the watershed (downstream station, W-011).

Capisic Brook (Fig. 1 in Ch. 6): as in previous years, sampling was carried out at the upstream and downstream stations (S256 and S257, respectively). A limited amount of sampling occurred in the wetland fringe surrounding Capisic Pond, ~350 m below the downstream monitoring station (W-023).

Table 1. List of 2003 monitoring stations

Stream	Major monitoring			Fish surveys	Algal surveys	Wetland surveys
	Upstream	Middle	Downstream			
Birch Stream		S312	S682[1]	S312, S682	S691	
Trout Brook	S675		S302	S302	S302	W-093
Barberry Creek		S387		S387	S672	
Capisic Brook	S256		S257	S257	S257	W-023

[1] Only a limited amount of data was collected at this station

Biological Monitoring

1. In each stream, the macroinvertebrate community was sampled once during a 4-week period (July through August) at the major monitoring stations listed in Table 1. One exception was the late upstream station in Trout Brook, where macroinvertebrates were sampled somewhat later (August through September) because the first set of bags at this station was vandalized on August 21, and had to be replaced with new bags on August 22. Sampling was performed using the protocol detailed in Davies and Tsomides (2002; App. A i). Briefly, at each station, three replicate rock bags (see cover page) were deployed in the stream for ~28 days in riffle/runs. At the end of the colonization period, the bags were retrieved and the contents washed into a sieve bucket. These contents were transferred into labeled mason jars, and preserved with 95 % ethyl alcohol to yield an ~70 % alcohol-water solution. Samples were sorted at the MDEP laboratory, and identified by a macroinvertebrate taxonomist (Freshwater Benthic Services, Petosky, MI; or Lotic, Inc., Unity, ME). Biological data were analyzed using a statistical model which assigns samples to State of Maine water quality classes (see Ch. 1, Maine's Rivers and Streams), or to a Non-Attainment (NA) category.

2. Fish assemblages were investigated at the stations listed in Table 1 by staff of the MDEP Rivers section by electrofishing a 100 m long stretch, recording data on species composition and fish length. Details about the survey technique and equipment is given in App. A ii. Fish diversity in Maine rivers and streams is generally fairly low compared to many other parts of the country, but a healthy stream the size of the urban streams studied here could be expected to have around six to seven different species, including American eels, brook trout, sticklebacks, blacknose dace, golden shiner, white sucker, and creek chub.

3. Algal assemblages were sampled at the stations listed in Table 1 by staff of the MDEP Biomonitoring section on July 9 (Portland area streams) and July 28 (Bangor), 2003 using the methods described in App. A iii. For this assessment, algal samples were collected by brushing a defined area (1" circle) on a number of rocks, and collecting the resulting material in a sampling tray. These samples are currently being analyzed by a professional taxonomist (Dr. J. Stevensen, University of Michigan). Like macroinvertebrates, algal communities also respond to disturbances or stressors by changing species composition and abundance, and can hence provide additional information on the health of the entire system.

4. Wetlands associated with the study streams were sampled on Trout Brook and Capisic Brook at the stations listed in Table 1 by staff of the MDEP Biomonitoring section on June 12, 2003 using the methods described in App. A iii and iv. For this assessment, three different types of samples were collected: 1) dip net sweeps, for analysis of benthic macroinvertebrates; 2) plant clippings, for analysis of epiphytic algae; and 3) water grab samples, for analysis of water column phytoplankton. Macroinvertebrate samples were identified by professional freshwater macroinvertebrate taxonomists (Lotic Inc., Unity, Maine), and data were analyzed using statistical tests and best professional judgment. Algal samples are currently being analyzed by a professional algal taxonomist (Dr. J.

Stevensen, University of Michigan). Like river and stream data on macroinvertebrates and algae, wetland data also can be used to assess system health.

Water Quality Monitoring

1. Standard water quality parameters (instantaneous dissolved oxygen, specific conductance, temperature and pH) were monitored at most of the major monitoring stations (Table 1) seven to eleven times during the period May through October using electronic field meters as detailed in App. A v. Exceptions were stations S682 on Birch Stream, where only two measurements were collected for these parameters, and S675 on Trout Brook where the first four measurements were collected at the early upstream station, leaving four to six measurements to be collected from the late upstream station. Measurements were usually taken between 10 a.m. and 5 p.m. with a few data collected as early as 8 a.m. or as late as 6 p.m. One single data point exists for these parameters for the wetland stations on Trout Brook and Capisic Brook from the sampling event on June 12. Dissolved oxygen (DO) concentrations are important for all aquatic fish and invertebrates as oxygen is required for respiration. Generally speaking, a concentration of 7 mg/L or above is considered favorable for healthy animal communities. Specific conductance, also called conductivity or SPC, is a measure of the ability of water to conduct an electrical current, which is related to the concentration of ions in the water. As many of these ions originate from human sources (e.g., fertilizers, road salts, metals abrading from car breaks and tires), conductivity can be used as a quick indicator of water pollution. In streams experiencing minimal human disturbance, conductivity is typically below 75 μS/cm while urban streams in Maine have been found to have conductivity levels anywhere from 300 to 2,500 μS/cm (MDEP Biological Monitoring Program, unpublished data). Results of quality assurance/quality control (QA/QC) procedures performed for water quality parameters are shown in App. F i.

   A DO profile was established above the late upstream station on Trout Brook on August 3, 2004. Measurements were taken at 2-m intervals starting at a small cobble dam immediately above the monitoring site, and proceeding upstream for up to 40 m. Temperature, DO, and SPC were measured at each point, usually in mid-water (water depth was ~20 cm), except where groundwater input was detected; in that case, measurements were generally taken at the bottom and surface. For the first 20 m, measurements were taken in the middle of the channel; further upstream, the channel was divided, and measurements were taken in the left or right channel (looking downstream) with the left channel showing a greater influence of spring water input.

2. Diurnal dissolved oxygen (DO) concentrations were measured five to six times between early July and late September at most of the major monitoring stations listed in Table 1 using electronic field meters as detailed in App. A v. No measurements were taken at the downstream station on Birch Stream. On Trout Brook, one measurement was taken at the early upstream station, and five at the late upstream station. Morning measurements were taken between 7:05 and 8:55 a.m., and afternoon measurements between 2:30 and 4:50 p.m. (one measurement at 5:40 p.m. at upstream station on Capisic Brook). The diurnal range of DO concentrations can indicate whether problems may exist with excessive algal

growth that can lead to high DO concentrations during the day, and low concentrations at night. Generally speaking, a diurnal range of >2 mg/L DO, with low values in the morning and high values in the afternoon, is considered an indication of excess algal growth. Results of QA/QC procedures performed for diurnal DO measurements are shown in App. F i.

3. Continuous data of dissolved oxygen (DO), temperature, conductivity, and turbidity were collected at 10 min intervals at the middle station on Birch Stream (from August 13 to 18; 6 days), at the downstream stations on Trout Brook (from July 24 to August 4, 12 days) and Capisic Brook (from July 8 to 15, 8 days), and at the single station on Barberry Creek (from July 9 to 21; 13 days). In 2004, continuous conductivity data were collected at and below the downstream station on Trout Brook from June 30 to July 7 (20 min intervals) to investigate the possibility of saltwater intrusions. Data were collected using a YSI data sonde as explained in App. A vi. Continuous monitoring of DO provides information on the minimum and maximum concentrations that occur in a stream, i.e., the diurnal range, and when they occur. Turbidity indicates the amount of solids suspended in the water, which is important as high concentrations of particulate matter can cause increased sedimentation in a stream and provide attachment sites for pollutants. In general, continuous monitoring of any parameter provides a much more comprehensive picture than individual measurements taken at certain intervals.

4. Temperature was monitored continuously (measurements taken every 30 min) for 78 to 93 days from June 26 (Bangor) or July 2/3/8/9 (Portland area) through September 26 (Bangor) or 24 (Portland area) at all major monitoring stations listed in Table 1 using Optic Stowaway temperature loggers. At the upstream station on Trout Brook, the logger was moved from the early to the late location on July 14. Detailed information on the loggers and their use can be found in App. A vii. Summer temperature is an important instream parameter as many coldwater organisms can be severely stressed above 21° C.

5. During baseflow conditions, water chemistry parameters were sampled as shown in Table 2. During stormflow conditions, two samples were collected at the middle station on Birch Stream [August 12 (SSD only), and November 20] as well as at both stations on Trout Brook, at the middle station on Barberry Creek, and at the downstream station on Capisic Brook (May 27 and November 21, 2003). These samples were analyzed for metals and ions (Ag, Al, As, Ca, Cd, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, Pb, Zn), Total Phosphorus (TP), and Total Suspended Solids (SSD). Stormflow samples for TP only were also collected on February 24 and 26, 2004 at the downstream station on Trout Brook, at the middle station on Barberry Creek, and at both stations on Capisic Brook. Samples were collected by different projects/MDEP sections as follows:
   - Urban Streams NPS TMDL Project: 7/15 and 16, 8/11 and 13, 9/9 and 10, 2003
   - MDEP Biomonitoring Section: 6/12 (wetland sampling), 7/9 and 7/28 (algae sampling), 8/25 and 27, 2003 (macroinvertebrate sampling)
   - MDEP Rivers TMDL Section: 5/27, 8/12, and 11/20 and 21, 2003; 2/24 and 26, 2004

   Detailed information on the sampling and analysis protocols for these parameters can be found in App. A viii and x- xxviii. The chain-of-custody form required by the analytical laboratory (State of Maine Health and Environmental Testing Laboratory, HETL) was completed upon sample delivery to the laboratory. Water chemistry parameters generally indicate the degree of pollution of a waterbody due to human activities. The following list provides information on the origins and significance of the parameters monitored:

- Nutrient levels reveal the enrichment status of a stream. Nitrogen and phosphorus, in their various forms, can originate from farms, lawns, wastewater treatment plants, or animal waste. Abundant nutrients can lead to increased algal growth which in turn can cause oxygen depletion, and may increase the abundance of macroinvertebrate grazers and filterers.
- DOC and TOC provide a measure of the organic loading of a stream; TOC and DOC originate from both natural (decay of leaves or other organic matter) and anthropogenic sources (combustion by-products). They may enter a stream in the form of leaf litter, rainwater, stormwater runoff, or wastewater. High DOC/TOC levels can increase the growth of microorganisms, and thus may cause oxygen depletion (i.e., increased BOD or COD).
- Chlorophyll *a* measures the concentration of living or dead phytoplankton in a waterbody, and is considered a response variable for nutrient concentration by USEPA (2000b).
- SSD in a stream consist largely of inorganic materials (silt, clay, etc.) with some organic materials (algae, detritus, bacteria, etc.) mixed in. This parameter can increase where erosion is a problem in or near a stream, or where sediments enter a stream from construction sites or as a result of road sanding. Suspended solids can smother organisms or reduce their feeding efficiency, clog fish gills, and reduce habitat quality and complexity through siltation. An indirect effect of sedimentation is the transport of metals and nutrients into the stream.
- TDS is the portion of SSD that passes through a filter, and consists of, for example, phosphate, (bi)carbonate, chloride, sulfate, calcium, or other ions. These components can originate from soils, urban runoff, fertilizers, or wastewater. Total dissolved solid concentration is important as water density affects osmotic processes in organisms.
- Bacteria are not generally of concern for aquatic organisms; however, they are a problem for classification attainment purposes if they are of human origin, and if a waterbody is classified as suitable for recreation in and on the water (as all four Urban Streams are). In this study samples were analyzed simply for the presence of bacteria with no regard for their origin. Potential origins other than humans include wildlife (e.g., deer), birds (e.g., ducks) or pets, all of which have been observed on or around the four streams.
- Metals (Cd, Cu, Pb, Zn, etc.) and chloride in a waterbody often are human in origin, and may come from point (industry) or non-point (road and parking lot dirt) sources as well as from sand used to deice roads in the winter and spring. A further source of chloride is seawater which can affect coastal streams during high tides. Many of these compounds can be toxic to aquatic organisms above certain levels, either immediately or after bioaccumulation has occurred.
- DROs are carbonaceous compounds that may be natural in origin (e.g., pentanoic acid, ethyl butenal) or man-made (e.g., fuel-type hydrocarbons including toluene, xylene, or C17-24 hydrocarbons). Owing to the non-specificity of the DRO

method, it may be difficult to determine the origin of DRO compounds.

- Alkalinity measures the buffering capacity of water, i.e., the ability of water to prevent pH changes due to acid inputs. This parameter is usually very low in Maine because of local geology but may be increased where sewage or livestock waste enter a stream. In terms of biological responses, alkalinity may influence the type of algae occurring in a stream. This parameter also can influence aluminum load in a stream as it determines whether this metal leaches out of soil.
- Dissolved silica in natural waters largely results from the chemical breakdown of silicate minerals during weathering. Diatoms extract and use silica in their shells and skeletons, and this mineral can be limiting for their growth. Diatoms are often the dominant group of benthic algae in terms of species number and biomass in stream, and are an important food source for macroinvertebrate grazers.

Results of quality assurance/quality control (QA/QC) procedures performed for water chemistry parameters are shown in App. F ii - iv.

Table 2. Baseflow sampling schedule (parameters, stations, dates in 2003)

Parameters	**Birch Stream**		**Trout Brook**			**Barberry Creek**	**Capisic Brook**		
	Middle (S312)	**Downstream (S682)**	**Late upstream (S675)**	**Downstream (S302)**	**Wetland (W-093)**	**Downstream (S387)**	**Upstream (S256)**	**Downstream (S257)**	**Wetland (W-023)**
Nutrients									
TKN, NO_3-NO_2-N[1]	7/16, 8/13, 8/27, 9/10	8/27	8/11	7/15, 8/11, 8/25, 9/9	6/12	7/15, 8/11, 8/25, 9/9	8/11, 8/25	7/15, 8/11, 8/25, 9/9	6/12
NH_3-N[1]	8/27			8/25	6/12	8/25	8/25		6/12
Ortho-Phosphate	7/16, 8/13, 9/10		8/11	7/15, 8/11, 9/9	6/12	7/15, 8/11, 9/9	8/11	7/15, 8/11, 9/9	6/12
Total Phosphorus	7/16, 8/13, 8/27, 9/10	8/27	8/11	7/15, 8/11, 8/25, 9/9	6/12	7/15, 8/11, 8/25, 9/9	8/11, 8/25	7/15, 8/11, 8/25, 9/9	6/12
SRP[1]					6/12				6/12
Dissolved organic carbon	8/13, 8/27	8/27	8/11	8/11, 8/25	6/12	8/11, 8/25	8/11, 8/25	8/11, 8/25	6/12
Total organic carbon	8/13		8/11			8/11	8/11		
Chlorophyll *a*	7/16,8/13, 9/10		8/11	7/15, 8/11, 9/9	6/12	7/15, 8/11, 9/9	8/11	7/15, 8/11, 9/9	6/12
Total suspended solids	7/16, 8/13, 8/27, 9/10	8/27	8/11	7/15, 8/11, 8/25, 9/9		7/15, 8/11, 8/25, 9/9	8/11, 8/25	7/15, 8/11, 8/25, 9/9	
Total dissolved solids	8/27			8/25		8/25	8/25		
Bacteria (*E. coli*)	7/16, 8/13, 9/10	8/13, 9/10	7/15, 8/11, 9/9	7/15, 8/11, 9/9		7/15, 8/11, 9/9	7/15, 8/11, 9/9	7/15, 8/11, 9/9	
Metals									
Cd, Cu, Fe, Pb, Zn	7/16, 8/13, 9/10		8/11	7/15, 8/11, 9/9		7/15, 8/11, 9/9	8/11	7/15, 8/11, 9/9	
Cr, Ni	8/13		8/11			8/11	8/11		
Cl, DRO[1]	8/13		8/11			8/11	8/11		
Alkalinity, Silica	7/28 (S691)			7/9		7/9 (S672)		7/9	
Ca, Mg, K, Na, Cl, Conductivity, Alkalinity, Color, Hardness					6/12				6/12

[1] TKN, Total Kjeldahl N; NO_3-NO_2-N, Nitrate-Nitrite-N; NH_3-N, Ammonia-N; SRP, Soluble Reactive Phosphate; DRO, Diesel Range Organics.

Habitat Assessments

1. Mean flow velocity across the stream was measured at all major monitoring stations listed in Table 1 (except for the lower station on Birch Stream) seven to eight times using a Global flow meter as detailed in App. A ix. On a few occasions, a flow meter was unavailable. In these instances, velocity was estimated by timing an object floating downstream on the water's surface for a measured distance. This was done three times, and the average velocity was calculated. To account for the difference in flow velocity between the surface and mid-depth, surface estimates were multiplied by 0.8 for rocky-bottom streams, or 0.9 for muddy-bottom streams (USEPA 1997).

   The variability of the flow regime in the thalweg of the stream channel (the deepest, fastest-flowing part) was studied at the same stations by measuring water velocity every 2 m along a 100-m long stretch of stream once in early September using a Global flow meter. The exact locations of the 100-m long stretches with respect to the rock bag locations are noted in the Results. A variable flow velocity regime is an important factor in habitat quality as it provides a wide range of environments for fish and invertebrates to occupy.

2. Stream width (wetted) and depth were measured at all major monitoring stations listed in Table 1 (except for the lower station on Birch Stream) eight to ten times between May and October. Width was measured by running a tape-measure across the stream channel perpendicular to stream flow. Average stream width was calculated from five measurements taken 5 m apart along the stream (middle, no. 3, width measured at middle rock bag location). Wetted rather than bankfull width was measured to allow tracking of stream width as accessible to aquatic life.

   Stream depth was measured with a meter stick at three locations across the channel along the middle (no. 3) stream width transect: at ¼, ½, and ¾ the stream width. The average depth was derived by dividing the total of the three measurements by 4 (to account for the zero depth on the side of the channel) (Platts et al. 1983).

3. The abundance and size structure of large woody debris (LWD, mean diameter >5 cm) was evaluated by measuring the mean diameter and length of all pieces of woody debris (branches, tree trunks, lumber) found inside the channel at all major monitoring stations listed in Table 1 (except for the lower station on Birch Stream); this was done once in early September. For each piece of LWD, the percent of the stream channel it spanned was estimated. From these data, absolute LWD mass (diameter * length) and relative mass within the channel (absolute LWD mass * % spanning channel) were calculated. At the same time, the number of pieces of small woody debris (2 - 5 cm diameter, length >100 cm) also was counted. Woody debris, especially LWD, is important as it provides stable attachment sites for macroinvertebrates, provides and traps organic material for consumption by microbes and macroinvertebrates, allows the formation of pools for fish, and traps sediment.

4. A physical characterization and habitat assessment (low gradient) was carried out at all major monitoring stations listed in Table 1 in the summer using field data sheets included

in USEPA 1999. These assessments cover parameters such as the appearance and smell of stream water and sediment, the composition of inorganic and organic substrate components, degree of embeddedness, the velocity/depth regime, width and quality of the riparian vegetative zone, etc. At the wetland stations on Trout Brook and Capisic Brook, a "Human Disturbance Ranking Form" was completed which assesses hydrologic or vegetative modifications to the wetland, evidence of chemical pollutants, impervious surfaces in the watershed, and the potential for NPS pollution. All of these assessments are qualitative in nature and provide a rapid assessment of the physical conditions in and along a stream or wetland reach and, to a limited extent, the watershed.

5. A professional fluvial geomorphologist investigated all four streams in the summer and fall of 2003 using a variety of field and computer analyses to determine the degree to which the natural shape of the stream has been altered. Analyses included historical changes in channel structure or location, and changes in landuse patterns, entrenchment ratios, bank stability, and buffer width. As mentioned in the introduction, urbanization can affect stream morphology in a variety of ways (e.g., higher storm flows can lead to bank erosion, riparian buffers may be eliminated, channel sinuosity may be reduced, and channel width may be altered) with resulting impacts on stream biota.

6. Data on spills of hazardous materials that occurred between 1978 and 2003 in the four watershed were taken from the Spill Report Master List (MDEP 2004a), and from paper records held in the Bureau of Remediation and Waste Management (BRWM) file room. Spill locations for which spatial information was available electronically were included in a GIS map. Spills were analyzed for their potential effect on stream biota based on available information.

   The location of combined sewer overflows (CSOs) located in the study watersheds was mapped using MDEP datalayers. CSO output (in millions of gallons, 1999/2000-2003) was obtained from MDEP staff (J. True).

STRESSOR IDENTIFICATION PROCESS

On May 17, 26 and 28, and June 3, 2004, a group of biologists and engineers from the MDEP held full-day workshops to apply the EPA Stressor Identification (SI) process (USEPA 2000a) to Capisic Brook (downstream station only), Trout Brook, Barberry Creek and Birch Stream. In preparation for each workshop, data presented in the respective chapter of this report (Ch. 3 – 6) were collated in a variety of formats:

- Site summaries were compiled for each impaired station containing a physical site description and a brief discussion of the dominant macroinvertebrate taxa collected in 2003. Summaries concluded with a table ranking the potential that certain candidate causes (e.g., low DO, sedimentation, toxicants) were responsible for the observed biological impairment (No, Maybe, Likely, or Probably); assessments were based on macroinvertebrate and abiotic data (App. D i).
- Macroinvertebrate community data (five dominant taxa) from all previous sampling events at all stations (excluding wetlands) on each stream were complemented with

basic biological and life history information, and interpreted to determine whether the community provided any indication of potential stressors ("candidate causes" of impairment) such as low DO or sedimentation (App. D ii).

- Spatial co-location tables were compiled to illustrate whether a number of factors (e.g., daytime DO, diurnal DO, continuous DO; instantaneous temperature, mean/maximum weekly temperature; etc.), grouped by candidate cause, were considered a problem at each impaired station as compared with two reference sites (for Capisic Brook, Trout Brook and Barberry Creek: upstream station on Capisic Brook in Portland, S256, and upstream section in Red Brook in South Portland; for Birch Stream: upstream station on Capisic Brook in Portland, S256, and Crooked Brook in Garland, S509) (App. D iii).
- Basic stream quality (DO, conductivity, temperature) and water chemistry data (baseflow and stormflow) from all four Urban Streams were graphed and tabulated together to allow easy comparison of data across streams (App. C i - iv).
- Eight conceptual models for standard candidate causes (Low Dissolved Oxygen, Increased Summer Temperature, Nutrients, Increased SPC, Increased Toxicants, Altered Hydrology, Habitat: Insufficient Large Woody Debris and Channelization, Increased Sediment Loading) were filled in to reflect the absence/presence of Sources of potential stressors, relevant Causal Pathways, and generalized Biological Impairments at each impaired station (App. D iv; USEPA 2000, Lane 2004).

During each workshop, a short presentation reviewing stream characteristics was followed by: analysis of available data using the materials listed above; determination of candidate causes (stressors), which included the elimination of causes that were deemed to be minor stressors; and completion of the Strength of Evidence (SoE) table. During the first workshop, it was decided to adapt the SoE table as developed by EPA (USEPA 2000) to the cases at hand. This adaptation involved the elimination of certain considerations and addition of others, with the goal of facilitating efficient completion of the tables given the predominantly non-point source nature of the stressors on the Urban Streams. Furthermore, a final section ranking stressors (H, High; M, Medium; L, Low; 0, No importance) based on all considerations was added to provide a quick summary result of the SI process. A blank sample of the modified SoE table, with the modifications indicated, is shown in App. D v, completed SoE tables for the four streams in App. D vi. The SoE tables were completed by assessing a number of considerations to determine whether they did (1 - 3 "+") or did not (1 - 3 "-") suggest that a particular stressor played a role in causing an observed biological impairment. In addition to "+" and "-", a "0" or "NE" (no evidence) could be assigned if available data were ambiguous, their interpretation uncertain, their significance unknown, or if there were insufficient data to make a clear call. An assessment of the utility of the SI process to the Urban Streams Project or stream assessment in general is presented in App. H.

Following the SI process, the stressors identified for each impaired station plus the sources specified in the conceptual models were listed in the SI section of each stream chapter. Based on the stressors and their sources, a suite of relevant structural and non-structural Best Management Practices (BMPs) and remedial actions aimed at alleviating or removing individual stressors were presented in the final section of each stream chapter. A summary of BMPs is shown in App. I.

Chapter 4: Trout Brook in Cape Elizabeth and South Portland

Headwaters
(October 2003)

Wetland Station (W-093)
(June 2003)

Late Upstream Station (S675)
(September 2003)

Downstream Station (S302)
(June 2003)

TABLE OF CONTENTS

REPORT

FIGURES

TABLES

APPENDICES

See Table of Contents at Beginning of Report for List of Appendices.

STREAM DESCRIPTION

Trout Brook, one of the four Urban Streams[1] in the Urban Streams Project, is located in Cape Elizabeth and South Portland in southern Maine (Fig. 1 in Ch. 1), and is of moderate length (~2.5 miles) and watershed size (~1,700 acres, Fig. 1). The stream originates in a woodland west of Spurwink Avenue near Valley Road; from there Trout Brook flows northward through a vegetable farm, a former wetland (where a number of drainage ditches flow into the stream), and a dense residential area before flowing into Mill Cove, the estuarine Fore River, Portland Harbor and Casco Bay. There are three tributaries to Trout Brook: the most upstream one enters the stream near the headwaters, the middle one enters it just upstream of Mayberry Street, and the most downstream one, Kimball Brook, enters Trout Brook immediately below the Highland Avenue culvert. The outline of the watershed as shown in Fig. 1 is based on information received from the City of South Portland (P. Cloutier, pers. comm.[2]), on 10 m contour lines, and actual stormwater drainage systems. In terms of water quality requirements, the Maine legislature designated the Cape Elizabeth section of Trout Brook (headwaters to dense residential area including upstream tributary) as statutory Class B, while the South Portland section (dense residential area to Mill Cove, middle tributary and Kimball Brook) is designated as Class C (see Ch. 1, Introduction).

The Maine Department of Environmental Protection (MDEP) Biological Monitoring Program has been studying four stations on Trout Brook since 1997 (Fig. 1). The downstream station just above the Highland Avenue road crossing, S302, and the middle station, S454, at the end of Mayberry Street (only studied in 2000), are both located in the lower third of the watershed (Fig. 1). The newly (2003) established upstream station, S675, ~100 m above Boothby Avenue, is located in the lower half of the watershed. The wetland station, W-093, ~400 m above Sawyer Street, is located approximately in the middle of the watershed. All stations receive runoff from the surrounding, largely residential area. They also experience effects of the upstream wetland area and the vegetable farm in the upper part of the watershed. All stations are furthermore influenced by a significant input of spring water just above the upstream station. During baseflow conditions in the summer of 2003, the upstream and downstream stations had a wetted width of 2.3 – 3.5 m, and a water depth of 4 – 8 cm with a flow velocity of 10 – 16 cm/s. Channel width at the two stations was 7.0 and 2.5 m, respectively, reflecting an overwidened channel structure at the upstream station. During summer baseflow conditions in 2000, the middle station had a wetted and channel width of ~2 m, and a water depth of ~15 cm with a flow velocity of 12 cm/s. The substrate at the upstream and downstream stations was dominated by rubble (40-45 %) with some gravel (20-25 %), sand (20-35), and some boulders (5-10 %) while the middle station was dominated by gravel (50 %) with some rubble (30 %) and sand (20 %). Trout Brook's surficial geology type is the "Presumpscot formation" which in this watershed is characterized by silts and clay with some sand; this suggests that any fine sediment observed in the stream is partly natural in origin. The riparian zone near the upstream station consists of trees and understory plants and is fairly undisturbed (width >10 m). Near the middle and downstream stations, some of the riparian buffer has been replaced with lawns and invasive plants such as Japanese Knotweed (*Polygonum cuspidatum*).

---

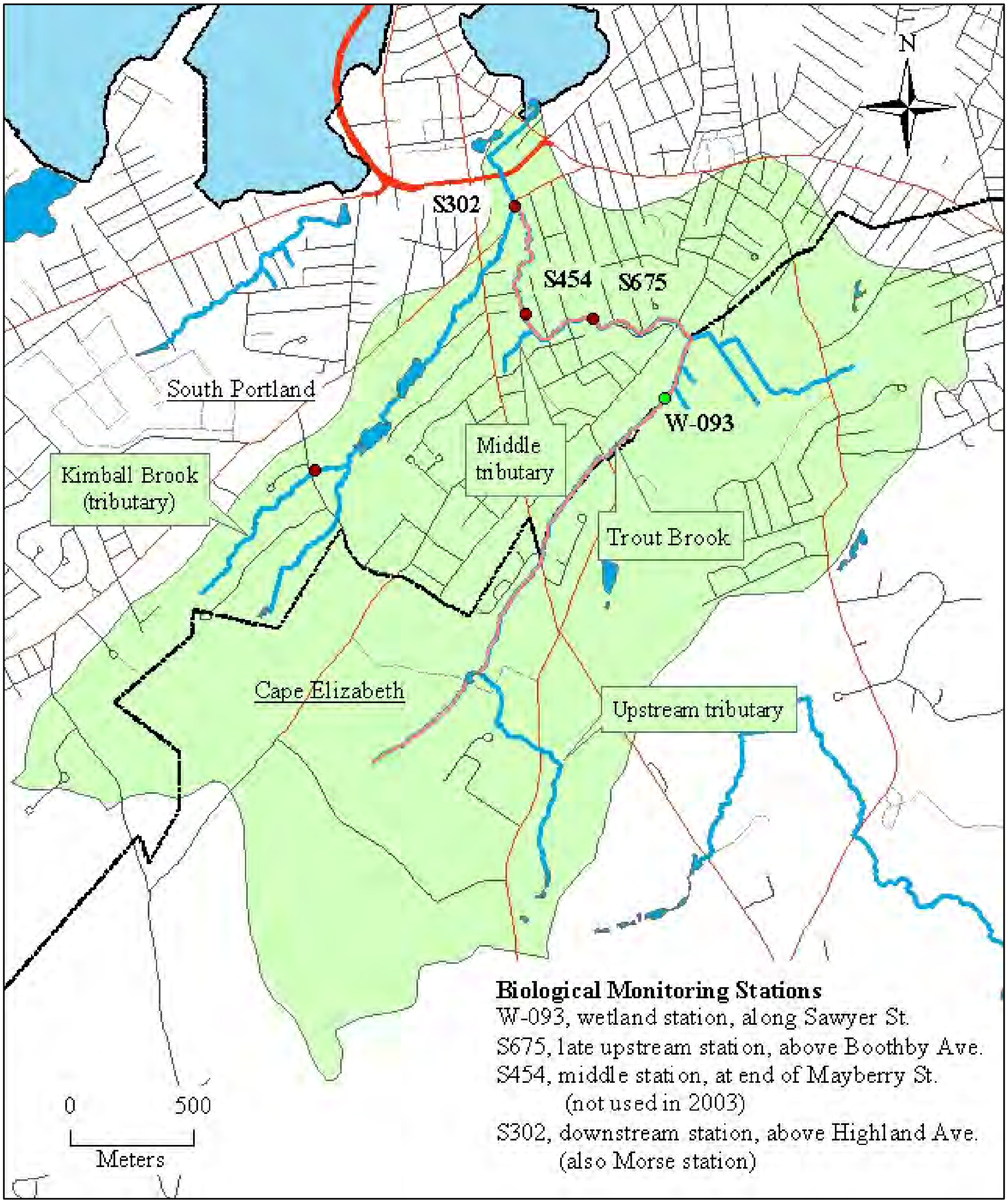
[1] Note that "Urban Streams" refers to the four streams included in this study, not to the universe of "urban streams" in Maine or elsewhere.

[2] Information on persons providing personal communications is given in the References

Most of the watershed is impacted by development (i.e., low/high intensity residential and dense residential development: 53 %; urban/industrial and commercial-industrial-transportation development: 7 %), resulting in a moderate percentage of the watershed being covered by impervious surfaces (13 %; calculated using the method shown in MDEP 2001b). Other landuse types are forests (26 %), grassland/crops/shrub-scrub (8 %),and wetlands (5 %). As a result of the elevated imperviousness, most of Trout Brook is affected by a variety of urban stressors typically associated with residential development and an extensive road system. Data collected by the MDEP Biological Monitoring Program in 1997 and 2000 at one station (S302), and in 2000 at a second station located further upstream (S454; Fig. 1), indicated that both stations had a degraded macroinvertebrate community that violated the Class C aquatic life criteria. In 1999, the downstream met Class C criteria. In addition, Morse (2001; see Previous studies, below) found habitat degradation and impaired macroinvertebrate communities in Trout Brook. Because of the aquatic life violations found in 1997 and 2000, the stream is scheduled for Total Maximum Daily Load (TMDL; see Ch. 1, Introduction, MDEP Urban Streams Project) development based on the data gathered in the Urban Streams Project.

This report presents the data available as of December 2004, and puts them into the context of overall stream health. Information contained in this report will form the basis for the development of a stream-specific Total Maximum Daily Load (TMDL; see Ch. 1, Introduction, MDEP Urban Streams Project) plan in 2005. The MDEP Biological Monitoring Program again monitored the macroinvertebrate community at the downstream and late upstream stations in Trout Brook in the summer of 2004; further sampling events may occur in future years depending on developments in the watershed, funding availability, and program needs.

Fig. 1. Trout Brook, Cape Elizabeth and South Portland. Watershed is shown in green, impaired segment in pink, town line in black.



PREVIOUS STUDIES

MDEP Biological Monitoring Program

The Biological Monitoring Program of the MDEP's Bureau of Land and Water Quality (BLWQ) collected macroinvertebrate data in the summers of 1997, 1999, and 2000 at the downstream station (S302), and in 2000 at the middle station (S454, Fig. 1). Sample collection and processing methods are detailed in App. A i, and briefly described in Ch. 2, Methods, Biological Monitoring, item 1. Macroinvertebrate samples were identified by either Lotic, Inc (Unity, ME; 1997, 2000) or Freshwater Benthic Services (Petosky, MI; 1999). The MDEP analyzed taxonomic data using a statistical model which assigned samples to one of three State of Maine water quality classes (A[1], B, or C) or to a Non-Attainment category. Analysis results were reported in the MDEP's Surface Water Ambient Toxics (SWAT) Monitoring Program technical reports (MDEP 2000, 2001a, 2002a).

Model results indicated that in 1997 and 2000, macroinvertebrates at the downstream station did not meet Class C aquatic life criteria with the dominant organisms consisting of tolerant crustaceans (predominantly amphipods, few isopods) and few chironomids (midge larvae; Table 1). In 1999, macroinvertebrates met Class C aquatic life criteria as amphipods made up a smaller proportion of the sample and some Ephemeroptera (mayflies) were found. In all years, an intermediate number of organisms was present (486 – 628, Table 1). A good general indicator of the quality of a macroinvertebrate community is the percentage of non-insects in a sample, as this increases with decreasing water quality. The percentage of non-insects at the downstream station was very high in all sampling years, namely 94, 76 and 98 % in 1997, 1999, and 2000, respectively. Water quality data collected at this station indicated adequate dissolved oxygen concentrations (7.1, 8.7, and 9.2 mg/L), high conductivity levels (792, 832 and 695 μS/cm), and low water temperatures (13.0, 15.0, and 14.6 ºC). Continuous water temperature data collected August 13 to September 8, 1997 (measurements taken every 5 min), and August 1 to 30, 2000 (measurements taken every 15 min) showed that daily mean temperatures were low, i.e., favorable for healthy macroinvertebrate communities. Daily maximum temperatures were slightly higher but still below 20 ºC (Figs. 2 and 3). Water chemistry sampling in 2000 (Table 2) showed that Total Nitrogen was the only parameter to exceed available Water Quality Criteria.

For the middle station, model results indicated that macroinvertebrates did not meet Class C aquatic life criteria in the single sampling year (2000) with the dominant organisms consisting of tolerant crustaceans (amphipods) and a few worms (oligochaetes) (Table 1). The number of organisms found was intermediate (387) while the percentage of non-insects was very high (82 %). No dissolved oxygen data are available, but the conductivity level was high (693 μS/cm) and water temperature low (14.4 ºC). Continuous water temperature data collected August 1 to 30, 2000 (measurements taken every 15 min) were very similar to those recorded at the downstream station (Fig. 3). No water chemistry parameters were sampled at this station.

---

[1] For the purposes of the statistical model, State of Maine water quality classes AA and A are combined.

Table 1. Summary version of 1997, 1999, and 2000 macroinvertebrate model reports

Model variable	**Downstream (S302)**			**Middle (S454)**
	1997	**1999**	**2000**	**2000**
Total abundance of individuals	628	487	603	387
Generic richness	14	31	8	33
Plecoptera / Ephemeroptera abundance	0 / 0	1.3 / 14.7	0 / 0	0 / 0
Shannon-Wiener diversity index	0.63	2.03	0.23	2.52
Hilsenhoff biotic index	4.07	4.22	4.03	4.24
Relative abundance Chironomidae	0.03	0.07	0.01	0.11
EPT[1] generic richness	5	12	2	6
EP[1] generic richness/14	0	0.36	0	0
Presence of Class A indicator taxa/7	0.14	0.43	0	0.14
Five dominant taxa (%)	*Gammarus* (92) *Tvetenia* (3) *Caecidotea* (2) *Diplectrona* (2) *Hydropsyche* (1)	*Gammarus* (70) *Hydropsyche* (9) *Caecidotea* (4) *Cricotopus* (2) *Rheotanytarsus* (1)	*Gammarus* (97) *Caecidotea* (1) *Tanytarsus* (1) *Rhyacophila* (<1) *Hydatophylax* (<1)	*Gammarus* (51) *Tubifex* (20) *Limnodrilus* (9) *Tvetenia* (4) *Simulium* (3)
Model outcome (%)	NA (100)	Class C (BPJ[2])	NA (100)	NA (100)

[1] EPT are Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). EP are Ephemeroptera and Plecoptera.

[2] BPJ, Best Professional Judgment indicates that the model outcome was adjusted (in this case from a "B" to a "C") based on data interpretation by a professional MDEP biologist.

Fig. 2. Continuous water temperature at downstream station in 1997

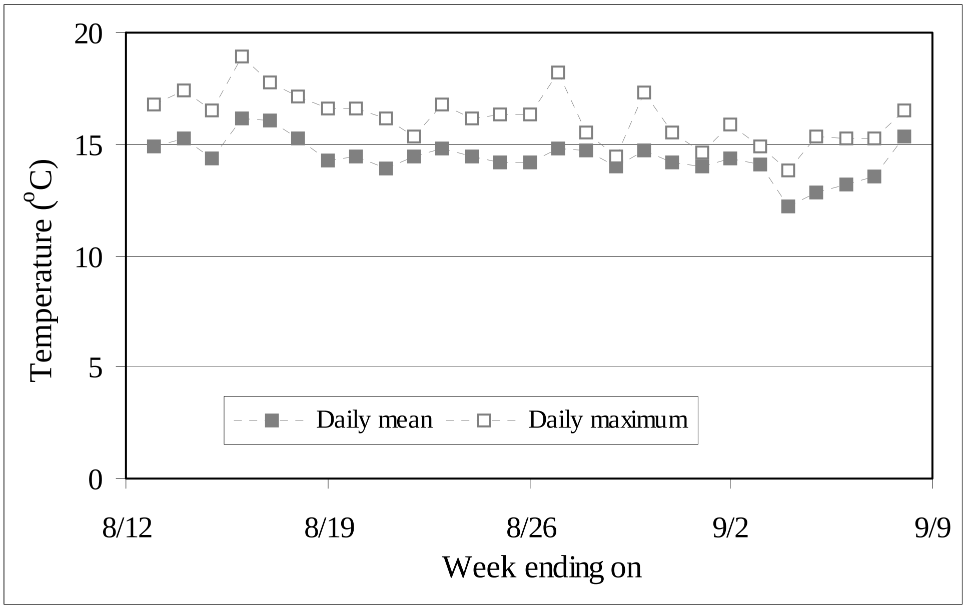


Fig. 3. Continuous water temperature at downstream and middle stations in 2000

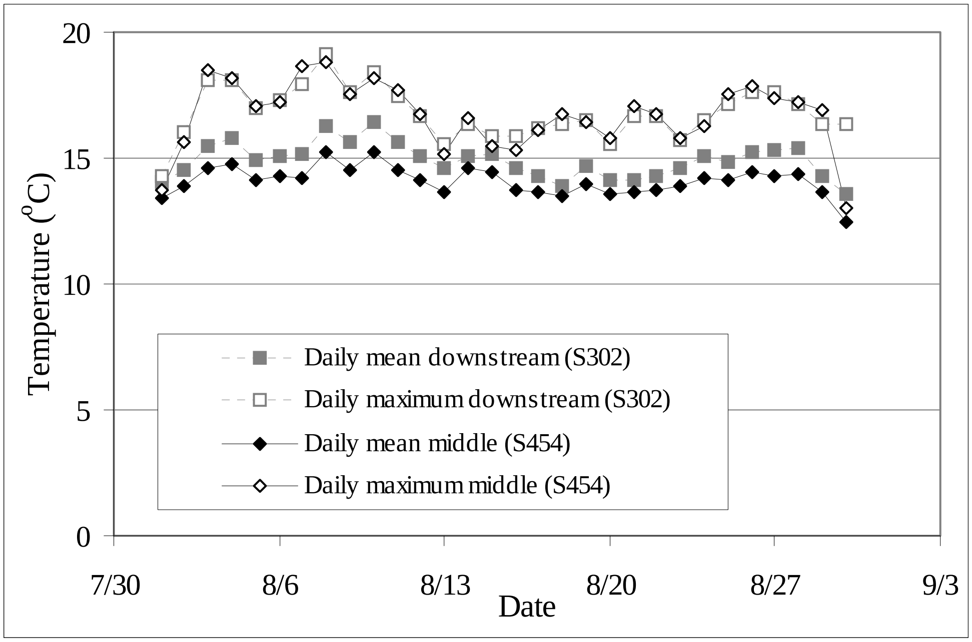


Table 2. Water chemistry data for downstream station from summer 2000. Highlighted field indicates problem parameter.

Parameters (unit)	**Downstream (302)**	**Water Quality Criteria**	
Nutrients (mg/L)			
Ammonia-Nitrogen	0.05	NC	
Nitrate-Nitrite-N	0.6	NC	
Total Nitrogen	0.77	0.71[1]	
Total Phosphorus	0.017	0.031[1]	
Dissolved Organic Carbon	1.7	NC	
Total Suspended Solids	1.8	NC	
Metals (µg/L)		**CMC**[2]	**CCC**[2]
Cadmium	ND 0.05	0.64	0.32
Chromium	ND 0.5	16	11
Iron	432	NC	1,000
Lead	ND 0.5	10.52	0.41
Zinc	3.41	29.9	27.1

NC, No Criteria; ND, Not Detected, i.e., below stated detection limit of test.

[1] Criteria recommended by EPA for Ecoregion XIV, which includes Trout Brook.

[2] CMC and CCC are types of Maine Statewide Water Quality Criteria (SWQC; MDEP SWQC). CMC (Criteria Maximum Concentration) and CCC (Criteria Continuous Concentration) denote the level of pollutants above which aquatic life may show negative effects following brief (acute) or indefinite (chronic) exposure, respectively.

University of Maine study

Chandler Morse, a graduate student at the University of Maine in Orono, studied one station on Trout Brook, namely the MDEP downstream station, in the summer and fall of 1998, and spring of 1999 (S302, Fig. 1; Morse 2001). Like the MDEP biomonitoring studies, Morse also found that the macroinvertebrate community in Trout Brook was degraded: taxa richness was low (18 taxa in both fall of 1998 and spring of 1999), and there were no Ephemeroptera[1] (mayflies) or Plecoptera (stoneflies) taxa, and only few (6) Trichoptera (caddisflies) taxa . The density of organisms per sample was intermediate (~284 and 365). Summer water temperature, predawn DO concentrations, and pH were good, and nutrient levels were quite low, but conductivity (SPC) was elevated in fall and spring (Table 3). According to Morse's analysis, landuse types in the watershed of Trout Brook were predominantly urban (47 %), with a significant amount of forests (33 %), and some wetlands and agriculture (11 and 7 %, respectively; from Fig. 6 in Morse 2001). A qualitative habitat survey, which integrated 10 different metrics indicating habitat quality, resulted in a Marginal ranking (110, range is 60 – 119; ranking categories are Poor, Marginal, Suboptimal, Optimal; overall worst/best score is 0/240). A Stream Reach Inventory and Channel Stability Index assessment, which integrated 15 metrics and evaluated the channel for instability and erosion/deposition, resulted in a Fair ranking (95, range is 77 – 114; ranking categories are Excellent, Good, Fair, Poor; overall best/worst score is 33/162). Morse's conclusion from his study was that Trout Brook, like other urban streams he studied with >6 % impervious surfaces (including Barberry Creek and Birch Stream), showed a variety of impacts related to urban development, mainly declining habitat quality and decreased diversity of macroinvertebrate taxa (Morse 2001).

Table 3. Morse (2001) data. Highlighted field indicate problem parameter.

Parameter	**Summer 1998**	**Fall 1998**	**Spring 1999**
Water temperature (ºC)	15.4	4.6	7.5
DO, predawn (mg/L)	9.1	12.4	11.9
pH	7.7	7.3	7.9
Specific conductance (SPC; μS/cm)	217	455	577
NO_3-Nitrogen (mg/L)	0.199	0.429	0.27
Total Phosphorus (mg/L)	0.010	0.006	0.005
Total Suspended Solids (mg/L)	3.2	3.8	4.3

---

[1] Ephemeroptera, Plecoptera, and Trichoptera are often collectively referred to as EPT taxa.

RESULTS OF 2003 STUDY

Biological Monitoring

1. Macroinvertebrate samples collected from rock bags in August (downstream) and September (late upstream[1]) after an exposure period of four weeks in the stream showed that both stations failed to meet Class C aquatic life criteria (Table 4; full model outputs for the 2003 sampling events are shown in App. B ii). Both stations had degraded communities with a reduced generic richness, scarcity of sensitive taxa, predominance of tolerant organisms (crustaceans, midge larvae), low to intermediate diversity index, and an intermediate to high Hilsenhoff biotic index, resulting in a model outcome of "Non-Attainment" for both stations. Compared to the late upstream station, the following community attributes are noteworthy at the downstream station: the large dominance of the amphipod *Gammarus*; the occurrence of the MDEP Class A indicator *Glossosoma* and six additional Trichoptera genera (some sensitive); and the extremely high percentage of non-insects (80 % *versus* 17 %). Analysis results were reported in the MDEP's 2002-2003 SWAT Monitoring Program technical report (MDEP 2004c).

Table 4. Summary version of 2003 macroinvertebrate model reports

Model variable	**Downstream (S302)**	**Late upstream (S675)**
Total abundance of individuals	208	477
Generic richness	29	38
Plecoptera / Ephemeroptera abundance	0 / 0	0 / 0
Shannon-Wiener diversity index	1.97	3.42
Hilsenhoff biotic index	4.27	6.40
Relative abundance Chironomidae	0.06	0.73
EPT[1] generic richness	7	1
EP[1] generic richness/14	0	0
Presence of Class A indicator taxa/7	0.14	0
Five dominant taxa (%)	*Gammarus* (70) *Dubiraphia* (7) *Caecidotea* (5) *Glossosoma* (4) *Tvetenia* (2)	*Tanytarsus* (33) *Micropsectra* (20) *Rheotanytarsus* (7) *Caecidotea* (7) *Dubiraphia* (6)
Model outcome (%)	NA (100)	NA (100)

[1] EPT are Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). EP are Ephemeroptera and Plecoptera.

2. The fish assemblage at the downstream station was investigated on June 19, and consisted of 23 brook trout (*Salvelinus fontinalis*; 2-12") including 4 young-of-the-year, and 19 American eels (*Anguilla rostrata*; 3-20" in length). Fish were not investigated at the upstream station.

---

[1] The new station (S675) was initially established in a section of stream that began to dry out in early July. To avoid sampling problems, the station was moved ~50 m downstream in mid-July. In the Results of 2003 Study section in this chapter, data from the upstream station are graphed and discussed in terms of "early" and "late" to indicate this downstream shift in sampling location.

3. The algae sample collected on July 9 from the stream bottom ~40 m above the downstream station has not yet been analyzed for species composition and abundance. A visual assessment of the site showed a sand and gravel substrate with a small amount of algae growing on available rocks. Aquatic plant biomass was low, with the dominant type of aquatic vegetation (rooted submergent, especially *Vallisneria*) covering only ~2% of the stream reach assessed. A similar situation was found on July 6, 2004.

4. The algae samples (epiphytic algae, phytoplankton) collected on June 12 at the wetland station ~400 m above Sawyer Street have not yet been analyzed for species composition and abundance. Dominant macropytes at this station were grasses and water lilies (*Nuphar*). The macroinvertebrate samples showed a low abundance (38 organisms), an intermediate generic richness (31), a predominance of tolerant organisms (chironomids, oligochaetes) and few sensitive organisms [1 *Paraleptophlebia* (mayflie), 1 *Enallagma* (dragonfly), 2 Limnephilidae (caddisflies)].

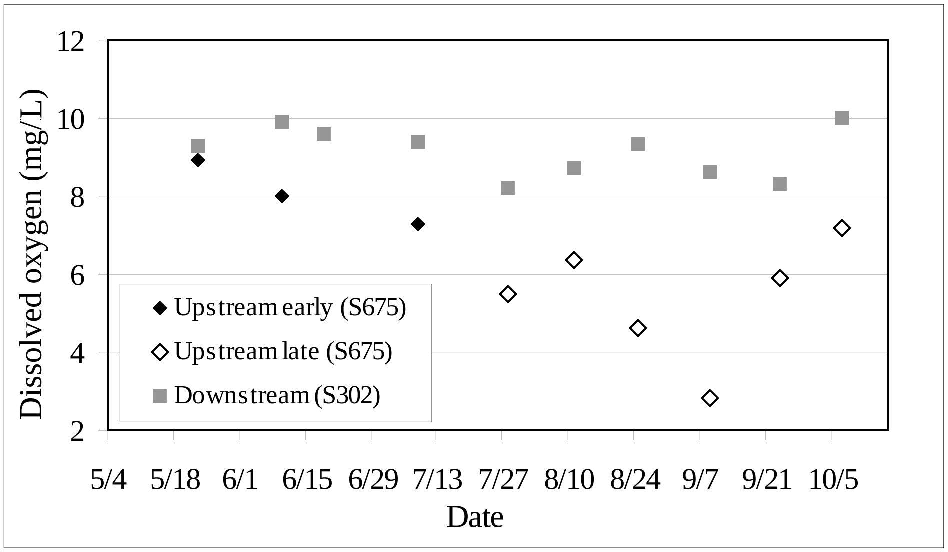
Water Quality Monitoring

1. Standard water quality parameters

a) *Instantaneous dissolved oxygen*

Instantaneous dissolved oxygen (DO) concentrations at the downstream station on Trout Brook were usually high, ranging from 8.2 - 10.0 mg/L (gray squares in Fig. 4). At the upstream station, DO concentrations differed markedly between the early and late locations, ranging from 7.3 - 8.9 mg/L at the early location (black diamonds in Fig. 4), and from 2.8 - 7.2 mg/L at the late location (open diamonds in Fig. 4). The single DO measurement taken at the wetland station on June 12 was 9.0 mg/L. Measurements taken on May 8, 2004, at the downstream and late upstream stations were 9.5 and 8.2 mg/L, respectively. On July 6, 2004, DO was at 9.2 mg/L at the downstream station.

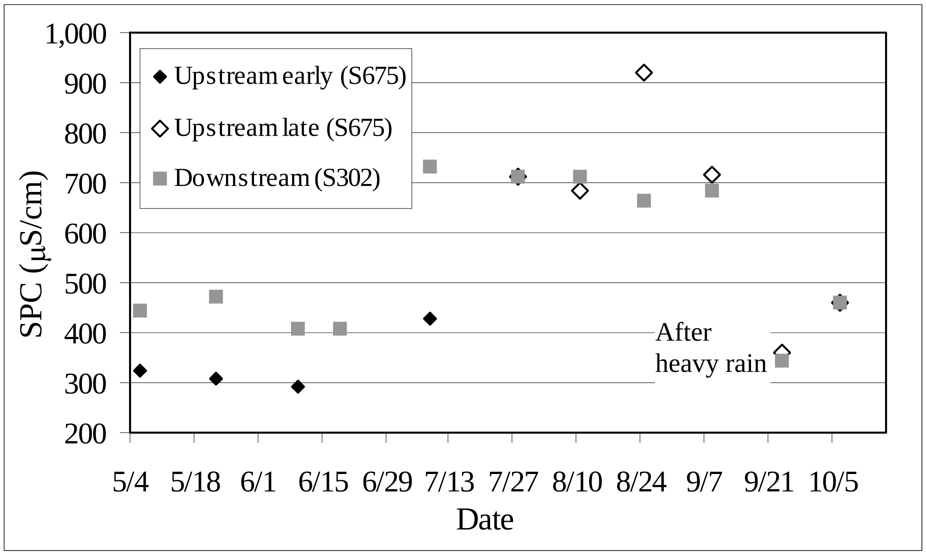
Fig. 4. Instantaneous dissolved oxygen



b) *Instantaneous specific conductance*

Instantaneous levels of specific conductance (also conductivity or SPC) at the downstream station were generally high but varied widely throughout the sampling season, ranging from 346 - 734 μS/cm (gray squares in Fig. 5). At the early upstream station, conductivity levels were lower and less variable, from 291 - 430 μS/cm (black diamonds in Fig. 5). At the late upstream station, conductivity levels were quite high and variable, from 360 - 922 μS/cm (open diamonds in Fig. 5). As shown on Figure 5, low conductivity was recorded on September 24 after heavy rain (0.6") the previous day had diluted the ions in the water. The single conductivity measurement taken at the wetland station on June 12 was 318 μS/cm; a water sample taken at the same time and analyzed in the laboratory measured SPC at 429 μS/cm. Measurements taken on May 8, 2004, at the downstream and late upstream stations were 453 and 455 μS/cm, respectively. On July 6, 2004, SPC was at 673 μS/cm at the downstream station.

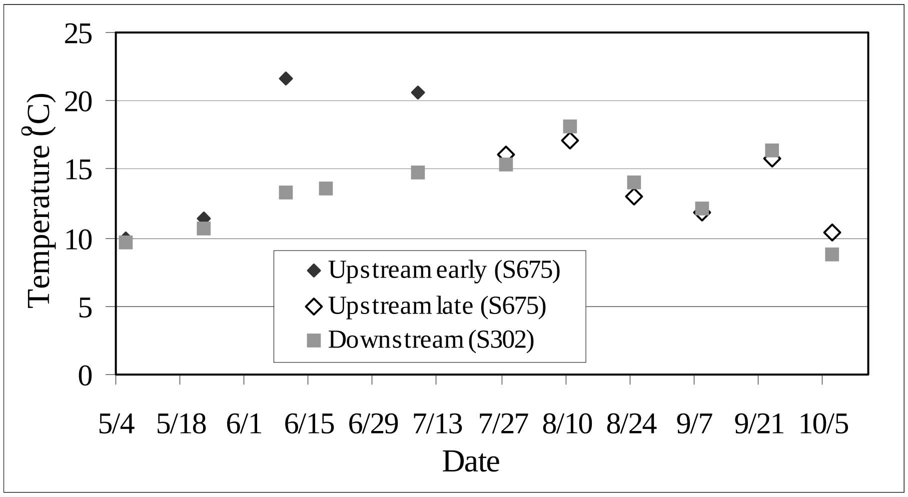
Fig. 5. Instantaneous specific conductance



c) *Instantaneous water temperature*

Instantaneous water temperature was quite variable at all stations, ranging from 8.8 - 18.2 ºC at the downstream station (gray squares in Fig. 6), from 10.0 - 21.6 ºC at the early upstream station (black diamonds in Fig. 6), and from 10.4 - 17.1 ºC at the late upstream station (open diamonds in Fig. 6). The single temperature measurement taken at the wetland station on June 12 was 20.7 ºC. Measurements taken on May 8, 2004, at the downstream and late upstream stations were 13.6 and 13.0 ºC, respectively. On July 6, 2004, water temperature was at 16.0 ºC at the downstream station.

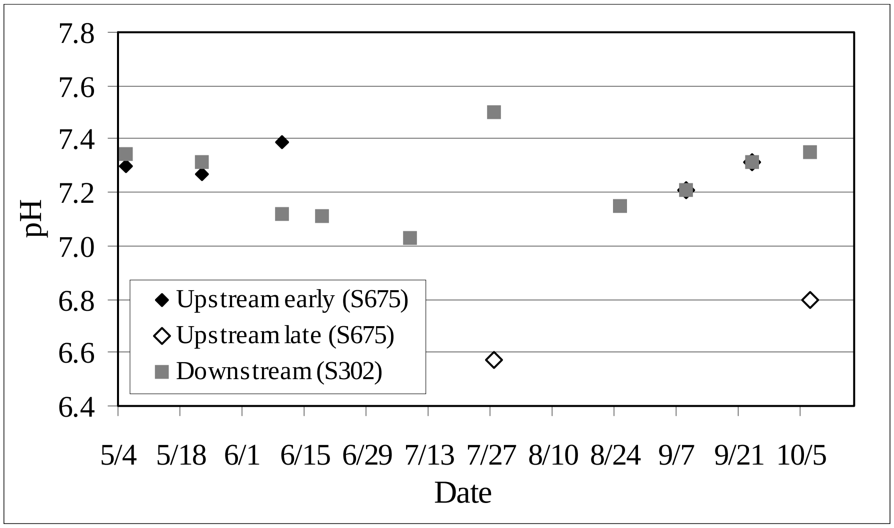
Fig. 6. Instantaneous water temperature



d) Instantaneous pH

Instantaneous measurements of pH did not vary widely at any measurement location: at the downstream station, pH ranged from 7.0 - 7.5 (gray squares in Fig. 7); at the early upstream station, it ranged from 7.3 - 7.4 (black diamonds in Fig. 7); and at the late upstream station, it ranged from 6.6 - 7.3 (open diamonds in Fig. 7). The single pH measurement taken at the wetland station on June 12 was 7.4; air equilibrated pH was measured at 7.5 at this station. On July 6, 2004, a pH of 7.2 was measured at the downstream station.

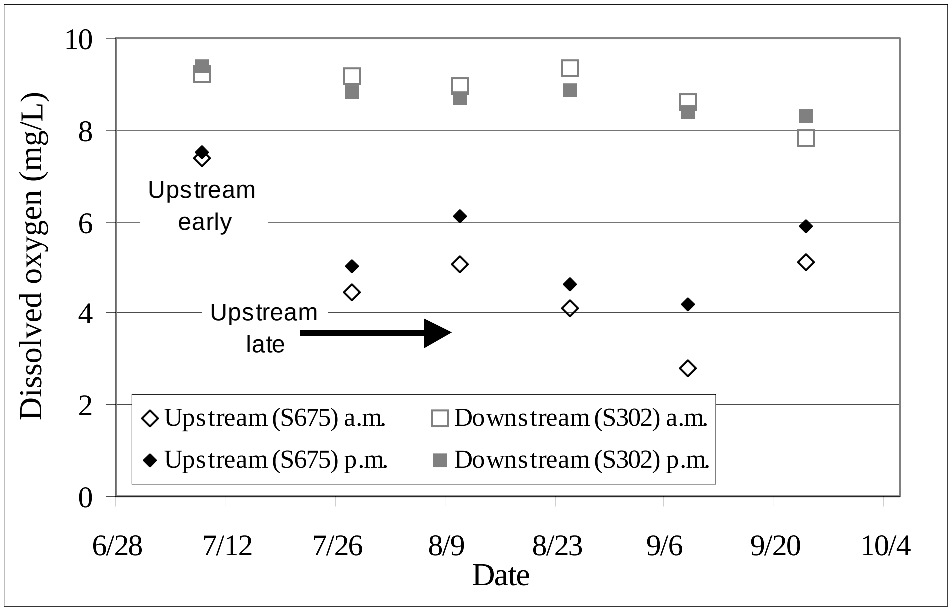
Fig. 7. Instantaneous pH



2. Diurnal dissolved oxygen

Dissolved oxygen concentrations measured at the downstream station in early morning and mid-afternoon were quite similar throughout the summer with a maximum diurnal difference of 0.5 mg/L (squares in Fig. 8). The single measurement that was collected at the early upstream station showed a diurnal difference of 0.1 mg/L (diamonds in Fig. 8). At the late upstream station, DO concentrations were much lower than at the downstream station and the diurnal range was greater (maximum difference of 1.4 mg/L; diamonds in Fig. 8).

Fig. 8. Diurnal dissolved oxygen

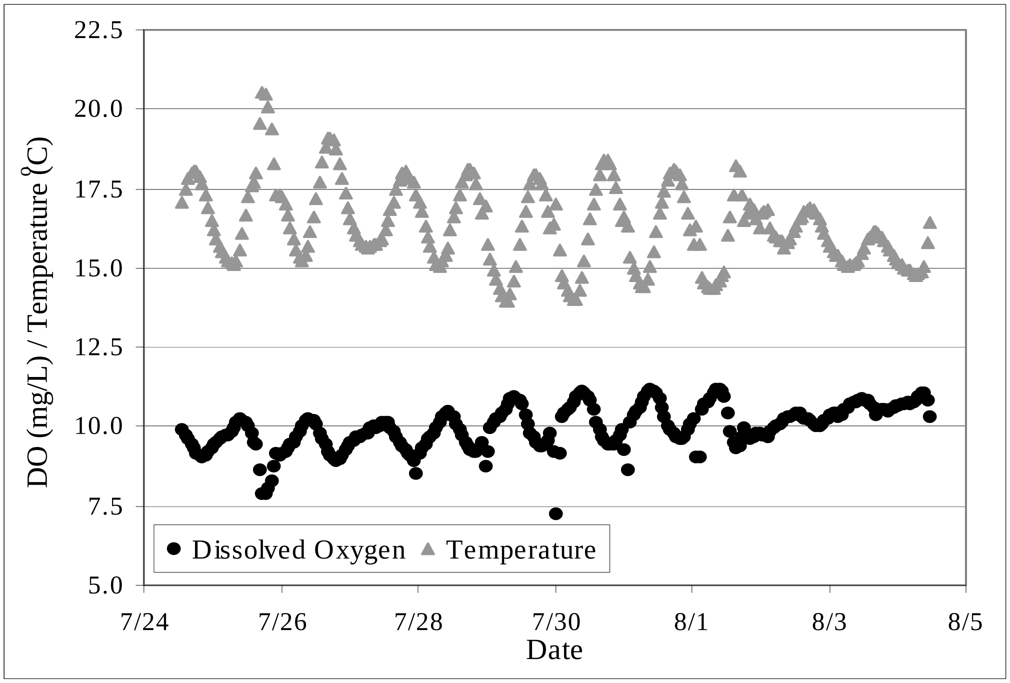


3. Continuous data collection below downstream station (below Highland Avenue culvert; 12 days, July 24 to August 4)

a) Continuous dissolved oxygen and water temperature

Mean hourly dissolved oxygen (DO) and water temperature calculated from records collected every 10 min indicated that both variables showed strong diurnal fluctuations (Fig. 9). Dissolved oxygen concentrations were highest in the early morning soon (~2 hours) after water temperatures were lowest while, conversely, DO concentrations were lowest in early evening soon after water temperatures were highest. Except for one reading at 7.3 mg/L, all DO concentrations were above 7.9 mg/L. Diurnal differences exceeded 2 mg/L on 4 out of the 10 full days of measurements (minimum/maximum difference was 0.5/3.9 mg/L). Water temperatures were >20 ºC during one 2.5 hour period, but most of the time they were much cooler than that.

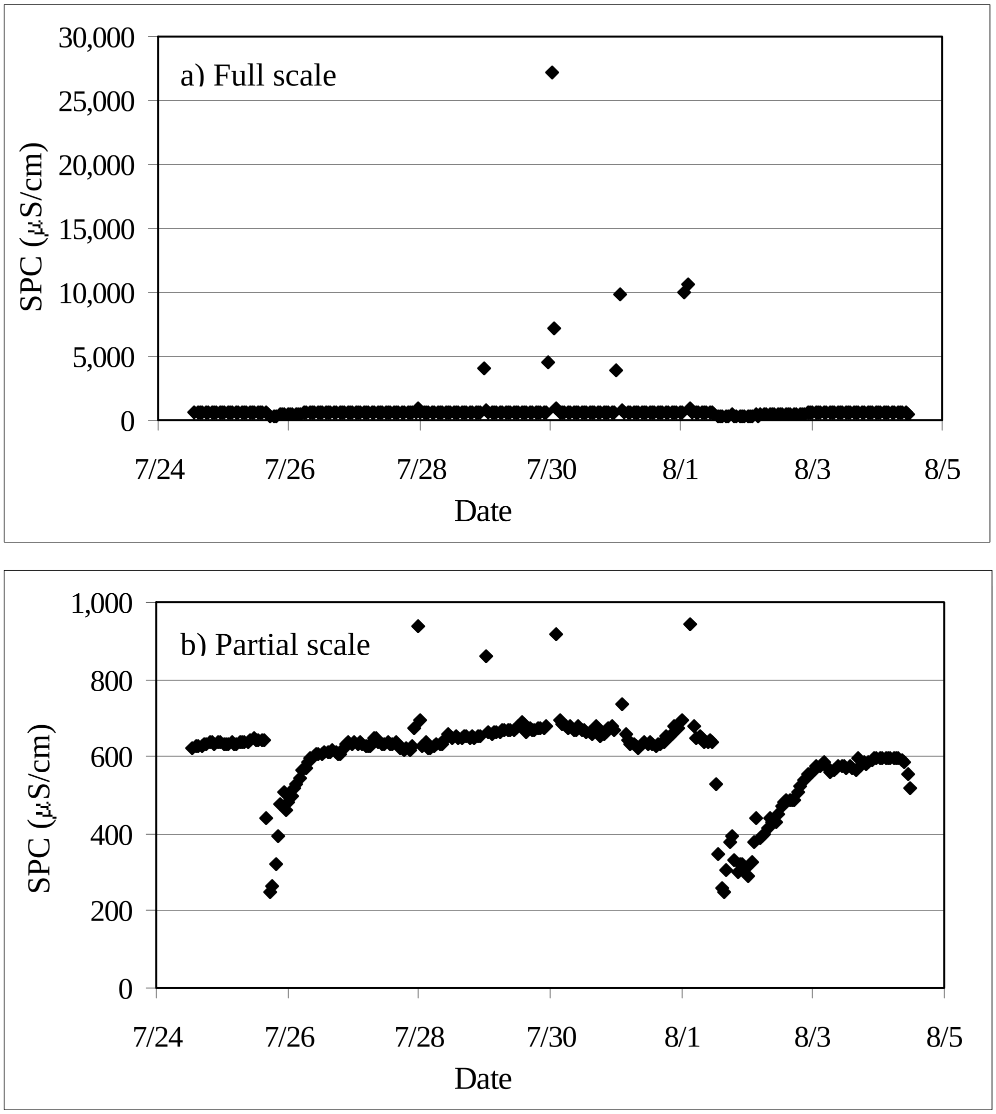
Fig. 9. Continuous dissolved oxygen and water temperature at downstream station (12 days)



b) Continuous specific conductance

Mean hourly conductivity calculated from records collected every 10 min showed remarkable variation, ranging from 246 to 27,162 μS/cm (Fig. 10 a and b; same data with different scales). The majority of the time, conductivity ranged from 500 - 700 μS/cm (Fig. 10 b). Several values >20,000 μS/cm (maximum value 30,903 μS/cm) were recorded on three successive nights (7/30 and 31, 8/1) between midnight and 2 a.m. Note that only the first spike on 7/30, which lasted for ~80 min, appears in the mean hourly averages (Fig. 10 a) while the subsequent, shorter spikes (20-30 min) are evened out by substantially lower measurements. It is not known conclusively what caused those spikes but consultation of tide tables for the Fore River showed that high water occurred at 12:13 a.m., 12:54 a.m., and 1:38 a.m. on the three nights in question, suggesting that salt water intrusion caused the spikes. Decreases in conductivity occurred following rain events: light rain (0.13”) on July 25 caused a strong decrease lasting ~18 hours while heavy rain (1.0”) on August 1 followed by light rain (0.06”) on August 2 caused a similar decrease lasting ~48 hours.

Fig. 10. Continuous specific conductance at downstream station (12 days)



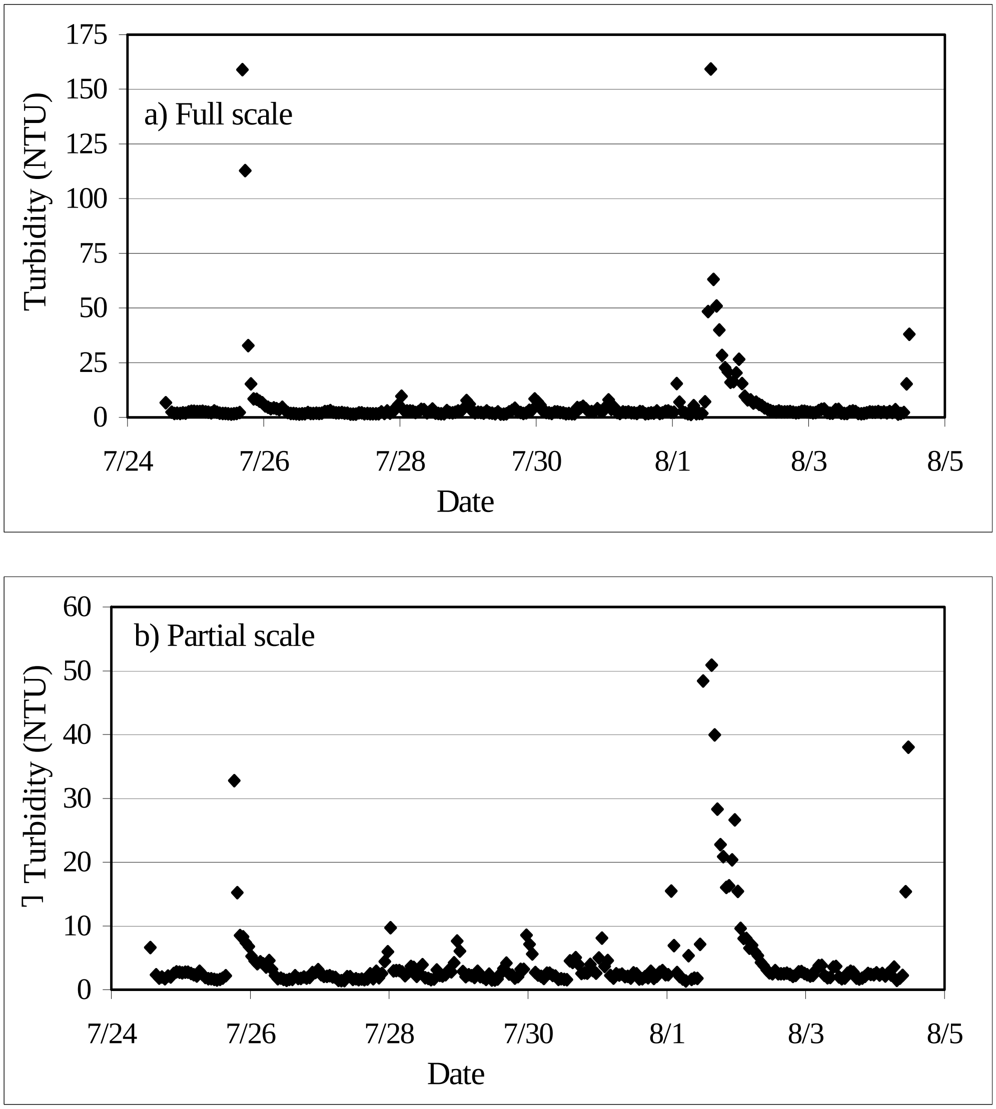
c) Continuous turbidity

Mean hourly turbidity calculated from records collected every 10 min showed large variation, ranging from 1 - 657 NTU (Fig. 11 a and b; same data with different scales). The maximum instantaneous value measured was 1,787 NTU. The majority of the time, turbidity ranged from 1 - 10 NTU (Fig. 11 b), and the EPA-recommended criterion of 3.04 NTU (EPA 2000b) was exceeded 30 % of the time. The two spikes recorded on July 25 and August 1 (Fig. 11 a) occurred during rain events and are likely related to the turbulence created by rainwater and storm runoff entering the stream causing sediment to be stirred up (App. G, Fig. 6), and likely also bringing sediment into the stream. Small spikes, i.e., those reaching ~10 NTU (Fig. 11 b), occurred on several days and were not associated with rain events; instead these small spikes showed a temporal pattern in that they always occurred around midnight[1].

---

[1] Data collected in 2004 suggest that these turbidity spikes may have been related to saltwater intrusions (see Discussion, Water Quality Monitoring, Saltwater Intrusions, below)

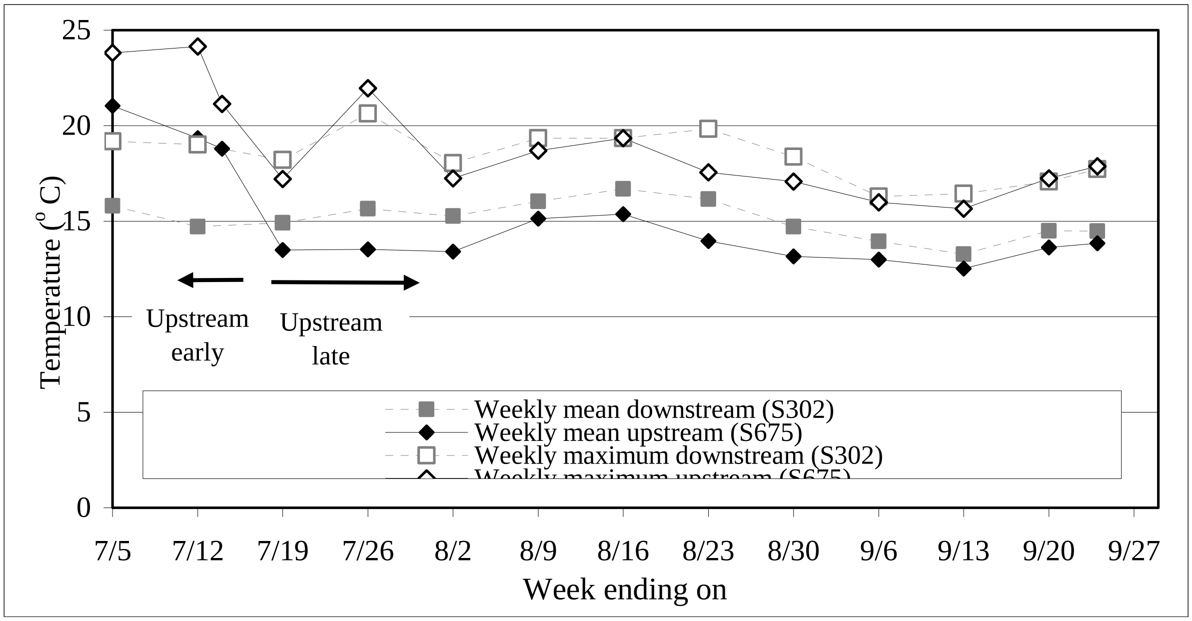
Fig. 11. Continuous turbidity at downstream station (7 days)



4. Continuous water temperature (85 days, July 2 to September 24)

    Continuous water temperature at the downstream station (squares and dashed lines in Fig. 12, measured at 20-min intervals) showed relatively cool and stable weekly mean temperatures between 13.3 and 16.7 ºC, and warmer, more variable weekly maximum temperature between 16.3 and 20.6 ºC. At the early upstream station (diamonds and solid lines in Fig. 12), the weekly mean temperature for the 11 days the temperature logger was in place at this station was quite high, around 20 ºC, and the weekly maximum temperature was even higher, around 23 ºC. At the late upstream station (diamonds and solid lines in Fig. 12), the weekly mean temperature was quite cool, between 12.5 and 15.4 ºC, while the weekly maximum temperature was significantly higher, between 15.7 and 22.0 ºC.

Fig. 12. Continuous water temperature (85 days)



5. Water chemistry

Water chemistry data are summarized in Tables 5 - 7. Table 5 shows the results from five baseflow sampling events at the downstream station and three at the late upstream station, Table 6 shows the results from two stormflow sampling events at both stations, and Table 7 shows the results from one baseflow sampling event at the wetland station. Tables 5 and 6 include numeric criteria for water quality where available. Criteria recommended by EPA for Region XIV present nutrient levels that protect against the adverse effects of nutrient overenrichment (USEPA 2000b). The Maine Statewide Water Quality Criteria (MDEP SWQC) CMC and CCC[1] define acute (brief exposure) and chronic (indefinite exposure) levels, respectively, above which certain compounds can have detrimental effects on aquatic organisms. In general, CMC should be used to interpret results from stormflow samples while CCC should be used to interpret results from baseflow samples. Highlighted fields in the tables indicate cases where the sampling results exceeded the numeric criteria, i.e., cases where negative effects may occur in aquatic organisms.

Table 5. During baseflow conditions, Total Nitrogen (TN) exceeded the EPA-recommended Ecoregion XIV criterion at the downstream station in all sampling events. Bacteria (*E. coli*) exceeded the State of Maine criterion for the mean count of bacterial colonies three times, and the criterion for the instantaneous count once. Note however that Maine's criteria are for *E. coli* of human origin and that the origin was not determined in this study. Lead was the only metal analyzed that exceeded Maine SWQC (MDEP SWQC) chronic criteria although in some cases the sensitivity of the analysis was insufficient to determine whether criteria were exceeded (copper: for CMC and CCC; cadmium and lead: for CCC only). At the late upstream station, TN exceeded the EPA-

---

[1] CMC, Criteria Maximum Concentration; CCC, Criteria Chronic Concentration

recommended criterion in the single sampling event, and *E. coli* exceeded State criteria for the geometric mean of counts of bacterial colonies two out of three times. Total and dissolved organic carbon (TOC, DOC) were relatively low at both stations, while TSS usually was below the detection limit of the test but was elevated on one date at the downstream station. Additional data not shown in Table 5 were collected at the downstream station on July 9 during algal sampling: alkalinity, 54 mg/L; and silica (by calculation), 15 mg/L.

Table 6. During stormflow conditions at the downstream and late upstream stations, the following violation of criteria were found: Total Phosphorus (TP) exceeded the EPA-recommended criterion twice at each station (by a factor of 3 - 7); aluminum exceeded the Maine SWQC (MDEP SWQC) acute criterion three times (once downstream, twice late upstream); copper exceeded the acute criterion once at each station; and zinc exceeded the acute criterion once at the late upstream. The TP values recorded during stormflow conditions were up to 20 times higher than during baseflow conditions (Table 5; no aluminum data were collected at baseflow; Cu and Zn were non-detects at baseflow). There are no criteria for Total Suspended Solids (SSD) but SSD values at stormflows were up to ~35 times higher than during baseflows (Table 5).

In addition to the data shown in Table 6, two TP stormflow samples were collected on February 24 and 26, 2004 at the downstream station, with values of 0.021 and 0.1 mg/L, respectively. Only the second of these samples exceeded the EPA-recommended criterion (0.031 mg/L; by a factor of 3).

Rainfall amounts for storm sampling events were as follows: May 26: 0.91” mostly in early evening, May 27: 0.03” at 12:30 am; November 20: 0.72” during mid to late morning, November 21: 0.28” at ~4 - 9 a.m.; February 23 - 26, 2004: no precipitation but daytime highs were 1-3 ºC, i.e., some melting likely occurred (Weather Underground 2003/2004).

Table 7. Several of the parameters analyzed for water chemistry ranked among the top 10 % of all samples ever collected in ME wetlands by the biomonitoring unit: nutrients (NO_2-NO_3-N, TN), anions and cations (Ca, Mg, K, NA), chloride, conductivity, alkalinity, and hardness. Total Nitrogen and values TP were higher than baseflow values for the downstream and late upstream stations (Table 5).

Table 5. Water chemistry data (baseflow) from summer 2003. Highlighted fields indicate problem parameters.

Parameters	**Station (#)**	**Upstream late (S675)**			**Downstream (S302)**					**Water Quality Criteria**	
	Sample date	**15-Jul**	**11-Aug**	**9-Sep**	**15-Jul**	**11-Aug**	**25-Aug**	**28-Aug**	**9-Sep**		
Nutrients	**Unit**										
Total Kjeldahl N	mg/L		0.2		0.2	~0.3	0.2	0.7	0.2	NC	
Nitrate-Nitrite-N	mg/L		0.54		0.78	0.58	0.8	<0.01	0.74	NC	
Ammonia-Nitrogen	mg/L						0.02			NC	
Total Nitrogen	mg/L		0.74		0.98	~0.88	1.02	0.7	0.94	0.71 [1]	
Ortho-phosphate	mg/L		0.004		0.007	0.007			~0.006	NC	
Total Phosphorus	mg/L		0.014		0.018	0.019	0.013		0.011	0.031 [1]	
Dissolved Organic Carbon	mg/L		2.8			2.6	2.5			NC	
Total Organic Carbon	mg/L		4.3			3.8				NC	
Chlorophyll *a*	mg/L		~0.0014		~0.0013	~0.0015		~0.0121	~0.0007	0.00375 [1]	
Total Suspended Solids	mg/L		ND 2		3		ND 2	17	ND 2	NC	
Total Dissolved Solids	mg/L						480			NC	
Diesel Range Organics	µg/L		<50			<50				NC	
Bacteria (*E. coli*)	# col./100 ml	166	161	104	1300	344		613	161	949 [2, 3]	142 [2, 3]
Metals										**CMC**[4]	**CCC**[4]
Cadmium	µg/L		ND 0.5		ND 0.5	ND 0.5			ND 0.5	0.64	0.32
Copper	µg/L		ND 5		ND 5	ND 5			ND 5	3.89	2.99
Iron	µg/L		300		340	490			140	NC	1,000
Lead	µg/L		ND 3		ND 3	ND 3			3	10.52	0.41
Zinc	µg/L		ND 5		ND 5	ND 5			ND 5	29.9	27.1
Chromium	µg/L		ND 1			ND 1				16	11
Nickel	µg/L		5.5			5				363.4	40.4
Chloride	mg/L		156			147				860	230

NC, No Criteria; ND, Not Detected, i.e., below stated detection limit of test

[1] Criteria recommended by EPA for Ecoregion XIV, which includes Trout Brook. Total Nitrogen is the sum of preceding three parameters.

[2] Criteria (instantaneous/geometric mean counts of the # of *E. coli* colonies) defined by Maine's Water Classification Program for Class C waters.

[3] Results are for bacteria of any origin while Maine standards are for bacteria of **human** origin. Note that in some studies where the origin of bacteria has been investigated, the majority of bacteria were not of human origin.

[4] CMC and CCC are types of Maine Statewide Water Quality Criteria (SWQC; MDEP SWQC). CMC (Criteria Maximum Concentration) and CCC (Criteria Continuous Concentration) denote the level of pollutants above which aquatic life may show negative effects following brief (acute) or indefinite (chronic) exposure, respectively.

Table 6. Water chemistry data (stormflow) from 2003. Highlighted fields indicate problem parameters.

Parameters	**Station (#) Date**	**Upstream late (S675)**		**Downstream (S302)**		**Water Quality Criteria**	
	Unit	**27-May**	**21-Nov**	**27-May**	**21-Nov**		
Total Phosphorus	mg/L	0.22	0.11	0.15	0.094	0.031[1]	
Total Suspended Solids	mg/L	70	29	50	29	NC	
Metals						**CMC**[2]	**CCC**[2]
Arsenic	µg/L	ND 3	ND 3	ND 3	ND 3	360	190
Aluminum	µg/L	2,000	850	970	500	750	87
Cadmium	µg/L	0.6	ND 2	0.5	ND 2	0.64	0.32
Chromium	µg/L	4	2	2	1	16	11
Copper	µg/L	7	ND 5	6	ND 5	3.89	2.99
Iron	µg/L	4,600	1,800	2,500	1,100	NC	1,000
Lead	µg/L	8	3	6	3	10.52	0.41
Nickel	µg/L	9	4	6	3	363.4	40.4
Silver	µg/L		ND 1		ND 1	0.25	NC
Zinc	µg/L	~31	16	~22	10	29.9	27.1
Calcium	mg/L	16	17	20	18	NC	
Magnesium	mg/L	3.1	3.3	3.8	3.4	NC	
Potassium	mg/L	2.7	4.0	3.1	3.9	NC	
Sodium	mg/L	25	24	34	27	NC	
Manganese	mg/L	0.52	0.15	0.30	0.08	NC	

NC, No Criteria; ND, Not Detected, i.e., below stated detection limit of test.

[1] Criteria recommended by EPA for Ecoregion XIV, which includes Trout Brook.

[2] See footnote 4 in Table 5.

Table 7. Water chemistry data (baseflow, wetland station) from June 2003. Highlighted fields indicate problem parameters.

Parameters	**Station (#)**	**Wetland (W-093)**	
	Unit	**Value**	**Rank[1]**
Total Kjeldahl Nitrogen	mg/L	0.5	42 (of 54)
Nitrate-Nitrite-N	mg/L	0.67	1 (of 25)
Ammonia-Nitrogen	mg/L	0.03	70 (of 113)
Total Nitrogen	mg/L	1.2	8 (of 88)
Soluble Reactive Phosphate	mg/L	0.01	
Total Phosphorus	mg/L	0.04	47
Chlorophyll *a*	mg/L	0.004	78
Dissolved Organic Carbon	mg/L	5.80	124
Calcium	mg/L	27	10
Magnesium	mg/L	4.7	12
Potassium	mg/L	3.3	8
Sodium	mg/L	38	10
Chloride	mg/L	73	10
Conductivity	µS/cm	429	4 (of 101)
Alkalinity	mg/L	53	18
Color	PCU	42	120
Hardness[2]	mg/L	86.77	3 (of 48)

[1] Rank out of 142 samples except where noted. Rankings in the worst 10% of each category are highlighted.
[2] Water with a hardness of 0-60 mg/L is considered “soft”; 61-120 mg/L “moderately hard”.

Habitat Assessments

1. Flow regime

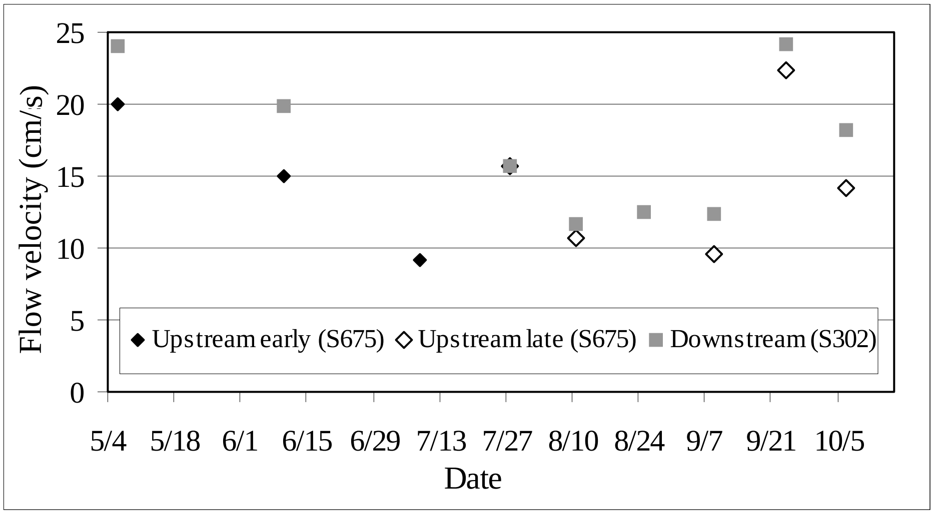
a) *Instantaneous flow velocity*

Instantaneous flow velocity was similar and quite variable at both stations (including visual estimates, which were reduced to 0.8 of observed surface flow to account for the lower velocity at mid-depth[1]): downstream it ranged from 12 - 24 cm/s with a mean of 16 cm/s (gray squares in Fig. 13); at the early upstream station, flow was recorded at 15 and 9 cm/s on the two measurement dates, i.e., at a mean of 12 cm/s (black diamonds in Fig. 13); and at the late upstream station, it ranged from 10 - 22 cm/s with a mean of 14.5 cm/s (open diamonds in Fig. 13).

---

[1] See Ch. 2, Methods for further explanation.

Fig. 13. Instantaneous flow velocity



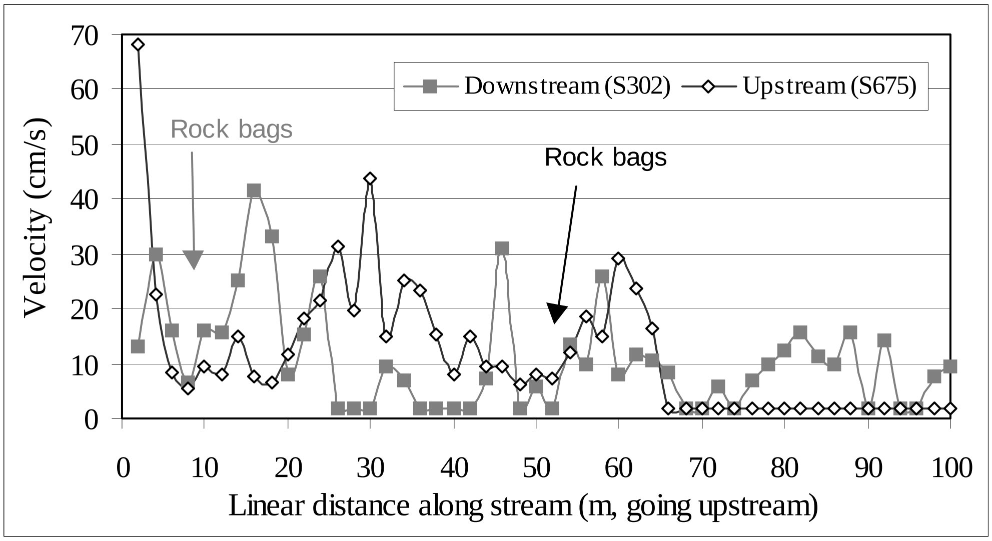
Note that first data point at both stations is visual estimate.

b) Thalweg velocity

At the downstream station, the survey started just below the rock bag location and proceeded upstream. At the late upstream station, the survey started at the rock bag location and proceeded upstream for ~50 m where the stream channel became indistinct because of braiding; to obtain data for a full 100-m stretch, measurements were then taken for ~50 m downstream of the rock bag location.

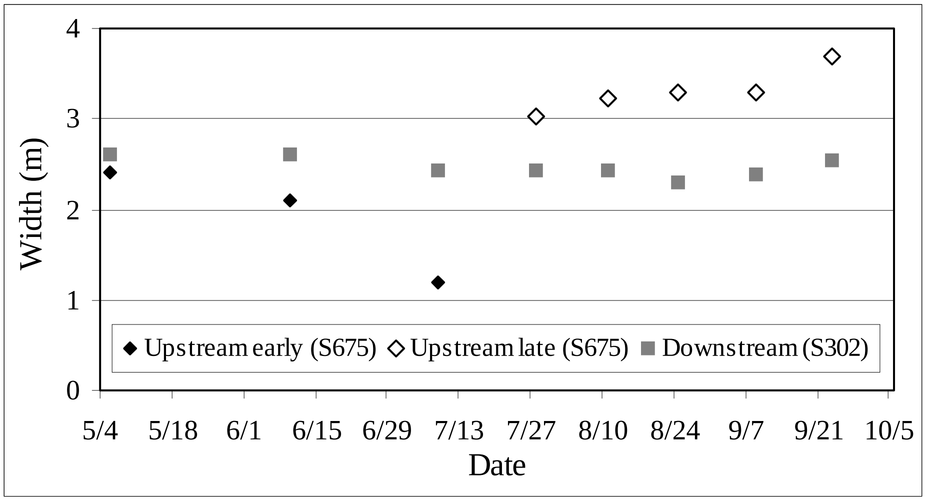
The thalweg velocity at and above the downstream station was highly variable, with velocities ranging from approximately 1 - 42 cm/s with a mean of 11 cm/s (gray squares in Fig. 14). At the late upstream station, a similarly variable flow regime with velocities ranging from approximately 1 - 68 cm/s and a mean of 12 cm/s was measured in the lower ~65 m of the 100 m stretch, but no flow was registered above this point, where the stream was dammed up by a small cobble dam (open diamonds in Fig. 14).

Fig. 14. Thalweg velocity



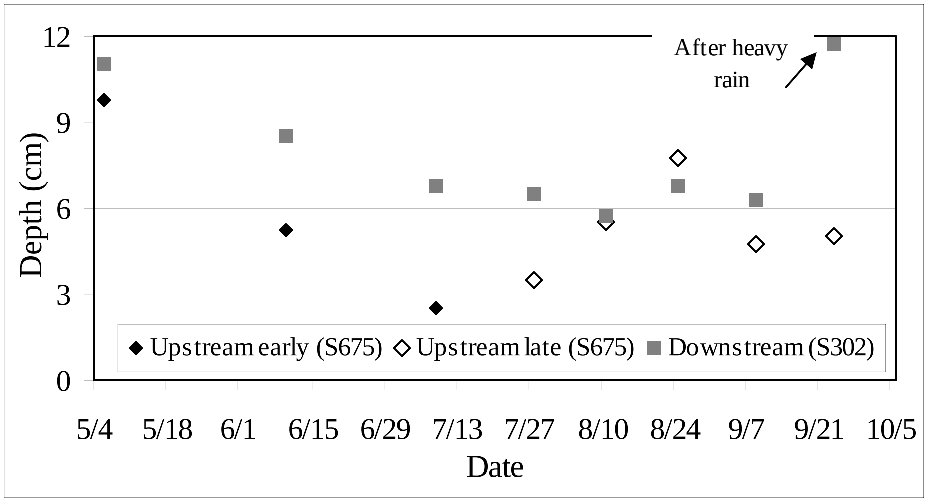
2. Mean stream width (wetted) at the downstream station was quite stable throughout the sampling period, ranging from 2.3 - 2.6 m with a mean of 2.5 m (gray squares in Fig. 15). At the early upstream station, wetted width declined significantly, from 2.4 - 1.2 m (black diamonds in Fig. 15), while at the late upstream station, it increased over time, from 3.0 - 3.7 m (open diamonds in Fig. 15). Bankfull width at the downstream station was much smaller than at the late upstream station (4.3 *versus* 6.0 m; Field 2003, Table 2, Reaches 2 and 4, respectively).

Fig. 15. Mean stream width (wetted)



Mean stream depth was quite variable throughout the sampling period at all stations. At the downstream station, it ranged from 5.8 - 11.8 cm with a mean of 7.8 cm (gray squares in Fig. 16). However, during the summer months, depth was quite stable at this station, between 5.8 and 6.8 cm. At the early upstream station, depth declined significantly, from 9.8 to 2.5 cm (black diamonds in Fig. 16). At the late upstream station, depth was variable, ranging from 3.5 - 7.8 cm with a mean of 5.6 cm (open diamonds in Fig. 16).

Fig. 16. Mean stream depth



3. Large woody debris (LWD, >5 cm mean diameter) above the downstream station was abundant (41 pieces) with a good size distribution (mean diameter of 5 - 25 cm; gray squares in Fig. 17). Around the late upstream station, much fewer pieces were found (22) and the size distribution was more limited (5 - 17 cm; open diamonds in Fig. 17). Note that LWD of >20 cm mean diameter was virtually absent. Small woody debris (2 - 5 cm diameter, >100 cm length) was more abundant at the late upstream station (65 pieces; open diamonds in Fig. 18) than at the downstream station (42; gray squares in Fig. 18).

Fig. 17. Distribution of large woody debris (>5 cm mean diameter)

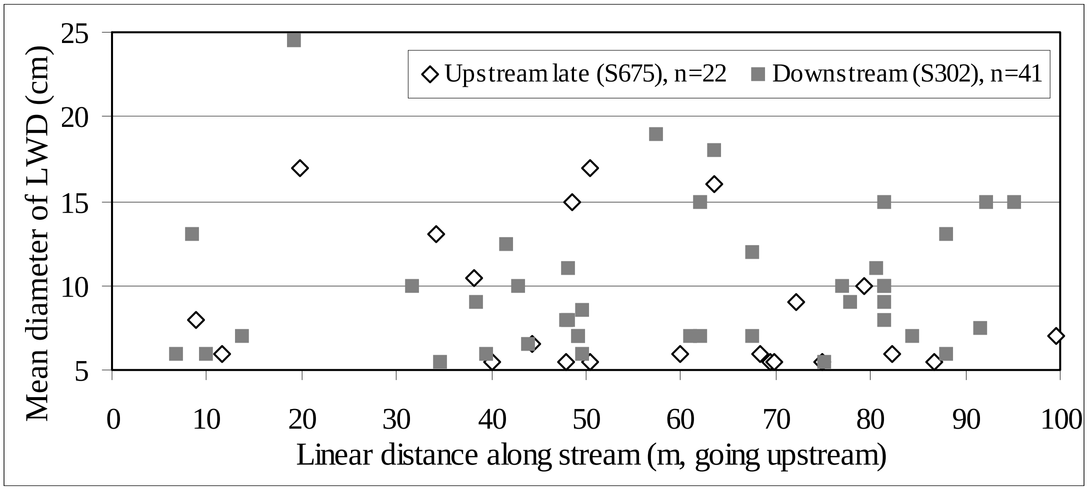
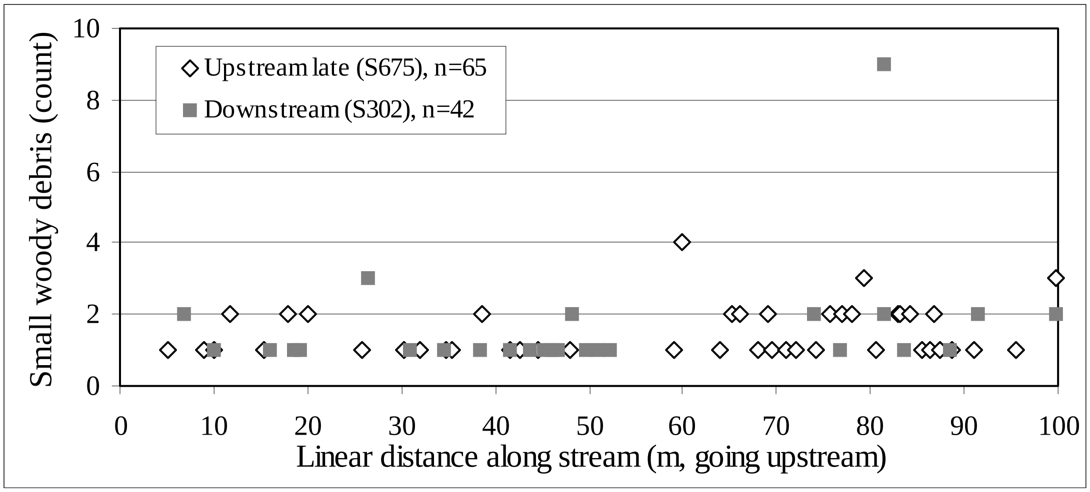
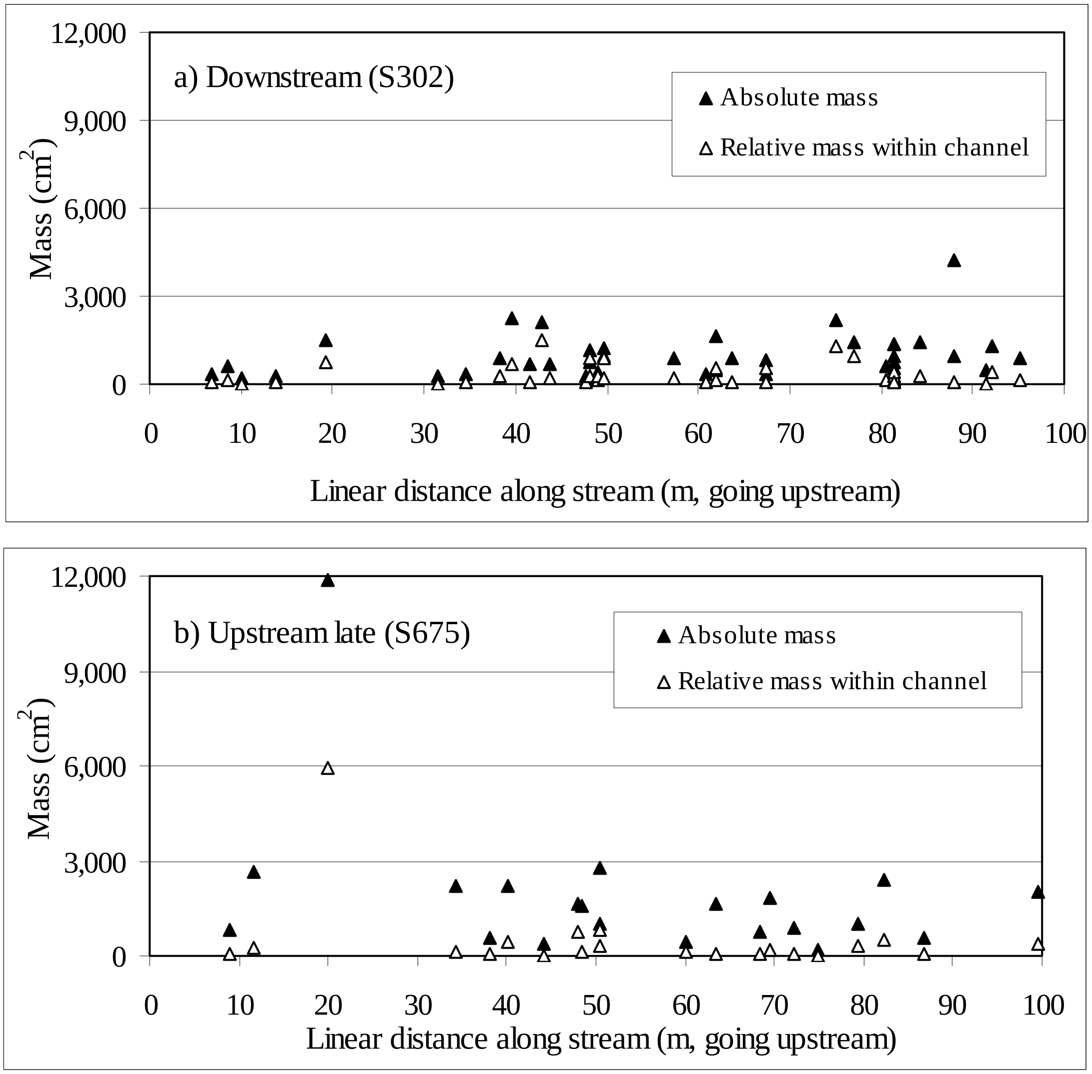


Fig. 18. Distribution of small woody debris (2-5 cm diameter, >100 cm length)



Absolute mass of LWD pieces (mean diameter * length) was similar at both stations, ranging largely from ~200 - 3,000 cm^2, with one outlier at each station (4,200 cm^2 downstream, 11,900 cm^2 upstream; black triangles in Figs. 19 a and b, respectively). Relative mass of LWD pieces (absolute mass * % spanning channel) was greater at the downstream station (23 - 1,470 cm^2, mean of 319 cm^2, open triangles in Fig. 19 a) than at the late upstream station (18 - 825 cm^2, with one outlier at 5,950 cm^2, overall mean of 512 cm^2, open triangles in Fig. 19 b). The decrease from absolute to relative mass was smaller at the downstream than at the late upstream station (Figs. 19 a and b), reflecting the higher mean percent of the channel spanned by pieces of LWD at the downstream station (30 *versus* 18 %).

Fig. 19. Absolute and relative mass of large woody debris



4. Results from the Physical Characterization assessment at the downstream and late upstream stations are summarized in Table 8. Observed problems were obvious sources of NPS pollution, moderate local watershed erosion, some channelization, and a sewage smell of the water.

Table 8. Summary version of completed Physical Characterization form

Parameter	Sub-Parameter	Downstream (S302)	Upstream late (S675)
Stream Characterization	Stream subsystem	Perennial	
	Stream type	Coldwater	
	Stream origin	Mixture of origins (spring-fed, swamp and bog)	
Watershed Features	Predominant surrounding landuse	Residential	
	Local watershed NPS pollution	Obvious sources	
	Local watershed erosion	Moderate	
Riparian Vegetation	Dominant type	Trees, herbaceous	Trees
Instream Features	Canopy cover	Partly open	
	Proportion of reach by stream morphology types	25% Riffle, 10% Pool, 65% Run	40% Riffle, 20% Pool, 40% Run
	Channelized	No (not recently)	Yes (not recently)
	Dam present	No	Yes (small, cobble)
Aquatic Vegetation	Dominant type (portion of reach with aquatic vegetation)	Rooted submergent (*Vallisneria*, 2 %)	Rooted submergent (10%)
Water Quality	Water odors	Sewage (slight)	Sewage
	Water surface oils	None	
	Turbidity	Stained (slightly)	
Sediment/ Substrate	Odors	None	
	Oils	Absent	
	Deposits	None	
	Undersides of stones black?	No	
Substrate Type	Boulder	5	0
	Cobble	50	40
	Gravel	20	30
	Sand	25	30
	Detritus (sticks, wood, coarse plant materials)	10	5

The Habitat Assessment at the downstream and late upstream stations resulted in scores of 124 out of a possible 200 (10 categories * 20 points) for optimal habitat, i.e., in the middle of the spectrum (Table 9). At the downstream station, the lowest scores were recorded for riparian vegetative zone width, vegetative protection, and pool variability. At the late upstream station, the lowest scores were recorded for channel sinuosity, and pool variability, sediment deposition, and channel flow status.

Table 9. Summary version of completed Habitat Assessment form (low gradient stream)

Habitat Parameter	**Downstream (S302)**	**Upstream late (S675)**
1. Epifaunal Substrate/ Available Cover	**14**, suboptimal[1] (30-50% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations, presence of additional substrate in the form of newfall but not yet prepared for colonization)	**13**, suboptimal (as on left)
2. Pool Substrate Characterization	**14**, suboptimal (Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present)	**13**, suboptimal (as on left)
3. Pool Variability	**11**, suboptimal (Majority of pools large-deep; very few shallow)	**10**, marginal (Shallow pools much more prevalent than deep pools)
4. Sediment Deposition	**14**, suboptimal (Some new increase in bar formation, mostly from gravel, sand or fine sediment; 20-50% of the bottom affected; slight deposition in pools)	**10**, marginal (Moderate deposition of new gravel, sand or fine sediment on old and new bars; 50-80% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent)
5. Channel Flow Status	**17**, optimal (Water reaches base of both lower banks, and minimal amount of channel substrate is exposed)	**10**, marginal (Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed)
6. Channel Alteration	**15**, suboptimal (Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, greater than past 20 yrs) may be present, but recent channelization is not present)	**14**, suboptimal (as on left)
7. Channel Sinuosity	**13**, suboptimal (The bends in the stream increase the stream length 1-2 times longer than if it was in a straight line)	**9**, marginal (as on left)
8. Bank Stability (score each bank, left/right)	**7/5**, suboptimal/marginal (7: as Late Upstream) (5: Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods)	**6/6**, suboptimal (Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion)
9. Vegetative Protection (score each bank, left/right)	**6/2**, suboptimal/poor (6: as on right) (2: Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 cm or less in average stubble height)	**8/8**, suboptimal (70-90% of streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; >½ of potential plant stubble height remaining)
10. Riparian Vegetative Zone (score each bank, left/right)	**6/0**, suboptimal/poor (6: Width of riparian zone 12-18 m; human activities have impacted zone only minimally) (0: Width of riparian zone <6 m; little or no riparian vegetation due to human act.	**8/9**, suboptimal/optimal (8: as 6 on left) (9: Width of riparian zone >18 m; human activities, i.e., parking lots, clear-cuts, lawns, or crops, have not impacted zone)

---

[1] For parameters 1-6, possible scores are 0-5 (poor), 6-10 (marginal), 11-15 (suboptimal), and 16-20 (optimal). For parameters 7-10, scores are given for left and right bank with bin sizes of 0-2, 3-5, 6-8, and 9-10.

The Human Disturbance Ranking Form used at the wetland station resulted in a score of 29 out of a possible 125 (5 points * 5 categories * 5 sections; Table 10). This score indicated very high disturbance, and ranked as the 10th worst score recorded in the 157 wetlands assessed by the MDEP biomonitoring program to date (highest score recorded was 44). Impervious surfaces areas in the watershed had the highest score of the five subsections, followed by the potential for NPS pollution, and hydrologic modifications to the wetland.

Table 10. Summary version of completed Human Disturbance Ranking Form

Factor assessed	**Score**	**Section Total**
Section 1. Hydrologic modifications to the wetland		
Man-made dikes or dams	0	4
Causeways, roads or railroad bed crossings, culverts	0	
Ditching, draining, dewatering	3	
Filling or bulldozing	1	
Other	0	
Section 2. Vegetative modifications to the wetland		
Timber harvesting in wetland	0	2
Other clearing/removal of vegetation	2	
Plowing, mowing or grazing in wetland	0	
Evidence of herbicide use in wetland	0	
Other	0	
Section 3. Evidence of chemical pollutants		
Discharge pipes	0	1
Oil, petroleum, chemicals observed, chemical odor present	1	
Soil staining, stressed/dying vegetation	0	
Trash, chemical containers, demolition debris, drums, etc.	0	
Other	0	
Section 4. Impervious surface areas in watershed		
Residential development	4	12
Commercial/industrial development	2	
Recreational development	1	
Roads and highway bridges	3	
Other (parking lots)	2	
Section 5. Potential for NPS pollution		
Excess sediment accumulation and eroding soil from human activities	3	10
Alterations to wetland buffer	2	
Livestock, feedlots, manure piles	0	
Evidence of fertilizer or pesticide use	3	
Other (grass clippings)	2	

5. An analysis of historic landuse changes in the Trout Brook watershed undertaken as part of the geomorphological assessment found that 35 % of the watershed had been built-up by 1964; this percentage rose to 54 % by 1998 (Table 1 in Field 2003). Over the same

time period, forest land declined from 29 to 27 %, agriculture from 22 to 9 %, and barren land from 13 to 9 %. No significant changes in channel position or dimension occurred during that period. Large sections of Trout Brook were, however, channelized in the past (Table 11): the upper part of the watershed above Ocean Street, and also above Boothby Avenue and from Highland Avenue down to Mill Cove. The effect of channelization on the section immediately below Highland Avenue is reflected in the low entrenchment[1] ratios measured here (1.6 and 1.4 for two cross-sections; Table 6 in Field 2003). This means that flows above the bankfull stage do not spread out into a floodplain but instead remain confined within the high banks created by channelization. During high flows, this condition can create erosive forces that can cause the transport of sediment originating from both the sandy substrate and stream banks. Overall, entrenchment was observed in a total of 51 % of Trout Brook (Table 11).

Table 11. Selected results from geomorphological survey

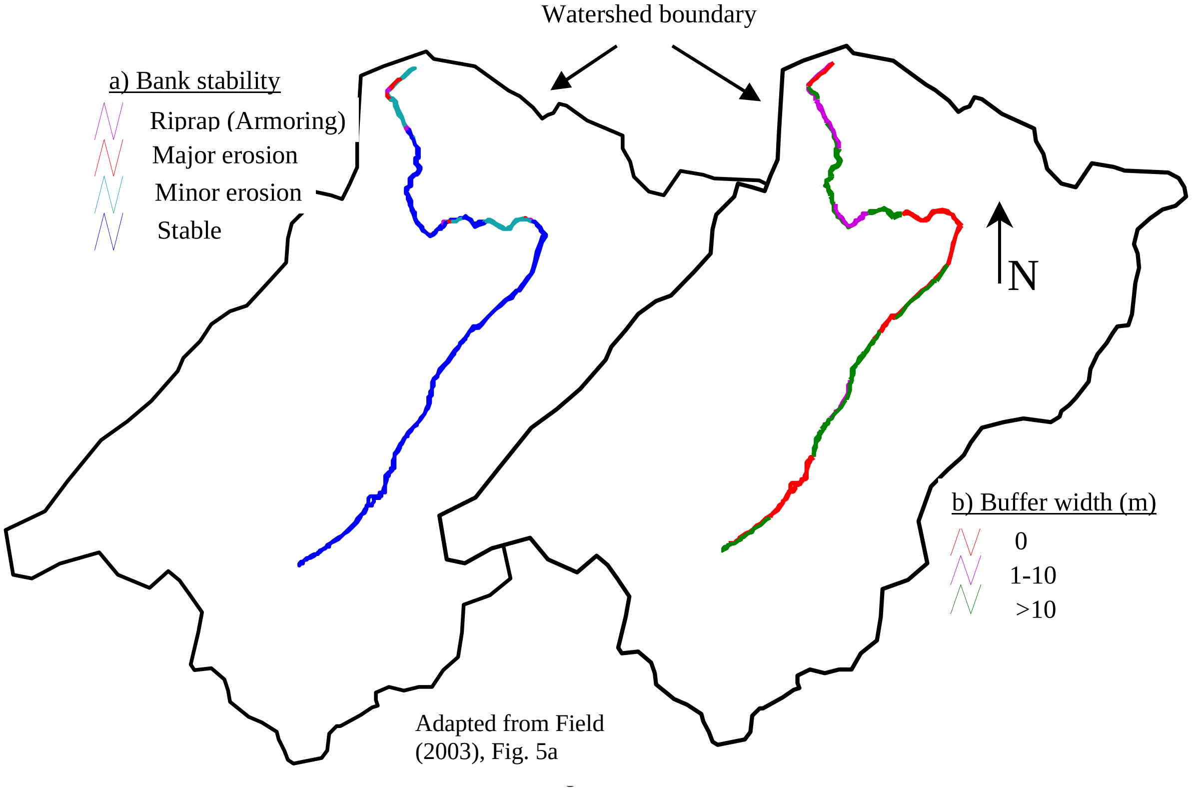
Feature		**Length (m)**	**Percent**
Channelization	Channelized	2,430	59.6
	Encroachment	426	10.5
	Unaltered channel	1,218	29.9
Entrenchment (entrenchment ratio)	Deeply entrenched (<1.4)	405	10.0
	Slightly entrenched (1.4 - 2.2)	1,650	40.6
	Not entrenched (>2.2)	2,014	49.5
Bank stability	Major erosion	186	2.3
	Minor erosion	1,299	15.9
	Armoring / Riprap	150	1.8
	Stable	6,550	80.0
Riparian buffer width	Absent (0 m)	3,221	39.4
	Narrow (1-10 m)	1,366	16.7
	Wide (>10 m)	3,595	43.9

The geomorphological survey showed only few areas where bank stability was identified as a problem (i.e., major erosion), predominantly in the lower part of the watershed, between Broadway and Mill Cove (Table 11; Fig. 20 a; Fig. 5a in Field 2003). Channel armoring with riprap was seen in only two places, where Broadway and Providence Avenue/Marsh Road cross the stream (Table 11). Buffer width was identified as a more extensive problem (Table 11; Fig. 20 b; Fig. 5a in Field 2003). Aggradation, i.e., deposition of sediment in the channel, was identified as an issue in the section between Highland Avenue and Broadway (Trout Brook Site 1 in Field 2003). Here, the original channel was constructed too large for the dominant discharge, and the channel is trying to re-establish an equilibrium through a reduction in bankfull width. This section is in Stage III of Schumm’s Channel Evolution Model (see Fig. 8 and Table 6 in Field 2003), i.e., is approaching the equilibrium stage (Stage V), which generally makes restoration efforts to re-establish sinuosity a good option.

---

[1] Entrenchment is the ratio of the channel width at two times the bankfull depth to the width at the bankfull stage (Field 2003).

Fig. 20. Bank stability (a) and buffer width (b) along Trout Brook



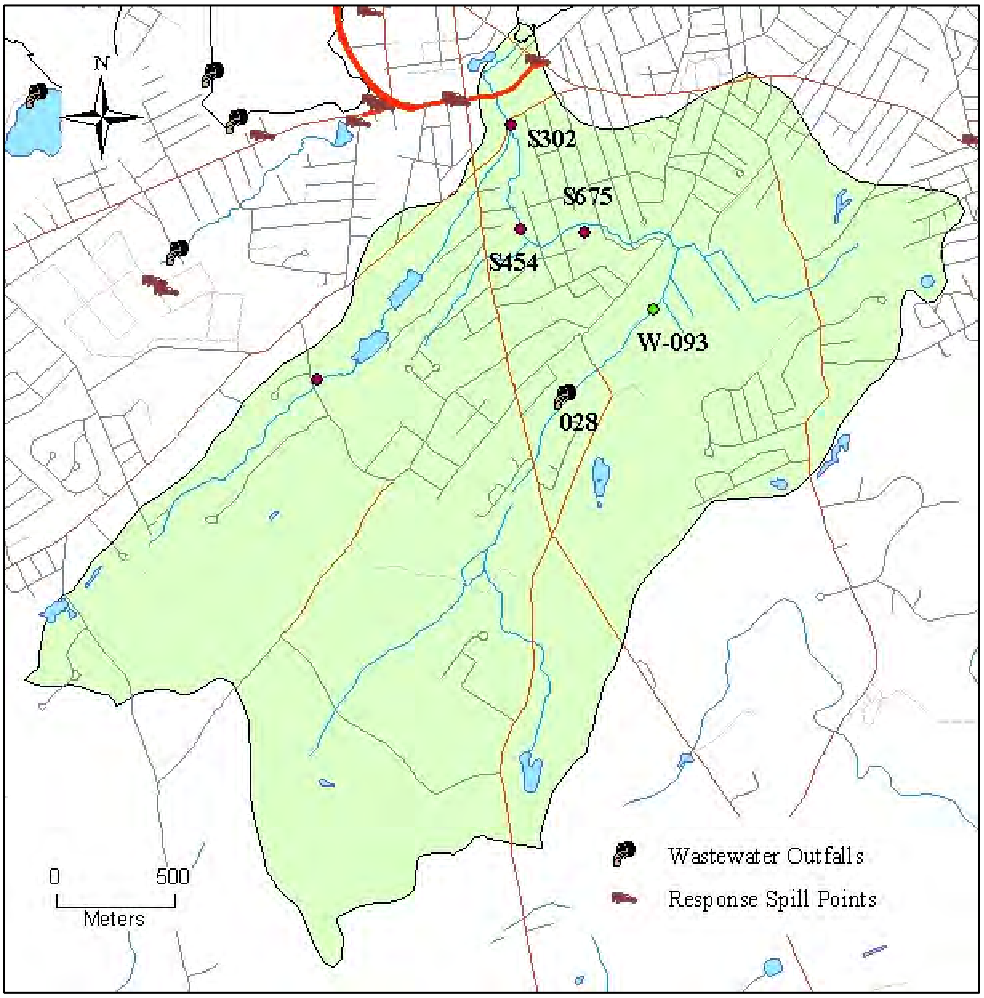
Adapted from Field (2003), Fig. 5a

The survey furthermore included two qualitative assessments of the entire stream. A Rapid Habitat Assessment (as in Table 9, above) showed that most of Trout Brook has a Fair ranking (ranking categories are Poor, Fair, Good, Reference; top score is 200; Table 3 in Field 2003). Specifically, the stream near the downstream biomonitoring station had a Good ranking (131, range is 71 - 130), while it had a Fair ranking near the upstream station (124, range is 71 - 130), and also a Fair ranking (103) near the wetland station. A Rapid Geomorphic Assessment, which is used to evaluate degradation, aggradation, widening, and planform adjustment processes showed that most of Trout Brook is near the high end of the Fair or the Good ranking (ranking categories are Poor, Fair, Good, Reference; top score is 80). Specifically, the stream near the downstream biomonitoring station had a Good ranking (60, range is 41 - 60), while it had a Fair ranking near the upstream station (38, range is 21 - 40), and a Good ranking near the wetland station (58).

6. An analysis of spills documented by the MDEP's Bureau of Remediation and Waste Management between 1976 and 2003 showed that few spills occurred within the watershed (App. E). The spills were confined to the time period between 1989 and 2002. Spatial (GIS-linked) information is currently available for only one of those spills (Fig. 21). In some cases the records contained no information on potential effects of a spill on nearby surface waterbodies, and it was hence not possible to determine whether those spills affected Trout Brook. All incidents concerned spills of heating oil with amounts ranging from <1 - 199 gallons. There was at least one case where a spilled product reached the stream. In that case, 100 gallons of oil were spilled in 1992 on Boothby

Avenue, approximately halfway between the downstream and late upstream stations (75 gallons were recovered, App. E).

Fig. 21. Spill points and wastewater outfalls (CSOs)



There is only one wastewater outfall (or combined sewer overflow, CSO; # 028; Fig. 21) in the watershed. It is located ~500 m above the wetland monitoring station, ~1,250 m above the late upstream station, and ~2,000 m above the downstream station. Discharge data for the last five years for this outfall are shown in Table 12. It is clear that a relatively large amount of stormwater mixed with sewage has been discharged into the stream, with the largest discharge occurring the year the macroinvertebrates attained class at the downstream station (1999; Table 1). As discharges occur above all monitoring stations, there may have been an effect on the 2003 data presented here.

Table 12. Discharge data for CSO # 028 going into Trout Brook

Year	Number of events	Gallons discharged
2003	4	52,688
2002	5	34,896
2001	6	170,460
2000	1	77,437
1999	4	254,903

DATA SUMMARY

The two stream stations studied on Trout Brook were quite similar in many respects. Summary results from all sampling events and assessments are listed in Table 13 and discussed below (in the Discussion), but briefly, both stations had impaired macroinvertebrate communities, high conductivity, elevated TN at baseflow and TP at stormflow, and several violations of metal criteria at stormflow, but relatively cool water and overall adequate habitat (but note geomorphological and riparian zone problems of stream as a whole). Dissolved oxygen concentration was good at the downstream station but low at the late upstream station. "Conclusions and Recommendations", below, contains recommendations on how to maintain good conditions, and suggestions for best management practices (BMPs) and remedial actions aimed at improving poor conditions.

Table 13. Data summary for 2003. Highlighted fields indicate problem parameters.

Parameter	**Downstream (S302)**	**Upstream late (S675)**	**Wetland (W-093)**
Biota			
Macroinvertebrates	Model result "Non-Attainment" (very low diversity, no E or P, 7 T, 1 Class A indicator, 80 % non-insects, intermediate Hilsenhoff Index)	Model result "Non-Attainment" (no E or P, 1 T, no Class A indicators, 17 % non-insects, high Hilsenhoff Index)	Low abundance, medium richness, few EOT[1]
Fish	Low diversity, but many brook trout		
Algae	(observation: few algae)	(observation: few algae)	
Water Quality Parameters			
Dissolved oxygen	Almost always >8 mg/L; diurnal fluctuations <0.6 mg/L	Usually <7 mg/L (as low as 3 mg/L); diurnal fluctuations <1.5 mg/L	Good (9.0 mg/L)
Specific conductance	High (usually 400-700 µS/cm); spikes up to 30,000 µS/cm due to tidal influence	Relatively high (usually ~700 µS/cm)	High (429 µS/cm)

---

[1] For wetlands, "O" (Odonata, dragonflies) are more appropriate indicators of community quality than "P" (Plecoptera) (J. diFranco, pers. comm.).

Table 13 (continued)

Parameter	**Downstream (S302)**	**Late upstream (S675)**	**Wetland (W-093)**
Water Quality Parameters (continued)			
Summer temperature	Cool (mean usually <18 ºC)	Warm (21 ºC)	Normal
Turbidity/ Suspended solids	Turbidity slightly elevated (usually 5-10 NTU); SSD at baseflow <2–17 mg/L, at stormflow 29 and 50 mg/L	No data for turbidity; SSD at baseflow <2–3 mg/L, at stormflow 29 and 70 mg/L	
Nutrients and bacteria	TN and bacteria exceed criteria at baseflow, TP at stormflow	TN and bacteria exceed criteria at baseflow, TP at stormflow	Nutrients and anions/ cations high compared to other ME wetlands
Metals/Anions and cations	No metal violations at base-flow; Al and Cu exceed CMC criteria at stormflow	No metal violations at baseflow; Al, Cu, and Zn exceed CMC criteria at stormflow	
Habitat Assessments			
Flow regime	Quite variable	Partly variable, partly slow	
Stream width/depth	Stable throughout summer		
Woody debris (mean % spanning channel)	Fairly good LWD and SWD, absolute mass greater than relative mass (30 %)	Limited LWD, good SWD, absolute mass much greater than relative mass (18 %)	
Physical characterization	Qualitative assessment: some problems (obvious sources of NPS pollution, moderate erosion)		
Habitat assessment (top score is 200)	Intermediate score (124)		
Human disturbance (best/worst score recorded in ME is 1/44)			Relatively high level of disturbance (score of 29)
Fluvial geomorphology survey	Major channelization, moderate entrenchment, few erosion problems, no/narrow riparian buffer along more than half of stream; Fair to Good Geomorphic Assessment (score 38-60; top score is 80); Fair habitat assessment (score 72-131; top score is 200)		
Spill points	Few spills		
Wastewater outfalls	One, upstream of wetland station, annual discharge 35,000 –170,500 gallons, to be removed in 2004/2005		

DISCUSSION

Biological Monitoring

The macroinvertebrate community observed at the downstream and late upstream stations consisted largely of tolerant organisms, such as amphipods, chironomids and isopods (Table 4). Noteworthy is the repeated dominance of the community at the downstream station by the brackishwater taxon *Gammarus* (up to 97 %), even in 1999 when the community attained Class C; this abundance pattern may be partly related to the periodic intrusion of saltwater into Trout Brook (see Specific Conductance, below). Of further interest is the occurrence of *Glossosoma* at the downstream station, a Class A indicator and sensitive trichopteran that requires cool water and high DO. Generic richness at both stations was intermediate but did not include any Ephemeroptera or Plecoptera although some Trichoptera were found, particularly at the downstream station. Macroinvertebrate data from the downstream station from 2003 (Table 4) are quite similar to those from previous years (1997, 1999, and 2000; see Previous Studies, Table 1), with the exception of total abundance which was lower in 2003 than in other years (208 *versus* 486 – 628). In five of six total sampling events, Trout Brook failed to meet the required Class C aquatic life criteria , i.e., conditions were insufficient to "*maintain the structure and function of the resident biological community …" (*Maine Water Quality Criteria for Classification of Fresh Surface Waters; Title 38 MRSA §465). Although Maine has not yet developed aquatic life criteria for macroinvertebrate communities in wetlands, a comparison between data from the wetland station on Trout Brook with those from high-quality wetlands also indicates that the community was impaired (J. DiFranco, pers. comm.). The continued evidence of impairment is not unexpected given that conditions in the watershed have not changed appreciably in recent years. Also, degraded macroinvertebrate communities similar to the one found in Trout Brook were found in the other three streams included in the Urban Streams Project (excluding the upstream station on Capisic Brook) as well as in other urban streams sampled by the MDEP's Biological Monitoring Program (unpublished data). However, to a certain extent, the result is unexpected because some water quality and habitat parameters (see below) appear sufficient to support functioning macroinvertebrate communities.

The relatively high abundance of healthy-looking brook trout, a fish that is sensitive to water pollution, at the downstream station is likely facilitated by the high dissolved oxygen concentration (generally >8 mg/L; Figs. 4, 8, and 9) and relatively low water temperature measured in this section of the stream (mostly <18 ºC; Figs. 6, 9 and 12). The presence of young-of-the-year trout indicates that this fish is reproducing in the stream. A review of the literature on temperature effects on salmonids by McCullough (1999) showed that adults have an upper thermal tolerance of a mean weekly temperature of 22.3 ºC or a maximum temperature between 19 and 25.6 ºC. Temperatures found in Trout Brook were generally well below the tolerance limits of adults.

The abundance of brook trout in the lower section of this stream is encouraging as it indicates that water quality is good enough to support a sensitive fish species. American eels, although known to be tolerant to water pollution, also occur in unpolluted waters, and their presence in Trout Brook is likely related to the proximity of this stream to the Fore River estuary. Both fish species are carnivores (brook trout consume primarily aquatic insects but also fish and small crustaceans; American eels consume mainly fish and invertebrates), and the absence of other fish species as well as the composition of the resident macroinvertebrate community may be influenced by the abundance of these two fish species.

Maine does not have aquatic life criteria for algal assemblages in streams, and taxonomic data for the downstream station are as yet outstanding, but a visual assessment indicated that algae were not very abundant (see Results, Biological Monitoring, item 3).

The data available by late May 2004 were analyzed with the goal of identifying specific stressors that are responsible for the observed impairment in the macroinvertebrate community in Trout Brook. The stressor identification process (see Ch. 1, Introduction, MDEP Urban Streams Project, and below) pointed to toxicants as the most likely factor to cause impairments at both stations, followed by degraded riparian habitat and altered hydrology at the downstream station, and degraded instream habitat, altered hydrology, and low DO concentrations at the late upstream station. The Total Maximum Daily Load plan (TMDL plan; see Ch. 1, Introduction, MDEP Urban Streams Project) will need to address these factors to enable the restoration of healthy aquatic communities in Trout Brook.

Water Quality Monitoring

Dissolved oxygen

The dissolved oxygen (DO) concentration (instantaneous, diurnal, and continuous, Figs. 4, 8, and 9, respectively) in Trout Brook at the downstream station always was favorable for healthy macroinvertebrate communities. This positive finding is likely attributable to four main factors: 1) the cool temperatures existing in this stretch of the stream (see below) allow the water to hold a high concentration of DO; 2) the low abundance of algae means that oxygen levels are not depleted due to algal respiration and decomposition; 3) the variable flow regime favors (re)aeration of the water, and 4) only few problems exist with high nutrient levels, which helps minimize algal growth.

The DO concentration at the late upstream station (instantaneous and diurnal, Figs. 4 and 8, respectively) was always below 7 mg/L, i.e., below what is generally considered an adequate level for biota. On several occasions, the concentration dropped below the Class C numeric criterion for DO (5 mg/L). One factor involved in lowering DO concentrations at the late upstream station in the summer may be a low flow velocity within the stream above this station as water flows through a marshy area (see Habitat Assessments, Flow velocity, below). However, the main reason for the low DO concentration recorded at this station is probably a significant input of spring water just above this station, in a channel/tributary entering the stream from the left (looking downstream). In the summer, this spring water is the main water source for the upstream station (pers. obs.), and thus it has a large influence on water quality. Based on observations at the station, this spring water likely is not groundwater coming from greater depths (which generally has a DO of ~6 - 10 mg/L) but instead ‘perched groundwater’, i.e., groundwater that collects in the surficial geology layer (Presumpscot Formation) and resides there for some time before draining into a stream (J. Hopeck, pers. comm.). This type of groundwater can have a low DO content due to chemical and biological processes occurring in the surface soils. The iron deposits observed in the area of springs near the station support the hypothesis of perched groundwater: in low-DO perched groundwater, iron is present in soluble form (Fe^{2+}) but upon meeting higher-DO surface water, it becomes oxidized (Fe^{3+}) and precipitates out. Further supporting evidence for the low DO concentrations being the result of the spring water influx is found in the high (8.2 mg/L) concentration measured in late spring of 2004, when (low-DO) spring water constituted only a fraction of total stream flow at the late upstream station.

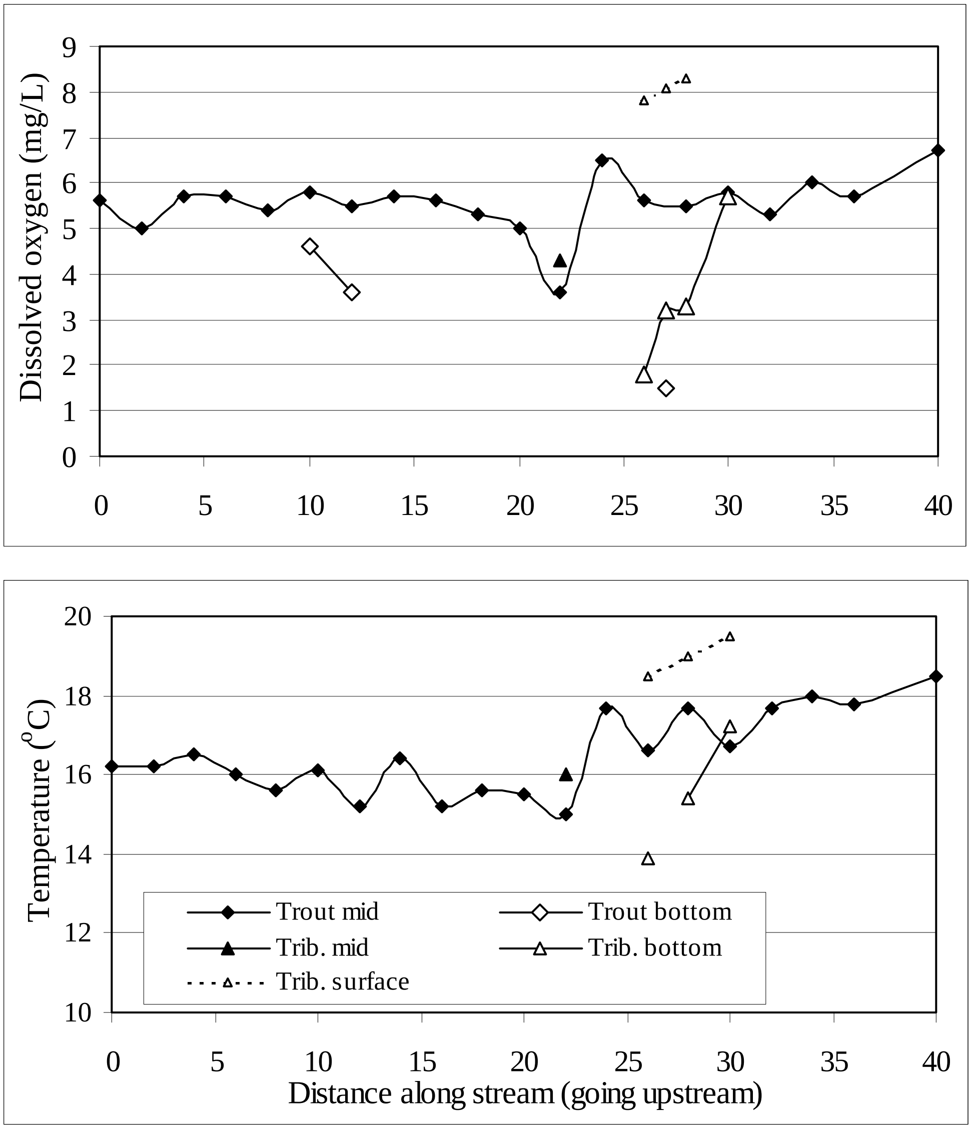
The hypothesis that low DO values are attributable to (perched) groundwater was confirmed with a DO profile collected in the stream itself and in the small "tributary" coming from the area of springs ("Trout" and "Trib.", respectively, in Fig. 22). Measurements were taken as described in Ch. 2, Methods, Water Quality Monitoring, item 1. The profile shows one area (at 26 m, Trib.) with strong gradients in DO and temperature between bottom and surface water (depth of ~20 cm), namely a DO concentration of 1.8 *versus* 7.8 mg/L, and a temperature of 13.9 *versus* 18.5 ºC. Smaller gradients also were found in the tributary at 27 and 28 m (Fig. 22). A gradient furthermore existed at 12 m in Trout Brook where DO was measured at 3.6 and 5.5 mg/L at the bottom and at mid-height, respectively (i.e., over ~10 cm; no temperature measurement was taken at the bottom but a pocket of cold bottom water was indicated by the "cold-feet test"[1]). Such gradients are unusual for a shallow channel and strongly indicate point sources of spring water influx. A marked decline in the DO concentration in the stream itself (from 6.5 to 3.6 mg/L) occurred where the tributary flows into Trout Brook (between 24 and 22 m in Fig. 22). No bottom *versus* surface measurements were taken in Trout Brook above the tributary but the "cold-feet test" did not indicate any signs of spring water influx. This section of Trout Brook is fed largely by water coming from upstream, where DO and temperature were similar as at the 40-m mark in Fig. 22. Additional evidence that groundwater inputs were localized included measurements taken above a culvert ~ 40 m further upstream that showed a DO concentration of 6.7 mg/L and a water temperature of 20.2 ºC, values more indicative of surface water rather than groundwater. The patterns encountered above the late upstream station suggest that the DO concentration at this station likely represents a natural situation which may have a negative effect on the composition of the resident macroinvertebrate community.

The DO concentration at 1:30 p.m. in Trout Brook at the wetland station was quite high given the water temperature (9.0 mg/L at 20.7 ºC). Percent DO saturation was not measured, but can be estimated using the water temperature to have been at ~100 %. This section of stream had abundant emergent vegetation (water lilies, grasses) which likely contributed to the high DO concentration. For comparison, at the downstream station, which had very few plants or algae, the DO concentration at a temperature of 20.7 ºC was only 7.8 mg/L or ~85 % (continuous sonde data, Fig. 9), suggesting that algae and plant contributed to oxygen enrichment at the wetland station. No diurnal measurements of DO were collected at this station, and it is unknown whether diurnal DO fluctuations exceeded 2 mg/L.

---

[1] Areas of spring-water influx were initially located by observing a noticeable chilling of feet in rubber boots.

Fig. 22. DO and water temperature profile at late upstream station in July 2004



"Trout", stream channel; "Trib.", tributary; "mid", "bottom", "surface": mid-water, at bottom, near surface of water.

Dissolved oxygen is required for respiration by all aquatic animals, but some organisms such as stoneflies, mayflies, and brook trout require relatively high oxygen concentrations for healthy functioning. Tolerant organisms like midge larvae or some worms on the other hand can survive at low DO concentrations. In 2003, DO levels generally were high enough to support healthy aquatic communities at the downstream station on Trout Brook, but not at the late upstream station.

Specific conductance

The levels of conductivity (instantaneous and continuous, Figs. 5 and 10, respectively) in Trout Brook are similar to those found in the other three streams included in the Urban Streams Project as well as in other urban streams sampled by the MDEP's Biological Monitoring Program (unpublished data). These levels are often much higher than those that would be encountered in minimally impacted streams in Maine, where conductivity is typically below 75 μS/cm (L. Tsomides, pers. comm.). While certain types of geological formations and certain soil types in a watershed can cause conductivity levels to be elevated naturally, it is likely that runoff from the extensive impervious surfaces near the monitoring stations contributes to high conductivity in this stream (also see discussion on Metals, below). Wetland data indicated that ion (Ca, Mg, K, Na) concentrations in Trout Brook were in the top 10 % of concentrations measured in Maine wetlands (Table 7), which may partly explain the occurrence of high conductivity, and identify some of the components responsible for it. It is noteworthy that conductivity decreased substantially (to ~200 μS/cm) following rain events (Fig. 10) indicating that an input of rain and stormwater temporarily diluted the ions measured with this parameter. Data from previous sampling events in 1997, 1999, and 2000 show that the conductivity levels at the downstream and middle stations have been high for several years (see Previous Studies), i.e., that water quality has been impaired for several years.

While little is known about how elevated conductivity in and of itself may impact biological communities, it is known that metals, which can cause high conductivity levels, can have negative effects on aquatic life (see discussion on Metals and chloride, below). To reduce conductivity levels in Trout Brook, it would be helpful to reduce the quantity of runoff the stream receives, or to improve runoff quality for example by channeling it through an infiltration or stormwater treatment system.

Saltwater intrusions

As shown in Fig. 10, continuous records of conductivity revealed large variations in this parameter that were not picked up by instantaneous measurements. Significant spikes in conductivity (~31,000, 21,000, and 25,000 μS/cm) were recorded during three consecutive nights (at 12:10, 1:00 and 2:00 a.m.) in July 2003, and examination of tide tables showed that high tide in the Fore River/Portland Harbor occurred around those times on the nights in question, suggesting an intrusion of saltwater into Trout Brook. In an attempt to clarify the situation, continuous conductivity data were again collected in early July 2004 with the goal of answering the following questions:

1) Are SPC spikes (>10,000 μS/cm in summer) always related to high tides in the Fore River/Portland Harbor?
2) At what tidal height do saltwater intrusions occur?
3) Do intrusions occur above as well as below the Highland Avenue culvert? (In 2003, continuous SPC measurements were taken only below the Highland Avenue culvert.)

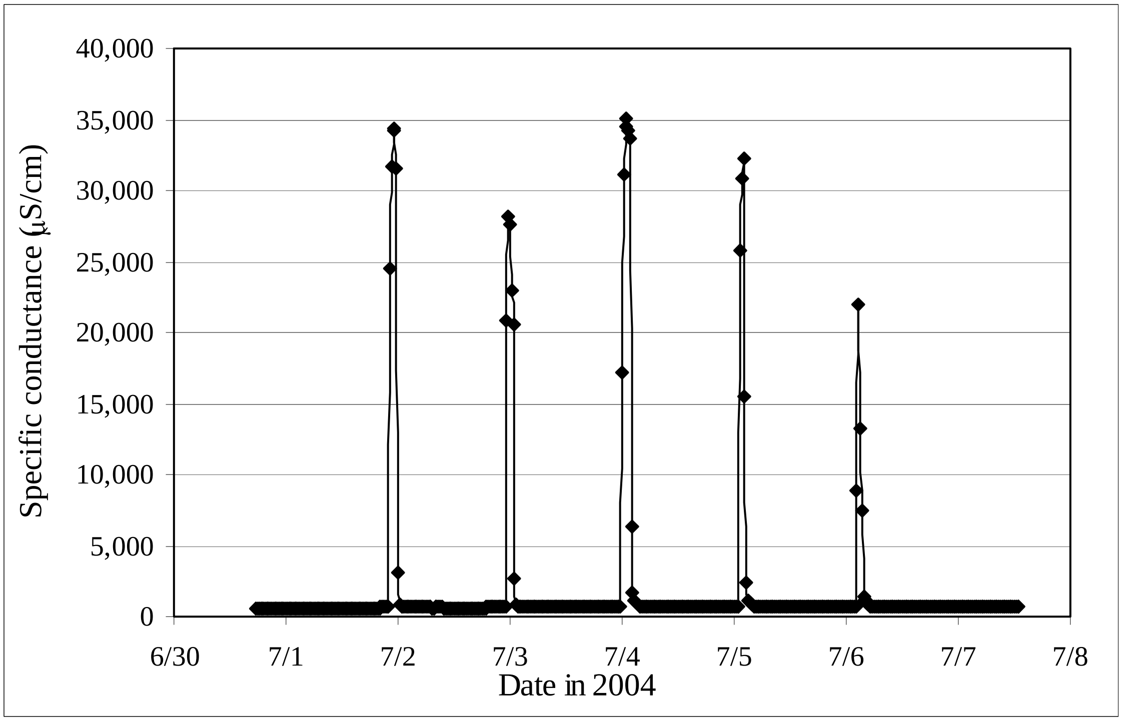
Measurements were taken between June 30 (5 p.m.) and July 7 (1 p.m.), 2004, and raw data collected every 20 min are shown in Fig. 23. Data showed remarkable variation, ranging from 590 to 35,080 μS/cm (Fig. 23) with a clear periodicity of ~25 h for the maxima, which closely tracked the occurrence of high tides (Table 14). Measurements of >10,000 μS/cm[1], which correspond to a salinity of 6.9 ppt at 16 ºC, lasted between 20 and 100 min, starting between 42 min before the time of high tide (at the highest tide level), and 6 min after the time of high tide (at the lowest tide level producing a signal; Table 14). Conductivity always increased very rapidly (between two measurement intervals) at the start of a saltwater intrusion but usually was slower to decrease from >10,000 μS/cm to previous levels (over two

---

[1] A level of 10,000 μS/cm was chosen here as a convenient measurement indicating a conductivity clearly exceeding what could be expected in an urban stream during baseflow conditions in the summer.

to four measurement intervals, i.e., 40 - 80 min). The lowest tidal height producing a signal was 11.0 feet, and no signal was detected at 10.4 feet (Table 14).

Fig. 23. Continuous specific conductance at downstream station in July 2004



Data sondes were deployed both above and below the Highland Avenue culvert but only data from the above-culvert location (i.e., from the downstream station) are presented here (Fig. 23). Data collected below the culvert showed a very similar pattern to those collected above the culvert, with somewhat higher maximum conductivities (up to 40,470 µS/cm), longer occurrence times of SPC >10,000 µS/cm (up to 2 h 40 min), a higher frequency (as above culvert but also on 6/30 and 7/7), and lower minimum tidal heights required for a signal (10.4 feet). The likely reason for the stronger tidal influence below the culvert is the slight elevation difference between the two measurement stations,- and the barrier the culvert presents to water flowing upstream.

Table 14. Tidal and conductivity data from early July 2004 at downstream station. Problem tides are highlighted.

Date in 2004	High tide information	Start of SPC >10,000 μS/cm	Maximum SPC[1]	Duration of SPC >10,000 μS/cm[2]
6/30	9:54 p.m., 11.2 ft	n.a.	620 μS/cm	0 min
7/1	10:40 a.m., 9.4 ft	n.a.	620 μS/cm	0 min
	10:50 p.m., 11.5 ft	10:21 p.m.	34,300 μS/cm at 11:21 p.m.	80 min
7/2	11:37 a.m., 9.6 ft	n.a.	630 μS/cm	0 min
	11:46 p.m., 11.6 ft	11:21 p.m.	28,130 μS/cm at11:41 p.m.	80 min
7/3	12:34 p.m., 9.7 ft	n.a.	650 μS/cm	0 min
7/4	12:42 a.m., 11.6 ft	12:00 midnight	35,080 μS/cm at 1:01 a.m.	100 min
	1:29 p.m., 9.8 ft	n.a.	650 μS/cm	0 min
7/5	1:38 a.m., 11.4 ft	1:21 a.m.	32,230 μS/cm at 2:01 a.m.	60 min
	2:24 p.m., 9.8 ft	n.a.	670 μS/cm	0 min
7/6	2:35 a.m., 11.0 ft	2:41 a.m.	21,930 μS/cm at 2:41 a.m.	20 min
	3:19 p.m., 9.7 ft	n.a.	640 μS/cm	0 min
7/7	3:32 a.m., 10.4 ft	n.a.	690 μS/cm	0 min

[1] Whenever maximum conductivity was <1,000 μS/cm, measurements were relatively constant over extended periods of time, and no time is specified in the table.

[2] Duration is calculated as the time between two measurements taken at 20 min intervals. Because measurements >10,000μS/cm likely also occurred (shortly) before/after the first/last elevated measurement, periods given in the table are minimum durations.

Conductivity data collected in July 2004 clearly indicate that the downstream station on Trout Brook is subject to tidal influence. The occurrence of saltwater intrusions appears to be limited to the highest tides, that is those of 11 feet or greater. Consultation of tide tables for 2004 showed that during the entire year, only 34 high tides (out of ~700) reached or exceeded 11 feet, with the majority of cases occurring in June/July and December. The arbitrary conductivity level of 10,000 μS/cm chosen here to indicate the beginning of a marine intrusion corresponds to a salinity of 6.9 ppt at 16 ºC, while the highest conductivity measured (35,080 μS/cm at 16.7 ºC) corresponds to a salinity of 26.8 ppt. For comparison, seawater has a salinity of ~35 ppt but an estuary such as the Fore River would have a lower salinity. While only few insects occur in marine waters, insect density and diversity can be quite high in estuaries, particularly in the more upstream reaches (Williams and Williams 1998; Williams and Hamm 2002). For instance, Williams and Hamm (2002) found that in three estuaries in New Brunswick, Canada, EPT taxa as well as some Coleoptera (beetles) and Diptera (flies, here: chironomids) dominated sites inundated by 25 % of high tides. The sensitive trichopteran *Glossosoma*, which was observed at the downstream station in Trout Brook, occurred at a site inundated by 33 % of high tides in an estuary in Wales, U.K. (Williams and Williams 1998). The literature therefore suggests that the mere occurrence of a limited number of saltwater intrusions would not necessarily have a negative impact on the macroinvertebrate community.

Water temperature

The relatively cool mean temperatures (continuous temperature in 1997 and 2000, Figs. 2 and 3; instantaneous, and short and long-term continuous temperature in 2003, Figs. 6, 9 and 12) at the downstream and late upstream stations on Trout Brook were favorable for sensitive biota. Maximum temperatures at these stations were mostly below 20 ºC, but occasionally reached up to 22 ºC, which is warmer than ideal for most aquatic organisms. These maxima occurred only for relatively short periods of time (~1.0 - 1.5 hours) before dropping below 20 ºC, and may thus not have had a major impact on animal health. Compared to the other Urban Streams, Trout Brook had the second lowest temperatures after the upstream station on Capisic Brook (App. C ii). Studies have shown that sensitive macroinvertebrates such as certain mayflies or stoneflies prefer temperatures below 17 ºC (see references in Varricchione 2002), while sensitive fish such as brook trout prefer mean temperatures below ~22 ºC (see Biological Monitoring, above). Factors responsible for the good temperature regime, especially at the late upstream station, are the closeness to a number of springs, which provide most of the flow in summer, and a riparian zone with many trees providing good shading along some reaches. It is important to preserve these conditions to ensure that favorable temperatures are maintained in Trout Brook, especially for the resident brook trout population.

One exception to the generally favorable temperature regime was the early upstream station where high temperatures were measured in a shallow area with little flow in early June and July, shortly before this location began to dry out (see Ch. 2, Methods). In late spring and in summer, this area did not show a definite stream channel but rather was made up of a network of small rivulets slowly draining into a marshy area. Furthermore, throughout the upper 1/3 of the watershed, down to Sawyer Street (~400 m above the early upstream station), Trout Brook flows largely through open, partly marshy areas with little flow in the summer, conditions that allow the water to warm up significantly. Given the conditions above and at the early upstream station, high summer temperatures may be natural for this location. If so, this area may not be good habitat for fish and aquatic invertebrates because of elevated temperatures and very low summer flows.

pH

In natural waters, pH usually falls between 6.5 and 8.5, and a range of 6.0 - 9.0 protects most aquatic life. All measurements taken on Trout Brook were within a range that favors healthy macroinvertebrate and fish communities.

Turbidity

Like the other Urban Streams, Trout Brook lies within the Presumpscot formation, a surficial geology type dominated by fine sediments. At all Urban Streams, silt and clay dominate over sand, contributing to an increase in turbidity during high flows due to suspended fines (App. G). Analysis of the data indeed showed that high flow events following rain storms caused large turbidity spikes on July 25 and August 1 (Fig. 11 a). During baseflow conditions, turbidity in Trout Brook was quite low (Fig. 11 b), although the turbidity criterion of 3.04 NTU recommended by EPA for Ecoregion XIV (USEPA 2000b), which includes Trout Brook, was exceeded 31 % of the time (485 out of 1,582 records). Total suspended solids were generally low in Trout Brook during baseflow conditions (Table 5, App. C iii) but elevated during stormflow conditions (Table 6).

Suspended solids, which affect the turbidity of a stream, can be of natural origin (clay, silt, sand, decaying vegetation, phytoplankton) or man-made (industrial wastes, sewage, winter road sand). Land use (e.g., urban *versus* forested) and local soil type (e.g., silt and clay *versus* bedrock) are important factors that influence turbidity levels in a stream. High concentrations of suspended solids can affect streams and the organisms living in them in a variety of ways: by modifying light penetration which affects plant growth; by smothering benthic organisms thus affecting their health; by increasing substrate embeddedness; by reducing available invertebrate living space; by reducing the flow of oxygen-rich surface water through stream gravels and cobbles where salmonid fish eggs may be incubated; by reducing the ability of visual predators to find prey; by clogging the gills of fish; and by potentially darkening the water which may lead to an increase in temperature through increased absorption of heat from sunlight. Turbidity in Trout Brook generally was not high enough to have a major negative effect on biota in the stream although some effects, particularly during storm events, may occur.

Nutrients and bacteria

The surface water samples collected at the downstream and late upstream stations during baseflow conditions exceeded the recommended EPA water quality criterion for Total Nitrogen (TN) on all sampling dates (Table 5). A similar result was found in 2000 at the downstream station (Table 2), and during limited sampling in the summer of 2004 at both stations (App. C iii). Furthermore, samples collected in August of 2004 at both stations exceeded the EPA criterion for Total Phosphorus (TP; App. C iii). Compared to the other impaired Urban Stream stations, Trout Brook in 2003 was generally similar in baseflow TN levels (App. C iii), the abundance of algae (low), and canopy cover (high) to both stations on Birch Stream and the middle station on Barberry Creek. Compared to the downstream station on Capisic Brook, which had excessive algal growth and an open canopy, TN levels in Trout Brook at baseflow were lower. During stormflow conditions, Total Phosphorus (TP) exceeded the EPA criterion on three out of four dates (Table 6). Compared to the other Urban Streams, Trout Brook had the highest stormflow TP values in the spring of 2003 and on one date in February 2004, but intermediate values in the fall of 2003, and low values on a second date in February 2004 (App. C iv). Data from the wetland sampling showed that nitrogen (nitrate-nitrite-N, TN) values were among the highest measured in Maine wetlands by the biomonitoring program (Table 7).

Nutrient levels are often increased in urban streams as runoff from land includes material that is high in nitrogen, such as animal waste, fertilizers, septic system effluent, or road dirt (CWP 2003). In Trout Brook, nutrient load may also be increased by runoff from the vegetable farm in the upper part of the watershed: a water sample collected ~300 m below the farm in summer 2004 showed elevated TN and TP values exceeding EPA-recommended nutrient criteria (App. C iii). (Water quality data upstream of the farm are not available.) Furthermore, many cities, including South Portland, operate a combined sewer overflow (CSO) system which can allow raw sewage to enter a stream during storm events. When this happens, the bacterial and nutrient load in the stream increases (see Spills and wastewater overflows, below). The MDEP's Biological Monitoring Program has found that, depending on site characteristics, elevated nutrient levels in urban streams may impact macroinvertebrate communities. This can occur for example when exposure of the stream to sunlight promotes excessive plant and algae growth which in turn may cause temporary DO depletion (L. Tsomides, pers. comm.). The small amount of algal growth, adequate dissolved oxygen concentrations, limited exceedances of nutrient criteria, and low Chl *a* values suggest that nutrients are not a significant stressor at the downstream station in Trout Brook. The same is likely true at the late upstream station where little algal growth and nutrient enrichment was observed also; at this station, however, dissolved oxygen concentrations were always low, likely due to natural causes (see discussion Dissolved oxygen, above). It is unclear why nitrogen levels at the wetland station ranked so high compared to other locations in Maine but potential reasons are the presence of a CSO ~500 m above the wetland station and runoff from the vegetable farm in the upper part of the watershed.

Maine's criterion for the mean count of bacteria (*E. coli*) colonies of human origin was exceeded at both stations on all sampling dates (by up to a factor of 9). However, it is not known whether this constitutes a true criterion violation as the analysis performed in this study did not differentiate among various sources for bacteria (pets, wildlife, birds, CSOs, leaking sewer systems). Most of these sources are present in the Trout Brook watershed: pet waste near the stream was observed during a watershed survey in April 2003 (pers. obs.); wildlife and waterfowl use the stream and surrounding area as a resource (pers. obs.); and large amounts of storm water mixed with raw sewage enter Trout Brook from a CSO each year (Table 12). According to information obtained from the City of South Portland (D. Pineo, pers. comm.), two other potential sources of bacteria (a few homes with septic systems on Kaler Road, and sewer pipes paralleling Trout Brook in the wetland and along Marsh Road) are unlikely to be major issues.

Although nutrients and bacteria may not be a significant issue in Trout Brook, simple measures to control them should be initiated. Such measures could include keeping pets away from the stream, picking up pet waste, minimizing fertilizer use on lawns in the vicinity of the stream or its tributaries, and ensuring that sewer and septic systems in the watershed are in good working order. Furthermore, the maintenance or re-planting of a vegetated riparian buffer along the stream corridor would allow for the filtration of lawn or yard runoff. However, to effectively control nutrient, and likely bacterial, loads in Trout Brook, entry of raw sewage into the stream needs to be prevented. To this end, the City of South Portland is currently working on separating the CSO in the wetland section, thus eliminating this potential stressor. Furthermore, the farm in the upper part of the watershed should be encouraged to minimize fertilizer use as nutrient levels were found to be elevated below the operation.

Metals and chloride

None of the metals sampled during baseflow conditions in 2003 exceeded Maine Statewide Water Quality Criteria (SWQC; Table 5) at the late upstream or downstream station. The same result was also found in 2000 at the downstream station (Table 2). Limited sampling in the summer of 2004 showed that aluminum exceeded the chronic criterion (CCC) once at each station (App. C iii). At the same time, copper was below the CCC at both stations, and lead was below the acute criterion (CMC; detection limit was above CCC). One sample collected below the farm in the upper part of the watershed showed that aluminum was at the CCC, copper was below it, and lead was below the acute criterion (detection limit for lead was above CCC; App. C iii). During stormflow conditions in 2003, aluminum, copper, and zinc exceeded Maine SWQC at one or both stations (Table 6). Unfortunately, for some samples the detection limits for certain metals were above the water quality criteria, for example in 2003 in the case of copper for both chronic and acute criteria. Varricchione (2002) studied a stream (Long Creek) in a highly developed area in South Portland, and found that copper, lead, and zinc exceeded acute criteria during three storm events. Compared to Varricchione's results, Trout Brook showed slightly fewer criteria violations.

The metals detected in Trout Brook likely originated as metal pollutants that had adsorbed onto particles of road dirt which were subsequently blown or washed into the stream. Beasley and Kneale (2002) and CWP (2003 and references therein) cited as sources for metal pollution in urban streams vehicles (tires, brakes, fuels, and oils), pavement (concrete, asphalt), rooftops, exterior paints, and surface debris (litter, winter road sand and salts). Lead may also enter the stream from CSO pipes (J. True, pers. comm.). Aluminum and iron can also occur naturally in streams as these metals are very abundant, and can leach out of soils with low pH-buffering capacity. Zinc can also originate from galvanized steel pipes used for culverts or storm drain systems. Sediment entering the stream from construction sites, winter sanding activities, or soil erosion also may carry metals (e.g., CWP 2003). Finally, spills of hazardous substances and CSO input also can add metals to a waterbody. Impacts of metals on streams can occur in the form of chronic or acute toxicity to aquatic organisms, contamination of sediments, and bioaccumulation in plants or animals (CWP 2003 and references therein). Negative effects of metals on macroinvertebrates and fish have been confirmed in several studies. Effects include declines in the rates of growth and reproduction, reduced population size, changes in community structure, and death (Paul and Meyer 2001, and Beasley and Kneale 2002, and references therein). To reduce metal pollution in Trout Brook, road runoff needs to be diverted away from the stream or treated before entering the stream. Also, sand left in parking lots and on roads after the end of the winter sanding season should be removed to reduce the sediment influx into the stream. While the City of South Portland has a road sweeping program in place (D. Pineo, pers. comm.) and is thus minimizing sand influx into the stream, it is not known whether businesses and schools in the lower part of the watershed also remove sands from their premises. If they do not, they should be encouraged to initiate this practice. Rigorous application of BMPs by construction companies and the greening of bare surfaces also would help reduce sediment/metal input into Trout Brook.

Chloride levels during baseflow conditions in the summers of 2003 and 2004 were far below the chronic criterion at the late upstream and downstream stations, and below the farm (App. C iii). Chloride concentrations are expected to be low in the summer as this pollutant predominantly reaches waterbodies as road runoff during the winter and spring. No winter/spring data exist for Trout Brook, and this data gap should be filled, preferably by deploying a continuous data sonde measuring conductivity. Conductivity is strongly affected by chloride because this anion typically occurs in high concentrations (in contrast to metals, it is measured in mg/L rather than μg/L), making SPC measurements a convenient way to determine chloride loads in winter and spring. Conductivity levels of up to ~23,000 μS/cm have been seen in studies of urban streams in the winter (S. Corsi, pers. comm.). This indicates high chloride toxicity as conductivities of 853 and 2,855 μS/cm correspond to the Maine SWQC (MDEP SWQC) chronic and acute criteria of 230 and 860 mg/L chloride, respectively (D. Heath, pers. comm.). According to storm drain maps obtained from the City of South Portland (D. Pineo), most snow that melts on roads, parking lots, or driveways in the watershed flows into Trout Brook either directly or via the storm drain system with outfalls located on Norman Street, at the intersection of Providence Avenue and Marsh Road, above Highland Avenue, and below Broadway. Additional outfalls are located on the tributaries to Trout Brook. The South Portland public works garage off Cottage Road, which includes sand/salt stored in a shed, drains into the Trout Brook watershed but this should not present a pollution hazard as the entire facility is connected to the sewer system (D. Pineo, pers. comm.).

Habitat Assessments

Flow regime

The variable flow regime found at the downstream and most of the late upstream station (instantaneous flow velocity and thalweg velocity, Figs. 13 and 14) is a positive feature of these sections of the stream as it provides aquatic organisms with a wide variety of environments to occupy, thus increasing the potential for a diverse biological community. Furthermore, a swift flow regime reduces siltation, and promotes re-aeration of the stream with dissolved oxygen.

Flow velocity in the upper ~35 m of the section around the late upstream station (Fig. 14) was very low, which is likely in part a natural condition. Above this section, near the early upstream station, the stream in the summer lacks a distinct channel but rather consists of a network of small rivulets slowly draining into a marshy area. At the outflow of this area (at the ~95 m mark in Fig. 15), a spring-fed channel joins the stream and helps re-establish a defined channel leading to the late upstream station where a small (~12” tall) cobble dam creates a pond-like situation before a distinct channel with good flow is re-established (at the ~65 m mark in Fig. 15). Above the dam, the stream bottom consists of fine sediment, indicating a significant siltation problem. Removal of the dam likely would improve flow patterns and reduce siltation for an additional ~25 m, leaving only the uppermost ~10 m within the marshy area to be less favorable habitat for macroinvertebrates in terms of flow velocity.

Stream width and depth

The patterns of stream width and depth (Figs. 15 and 16, respectively) at the downstream station reflect the morphology of the stream channel in this section of Trout Brook: the banks are fairly steep here so that changes in water volume within the channel have a greater effect on depth than width. In contrast, the stream channel at the late upstream station was very broad, with much exposed substrate, and changes in water volume within the channel had a noticeable effect on width. The decrease in depth at the downstream station between spring and summer is related to the usual decrease in baseflow between these two seasons. The depth pattern at the late upstream station may be partly explained by the method used to measure depth (measurements taken at 3 points evenly spaced between left and right edge-of-water rather than at 3 fixed points); at the shallow depth found at this station, taking a measurement on top of a cobble as opposed to on the stream bottom can significantly influence mean depth. At the early upstream station, the strong decrease in width and depth was related to the declining water level in this section of Trout Brook, which, as previously mentioned, led to the abandonment of this station.

On the whole, wetted width and depth at the downstream and late upstream stations on Trout Brook were relatively stable, providing similar amounts of submerged habitat to benthic organisms throughout the sampling period. At the early upstream station, habitat availability was markedly reduced between spring and summer, forcing benthic organisms into a much smaller environment, or else leaving them high and dry. As noted in previous sections, this stretch of Trout Brook provides less than ideal habitat for animal communities for a variety of reasons (low DO, high temperature, low flow velocity), a condition that is likely natural for this location.

Woody debris

Overall, woody debris abundance and size distribution were more favorable at the downstream than the late upstream station. This pattern is likely related to the availability of wood in the riparian zone. Above the downstream station, the riparian buffer width is 1 - 10 m or >10 m for ~900 m, while that distance is only ~100 m at the late upstream station. Furthermore, the wider channel at the late upstream station likely facilitates greater export of large woody debris (LWD) during high flows as pieces of wood are not caught on banks or exposed roots. A difference in LWD export is also indicated in the percentage of LWD spanning the channel, which is lower at the late upstream station (18 % *versus* 30 %). This suggests that flows more readily align LWD parallel to the direction of flow in this location, and subsequently carry LWD pieces away.

Absolute mass of LWD (diameter * length) was similar at both stations, but relative mass was greater at the downstream station. Relative mass takes into account the percent of the channel LWD spans, so that a trunk lying across the entire channel (i.e., spanning 100 %) would have the same absolute and relative mass (i.e., absolute mass * 1) while a trunk lying almost parallel to the flow would have much lower relative than absolute mass (e.g., absolute mass * 0.2). The comparison between these two measures, or the average percent spanning the channel at each station (30 and 18 % at the downstream and late upstream stations, respectively), can give an indication of flow patterns as a high maximum flow velocity tends to align LWD with the flow, thus reducing the percent spanning value. Data then suggest that maximum flows are greater at the upstream station. However, the occurrence of high maximum flows both upstream and downstream was indicated by other observations made at both stations, namely “flattened” herbaceous vegetation in the riparian zone following rain events (pers. obs.), and very high flows following a large storm event (3.3” of rain in 24 h, ending shortly before visit; App. G, Figs. 3 - 5). The greater relative mass (higher percent spanning) at the downstream station can be explained when examining bankfull width, which also influences the percent spanning as LWD is more likely to get snagged in a narrower channel, leading to a higher percentage. As the channel at the downstream station is much narrower than at the late upstream station (4.3 *versus* 6.0 m; Field 2003, Table 2, reaches 5 and 2, respectively), the percent spanning value would be expected to be higher downstream if maximum flow velocities are similar.

A comparison between LWD found in Trout Brook and in two reference streams exemplifies the situation in Trout Brook. For LWD >5 cm diameter, data collected in a reference stream northwest of Bangor showed that LWD abundance was similar in that stream and at the downstream station on Trout Brook (42 *versus* 41 pieces) but that the reference stream had a greater average mean diameter (12 cm *versus* 10 cm), and higher mean percent spanning (41 % *versus* 30 %). Differences between the reference stream and the late upstream station were greater (42 *versus* 22 pieces, 12 cm *versus* 9 cm, and 41 % *versus* 18 %). This suggests that the downstream station on Trout Brook has a more natural LWD composition than the late upstream station, likely because of the more intact riparian buffer and narrower channel. For LWD >20 cm diameter, the geomorphological survey noted an LWD abundance in Trout Brook overall of 0 pieces per 100 feet of channel in 95 % of the stream, 1 - 2 pieces in 5 %, and >3 pieces in 0 % of the stream (Field 2003, Table 4). The corresponding percentages in a reference stream in Cape Elizabeth (adjacent to South Portland) were 18 %, 66 %, and 16 %, indicating that large LWD in Trout Brook is much less abundant than in a natural setting.

The abundance of small woody debris (SWD) at the late upstream station reflects the large number of small trees growing up in that area, especially within the ponded up section above the cobble dam (above ~60 m in Fig. 18). If small trees are excluded, 50 pieces of SWD were found, about the same number as at the downstream station. Small woody debris is less valuable as woody debris than larger pieces because it is exported more readily (unless it is in the form of a live tree), and provides fewer possibilities for shelter, colonization, or trapping of materials.

Woody debris enhances the habitat quality for aquatic organisms by providing stable attachment sites, providing and trapping organic materials to be used as food sources, trapping sediments, increasing habitat diversity and being a food source in and of itself (Dolloff 1994). Trees in the riparian zone, before they become woody debris, also provide leaf litter, which is an important food source for a variety of macroinvertebrates. Trout Brook is fortunate in having a fairly intact riparian buffer for much of its length although ~ 40 % of channel length lacked any streamside/riparian buffer (Table 11). Because of its many advantages, it is important to maintain a wooded buffer where present, and plant trees where the buffer is impacted by lawns. An additional benefit of replanting is the stabilization of stream banks, which show signs of minor erosion in a few sections of Trout Brook (see Geomorphological assessment, below).

Qualitative stream/wetland and habitat assessments

Qualitative assessments of the physical features of the stream and riparian area, the instream and riparian habitat, and the wetland and watershed disturbance status showed that Trout Brook suffers some of the typical problems of a stream located in a highly developed area. Non-point sources of pollution in general (e.g., sediment, fertilizer/pesticide use, dumping of grass clippings and garbage) and impervious surfaces in particular (houses, roads, parking lots) were identified as concerns, as were a slight sewage smell at both stations, and alterations to the stream channel (channelization, reduced bank stability), riparian zone (narrow riparian buffer), and wetland area (draining, filling, removal of vegetation). Some of these issues were also documented in the geomorphological survey (see next section). On the whole, however, assessments and personal observations showed that the physical problems in and around Trout Brook appear limited in extent. This may be partly attributable to the fact that the watershed has been developed for many years, which has allowed the stream to approach a new equilibrium condition (see Geomorphological survey section below). Several of the areas of concern identified can negatively influence aquatic biota, either directly or indirectly. For example:

- High impervious surface cover in a watershed causes an alteration in stream hydrology, an increase in pollutant concentration, a decrease in rainwater infiltration, and direct impacts on the stream channel. These factors can lead to a reduction in habitat quality and stability, in water quality, and in baseflow volume.
- A sewage smell may indicate input of raw sewage (from a CSO or leaking sewer/septic systems) into the stream. This could be harmful for biota as elevated nutrient levels can cause excess algal growth and lowered DO concentrations.
- Channel alterations (i.e., straightening) reduce sinuosity of the stream, thus eliminating habitat diversity.
- Clearing of vegetation along the banks and in the riparian zone reduces bank stability, decreases filtration efficiency of the soil, and eliminates shading of the stream. These factors can cause increased sedimentation, decreased habitat stability, increased pollutant input, and elevated water temperatures.

Some of these areas of concern can be addressed relatively easily, for example by separating the CSOs (this project is underway, see Nutrients and bacteria, above), and by replanting the riparian buffer where lawns currently abut the stream. Other issues, however, such as the high percentage of impervious surfaces and channel alterations will require more effort, for example the installation of stormwater treatment systems, and the re-establishment of a natural channel morphology as described in the following section.

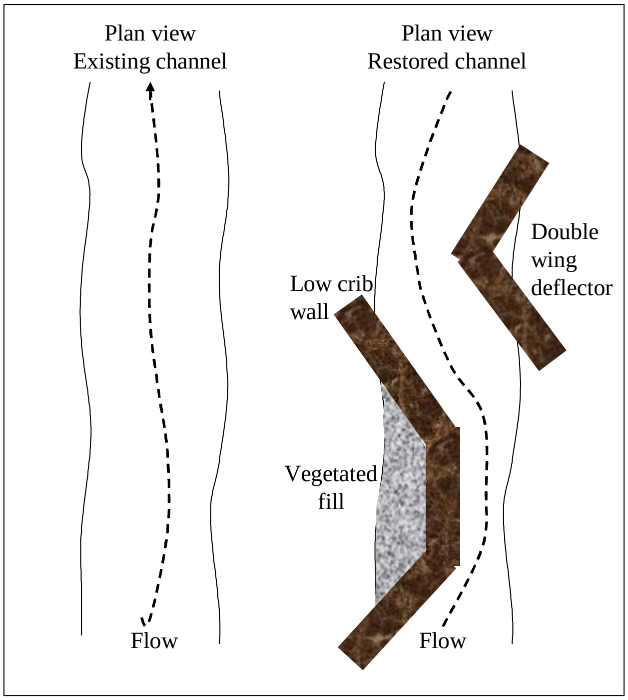
Geomorphological survey

Historical analyses of changes in watershed landuse and channel morphology as well as extensive field work showed that with 54 % of the watershed being built-up, stream geomorphology shows clear signs of damage from human intervention. More than half of the stream has been channelized, half of the stream is slightly or deeply entrenched, ~20 % of the stream shows signs of erosion or is armored, and more than half the stream has a riparian buffer of <10 m (Table 11, Fig. 20). The problems that were documented occurred throughout most of the watershed. Stream habitat was also impacted as shown in the Rapid Habitat Assessment. This assessment indicated that at both stations, stream habitat for biological communities is affected in terms of physical attributes such as epifaunal substrate and available cover, sediment deposition, bank stability, or bank vegetative protection. As discussed in the preceding section, the same assessment also was carried out on a smaller scale, just around each station, with similar results for both stations. Overall, the assessments documented that habitat problems were more pronounced in the lowest section of Trout Brook, near Mill Pond, and in the upper part of the watershed.

A Rapid Geomorphic Assessment showed that most of Trout Brook is near the high end of the Fair or within the Good ranking (ranking scale is Poor, Fair, Good, Reference). This type of assessment is used to document current geomorphological adjustment processes occuring in a stream in response to various watershed, floodplain, and channel modifications by evaluating channel degradation (incision or downcutting, i.e., lowering of stream bed elevation through erosion or scour of bed material), channel aggradation (i.e., raising of stream bed elevation through accumulation of sediment), channel widening, and changes in planform (i.e., the channel shape as seen from above). The assessment documented an overwidened channel, and resulting aggradation, in Trout Brook below the downstream biomonitoring station (below Highland Avenue). This indicates that the channel was constructed too large for the dominant flows when this section of the stream was channelized, and that the stream has subsequently been trying to re-establish equilibrium by reducing bankfull width (Field 2003). Aggradation, likely as a result of channel overwidening, is also evident in the stretch above Boothby Avenue (pers. obs.). While the majority of the aggrading sediment may be naturally derived from the underlying geology (see below), it is likely that some sediment enters the streams from roads, parking lots, or construction sites.

The geomorphological assessment of Trout Brook revealed signs of degradation due to development. Most of these problems are limited in extent, and some sections on Trout Brook are fairly intact, for example the section between Highland Avenue and Boothby Avenue. However, the stream would benefit from simple restoration activities, notably tree plantings in the areas where the riparian buffer is absent (Fig. 20 b), and also from more technically involved actitivities. For example, the previously channelized section above Boothby Avenue where aggradation is occurring may be a good candidate for having some of its sinuosity restored by installing double wing deflectors in the stream, vegetating the bars formed by accumulating sediment, or infilling behind crib walls (Fig. 24). Because this section of the stream was channelized many years ago (likely before 1964, Field 2003), the stream has had time to adjust to the alteration, and it is now approaching a new equilibrium condition.

Fig. 24. Restoration design for middle section (schematic representation, after Field 2003, Fig. 9a)



As a result, little future change should be expected, and a restoration project should be successful if no significant changes in the dominant peak discharge occur. Because of the highly complex nature of fluvial geomorphology, any restoration activity will require the extensive involvement of a trained professional.

Spills and wastewater overflows

An analysis of spill points documented by the MDEP's Bureau of Remediation and Waste Management showed that only few spills have occurred within the watershed, indeed the lowest number of all Urban Streams (App. E). This low number of spills is likely attributable to the low percentage of urban/industrial and commercial-industrial-transportation development within the watershed (7 % of total landuse, compared to 21 - 40 % in the other three streams), and the relatively low percent of impervious surfaces (13 % compared to 24 - 33 %). Because of a lack of detail in spill records, it was not possible to determine whether certain spills shown in App. E affected the stream but at least one spill (100 gallons of heating oil 75 of which were recovered; 1992) reached the stream. The high density of residential development in the middle and upper part of the watershed also suggests that undocumented spills of substances used in private households (e.g., automobile oil, paint or paint thinners, cleaning agents) may occur in the watershed, and may impact water quality in Trout Brook. Indeed, a watershed survey conducted by the South Portland Land Trust in April 2003 documented many signs of hazardous practices thoughout the watershed (pers. obs.; SPLT in prep.). On the whole, spills may have impacted stream quality and the health of resident biota. To reduce the future occurrence of spills in the watershed, outreach efforts targeting private households as well as businesses should be undertaken to inform the public of the negative effects spills of any amount and product may have on stream quality. Such public outreach efforts should be accompanied by suggestions for improvements to current practices of e.g., delivering, handling, and storing fuel oil or other hazardous products. Also, storm drain stenciling has proven useful in alerting the public to the fact that any substance reaching a drain will go into a nearby waterbody where it may cause harm.

Based on the data collected in this study it is not possible to link the observed impairment in the macroinvertebrate community at the downstream station directly to an influx of combined stormwater and raw sewage (Table 12). Two studies that documented organic pollution (i.e., enrichment) in streams due to CSO influx also found evidence for DO depletion (Sztruhar et al. 1997), and an alteration in benthic community structure (Rochfort et al. 2000). For Trout Brook, the available data indicate that enrichment is not a major problem (nutrients were eliminated as a stressor in the SI Process, see next section). One study on CSO discharges failed to establish toxic effects on benthic communities (Rochfort et al. 2000) and, it is unknown whether this is a problem in Trout Brook. To eliminate any potential impacts of raw sewage on the stream, the CSO must be eliminated, and the City of South Portland is currently (2004) working on this issue (D. Pineo, pers. comm.). Because of the particulars of this CSO separation project, this work will not result in an increase in the amount of stormwater runoff the stream receives.

STRESSOR IDENTIFICATION PROCESS

On May 26, 2004, the EPA Stressor Identification (SI) process was applied as described in Ch. 2. The extensive review of available data and discussion among the biologists and engineers present led to the identification of the stressors and their sources as listed below for the downstream and late upstream stations on Trout Brook. Although the stressors are ranked in their importance, all stressors are linked to a certain extent and their effects connected, making it difficult to apply a ranking scale. Consequently, all stressors identified may need to be addressed if the macroinvertebrate community is to recover. Similarly, although the sources for each identified stressor are listed in order of (likely) decreasing importance, sources are often interrelated, or their importance may change over space or time or depending on certain conditions, so that a ranking scale is generally difficult to apply. Where one source is of overriding importance, it is denoted below as "primary source".

Toxicants

This stressor was ranked highest (high importance) for both stations, with a total of 7 "+" and 0 "-"[1] (App. D vi). The role of toxicants in impairing biological communities was indicated by violations of acute criteria for certain metals, an elevated summer level of chloride, high conductivity, and by signals from the macroinvertebrate community (App. D i). As sources for the toxicants (metals, ions), the conceptual model (App. D iv) identified the following:

- *Likely sources:*
  - **Runoff from local roads and parking lots**: the lower half of the watershed has a dense system of roads and residences, most with paved parking areas, as well as a number of schools or other facilities with parking lots. Much of the runoff from those impervious areas enters Trout Brook either directly or through storm drains. As mentioned above (Discussion, Water Quality Monitoring, Metals) several studies have found elevated toxicant levels, especially metals and chloride, in urban stormwater runoff.
  - **Dumping**: instances of illegal dumping of materials were noted in a watershed survey in April 2003 (SPLT in prep.) and on other occasions, and included empty oil and paint containers, yard waste, gray water (septic waste) pipes, old bicycles, and other refuse discarded in or near the stream.
  - **Saltwater intrusion from Portland Harbor** at the downstream station: the large spikes in conductivity (up to 35,000 μS/cm) recorded in the summers of 2003 and 2004 are attributable to high tide events in the harbor spilling into Trout Brook. For many aquatic macroinvertebrates, saltwater intrusions can represent a toxic event. Such intrusions are a natural phenomenon at this location, and will influence biota in the stream regardless of other stressors.

---

[1] "+"indicates evidence that a stressor affects macroinvertebrate community.
"-"indicates evidence that a stressor does not affect macroinvertebrate community.

- *Possible sources:*
    - **Winter road sand/road dirt**: road sand accumulations, which were noted around the downstream station in late winter/early spring 2003, can be washed into the stream during storms, and deliver salt particles (including chloride) as well as other toxic compounds. The City sweeps road sand in the spring and also in summer and fall, thus minimizing sand influx.
    - **Natural sources**, i.e., soils: iron and aluminum are very abundant in soils and, depending on the acidity of the environment, can be easily leached out and transported into streams. Cadmium, copper, lead, and zinc are far less abundant naturally, but can occur in high concentrations in some locations.
    - **Atmospheric deposition**: toxicants originating from fossil fuel combustion by vehicles, industry, or power plants can be transported over large distances by air currents, and be deposited directly in a waterbody or on a pervious or impervious surface, from where they can be washed into a stream. In terms of wind patterns, Maine is downstream of many major industries in the central and eastern parts of the country, and depositions of, for example, PAHs and mercury in the state have been attributed to atmospheric transport (see www.maine.gov/dep/air/monitoring/ Atmosdepos.htm; 2/4/2005). Overall, however, the magnitude of this source of toxicants for Trout Brook is unknown.
    - **Documented spills**: analysis of spill records indicated that only few spills have been documented within the watershed. Overall the potential for spills to increase the toxicant load in Trout Brook seems relatively low.
    - **Sewage input from CSO** in wetland section: the sewage entering Trout Brook from the CSO during storm events contains largely household waste, which may contain toxic compounds. Note that the City is working on separating this CSO.
    - **Agricultural runoff** in the upper part of the watershed: Maxwell's Farm is a conventional vegetable grower that is likely to use herbicides and/or pesticides as well as fertilizers in its daily operations. It should be stressed that this study did not investigate the presence of herbicides or pesticides in the stream. It is not known whether these compounds, if they are being applied, have an effect on macroinvertebrate communities at the biological monitoring stations 2.6 – 3.2 km downstream.
    - **Sewage/septic leaks**: the sewer system, which parallels and crosses Trout Brook in a variety of places, is overall in sound condition although in certain sections (at Spurwink Avenue and Sawyer Street) breaks in the pipes may be present (D. Pineo, pers. comm.). Testing for bacteria near these locations could reveal any possible contamination.
    - **Public works garage**: this is located within the Trout Brook watershed (off Cottage Road) but is entirely connected to the sewer system (directly or via catch basins); salt is stored on site in a covered shed (D. Pineo, pers. comm.). The pollution potential from this source is assumed to be minimal.

Degraded Instream Habitat

This stressor was ranked second (medium importance) for the late upstream station with a total of 5 "+" and 1 "-"; it was not considered important for the downstream station with a total of 0 "+" and 5 "-" (App. D vi). The role of the habitat in impairing biological communities at the late upstream station was indicated by a reduced habitat diversity (due to a combination of reduced sinuosity, low stream depth, and by a reduction in large woody debris). As sources for the impaired instream habitat at the late upstream station, the conceptual model (App. D iv) identified the following:

- *Likely sources:*
    - **Channelization** in this section of the stream (primary source): the reduced sinuosity and homogeneous flow regime caused by channelization as well as the overwidening of the channel and resulting low stream depth and aggradation lead to reduced habitat diversity.
    - **Increased stormflow volume**: high flows resulting from extensive paved surfaces in the watershed can remove pieces of LWD from the stream channel thus reducing habitat complexity, and scour the substrate thus causing habitat disturbance.

Degraded Riparian Habitat

This stressor was ranked second (medium importance) for the downstream station with a total of 3 “+” and 1 “-“; it was not considered important for the late upstream station with a total of 0 “+” and 4 “-“ (App. D vi). The role of the riparian habitat in impairing biological communities at the downstream station was indicated by a presumed reduction in the potential for recolonization or recruitment. As sources for the impaired riparian habitat at the downstream station, the conceptual model (App. D iv) identified the following:

- *Likely source:*
    - **Reduced riparian tree cover** (primary source): the narrow width or complete absence of a riparian buffer along some sections of the stream reduces the availability of breeding habitat for adults.

Altered Hydrology

This stressor was ranked third (low importance) for the downstream station with a total of 2 “+” and 3 “-“, and also third (medium/low importance, same as DO) for the late upstream station with a total of 4 “+” and 1 “-“ (App. D vi). The role of altered hydrology in impairing biological communities was indicated by reduced channel and habitat diversity, observations indicating high peak flows, a potential reduction in baseflow, and by signals from the macroinvertebrate community (App. D i). Both low baseflow and high peak flows were identified as potential problems. As sources for the altered hydrology, the conceptual model (App. D iv) identified the following:

.

- *Likely sources:*
    - **High percentage of impervious surfaces**: the watershed has ~13 % impervious surfaces. Imperviousness causes changes in hydrology by increasing runoff volume, increasing peak discharge and flashiness (i.e. rise-to-peak-rate), increasing the frequency and duration of bankfull flows, and decreasing baseflow by reducing groundwater infiltration (CWS 2003).

  - **Stormwater outfalls**: these can create localized erosion problems, and in extreme cases cause the removal of organisms. Outfalls are located on Norman Street, at the intersection of Providence Avenue and Marsh Road, above Highland Avenue, and below Broadway (i.e., below the biomonitoring sampling stations) as well as on the tributaries to Trout Brook.
  - **Channelization**: this reduces channel diversity, thus promoting a uniform flow regime.

- *Possible source:*
  - **Increased consumptive uses**: irrigation with stream water at Maxwell's Farm may reduce baseflow levels in the summer but currently no data or information exist to confirm this hypothesis.

Low Dissolved Oxygen

This stressor was ranked third (medium/low importance, same as altered hydrology) for the late upstream station with a total of 4 "+" and 1 "-"; it was not considered important for the downstream station with a total of 0 "+" and 7 "-" (App. D vi). The role of low DO in impairing biological communities at the late upstream station was indicated by measurements of low DO concentrations, and by signals from the macroinvertebrate community (App. D i). As sources for the low DO at the late upstream station, the conceptual model (App. D iv) identified the following:

- *Likely source:*
  - **Perched groundwater** (primary source): as explained above (Discussion, Water Quality Monitoring, Dissolved oxygen), this type of groundwater has naturally low DO concentrations.

- *Possible sources:*
  - **Low channel gradient and channel modifications**: these factors can reduce the number of riffles in a stream thus reducing the potential for re-aeration.
  - **Sewage input from CSO** in wetland section: this can increase nutrient loads and promote excessive algal growth leading to DO depletion. As no excessive algal growth was observed, sewage influx appears to be a minor source.

Factors that were deemed to be minimal stressors in Trout Brook, and that were thus eliminated from further consideration, were nutrients and water temperature. Factors that were discussed but found to be unimportant as stressors were sedimentation for both stations, DO concentration and instream habitat for the downstream station, and riparian habitat for the late upstream station.

CONCLUSIONS AND RECOMMENDATIONS

Study results showed that macroinvertebrate communities in the lower half of Trout Brook are degraded, and do not meet Maine’s aquatic life criteria for a Class C stream. This is largely due to the fact that the majority of macroinvertebrates identified were tolerant (i.e., isopods, midges, flies), and that only few sensitive organisms were found (Table 4). The fish assemblage at the downstream station (above Highland Avenue) showed a low diversity (two species) but had a healthy population of the relatively sensitive brook trout, including young-of-year. These two findings seem somewhat incongruous as the conditions that brook trout require for survival would normally also promote healthy macroinvertebrate communities.

An analysis of general water quality indicators (dissolved oxygen, conductivity, temperature) and chemical parameters (nutrients, bacteria, metals) as well as habitat assessments indicated that Trout Brook shows some, but not all, of the effects often encountered in urban areas. For example, conductivity and total nitrogen levels as well as bacterial concentrations were high at both stations, and the instream and riparian habitat was degraded (because the stream channel was altered in several areas, sinuosity was reduced, the riparian buffer was compromised, wetlands were drained and/or ditched). On the positive side, however, dissolved oxygen levels were high at the downstream station, water temperature was relatively cool at both stations, water chemistry testing revealed few problems at either station (though some toxic problems were observed; Table 6), and some habitat parameters were fairly intact (good flow regime, few areas with major erosion problems). On the whole, it appears that Trout Brook should have a healthier macroinvertebrate community than it currently does. The data summarized in this report formed the basis for the SI process (see previous section), which resulted in a ranking of stressors and identification of sources according to their likely importance for causing impairments. Toxicants were ranked as the most significant stressor at both stations, followed by a degraded instream habitat at the late upstream station and a degraded riparian habitat at the downstream station, altered hydrology at both stations, and low dissolved oxygen concentrations at the late upstream station. Factors that were deemed to be minimal stressors in Trout Brook were nutrients and summer temperature. Factors that were found to be unimportant as stressors were sedimentation for both stations, DO concentration and instream habitat for the downstream station, and riparian habitat for the late upstream station. The stressors and their sources as identified during the SI process were used to develop recommendations for Best Management Practices (BMPs) and remedial actions aimed at removing or alleviating the stressors. Bacteria were not considered as a stressor during the SI process but have the potential to compromise the use of a stream for contact recreation; therefore, BMPs for reducing bacteria levels are presented below also. And finally, although nutrients are not currently considered a stressor in Trout Brook, total nitrogen and total phosphorus did exceed applicable EPA-recommended criteria on occasion and there is the potential that nutrients interact with other stressors to impact biological communities; therefore BMPs aimed at reducing nutrient load are presented as a preventative measure.

Trout Brook is included in Maine’s 305 (b) list of impaired waters for non-attainment of the aquatic life criteria that were set for Class C streams (MDEP 2002d, 2004b). As a result, the Maine Department of Environmental Protection is required to develop a TMDL (Total Maximum Daily Load) plan for the impaired section of the stream (namely the section from the headwaters to the downstream station; Fig. 1) aimed at restoring aquatic communities to Class C standards. The BMPs and remedial actions listed below will form the basis for the TMDL plan to be developed in 2005. Other data not yet available, i.e., algal taxonomy, additional water chemistry data, and flow data, also will be utilized in TMDL development. While concentrating on the significant stressors, the TMDL will take into consideration all stressors because physical, chemical, and morphological features of a stream are linked, and interact to affect biological communities.

The list of BMPs and remedial actions provided below is categorized by stressor and source, and provides suggestions as to which broad category of party (or parties) may be responsible for implementing BMPs (i.e., City of South Portland, industry/businesses, public, or all). Because many factors must be considered when choosing specific structural BMPs (e.g., target pollutants, watershed size, soil type, cost, runoff amount, space considerations, depth of water table, traffic patterns, etc.), the list below suggests a variety of BMPs without proposing particular types for particular situations. For detailed information on structural BMPs, their individual effectiveness, and required planning considerations see publications by the MDEP (1995, 2003a) and the City of Nashua (2003). A summary of stressors, goals, and relevant BMPs and remedial actions as presented below and in Ch. 3, 5, and 6 can be found in App. I.

<u>Goal: Reduction in Toxicants</u>

During the SI process, toxicants were identified as the most important stressor at both stations with runoff from impervious surfaces, dumping, and saltwater intrusions (downstream station only) as likely sources, and winter road sand/road dirt, natural sources, atmospheric deposition, documented spills, sewage input from CSO, agricultural runoff, and sewage/septic leaks as possible sources. A reduction in toxicant load would likely aid the recovery of the macroinvertebrate community. The following list provides BMPs and remedial actions aimed at reducing toxicant load.

BMPs and remedial actions

1. **Reduce storm runoff from impervious surfaces**: during rain and storm events, the stream receives a large amount of runoff either directly or via the storm drain system. This runoff is contaminated with metals (aluminum, cadmium, copper, iron, lead, zinc; Table 6) that are toxic to aquatic life. Two BMPs/remedial actions can be suggested for this situation:
    a) A reduction in impervious surfaces, and thus runoff quantity, for example through the replacement of asphalt with pervious cover (e.g., porous pavement blocks, grass/gravel pave) or the replacement of conventional roofs with green roofs. In some cases there may also be the potential for replacing impervious cover with bioretention structures (bio-islands/cells). The city could also promote shared parking areas between homes or between facilities that require parking at different times (e.g., business and church), and reconsider its minimum parking requirements for businesses. (All)
    b) Channeling of runoff through a treatment system to reduce runoff quantity and improve runoff quality by promoting infiltration and pollutant absorption/ straining/decomposition. There are several choices for such systems:

  - vegetative BMPs (e.g., vegetated buffers or swales);
  - infiltration BMPs (e.g., dry wells, infiltration trenches/beds/basins, driveway drainage strips, bio-islands/cells, decorative planters), which may need to be equipped with pre-treatment BMPs to filter out toxicants;
  - detention BMPs (e.g., dry/wet ponds, extended detention ponds, created wetlands); and
  - filter and separator BMPs (e.g., oil/grit and oil/water separators, flow splitters, Vortechnics^{TM}-type systems, water quality inlets, sand filters, leaf compost filters).

   For more information on these BMPs and their effectiveness and planning considerations see MDEP 1995 and City of Nashua 2003. (All)

2. **Reduce the incidence of spills** (both accidental and deliberate, i.e., dumping): a few documented spills of hazardous substances have occurred in the watershed (App. E), and incidences of dumping were observed during a watershed survey. A reduction in spill frequency would likely have a beneficial effect on water quality and biological communities. Outreach efforts are useful for educating the public and businesses about safe ways for handling hazardous substances (e.g., paint and paint thinner, motor oil, gasoline, chemicals, pesticides), and proper ways for disposal. Storm drain stenciling has been shown to be useful in informing the public that any substance reaching a drain will go into a nearby waterbody where it may cause harm. The city might also consider increasing the frequency of their hazardous waste collections. Information material listing non-hazardous alternatives to hazardous substances could also help reduce the number of spills. Finally, where it has not already been done, industry and businesses should seal up floor drains or connect them to the sewer system, as appropriate. (All, MDEP)

3. **Saltwater intrusion from Fore River (downstream station only)**: this is a natural phenomenon at this location and cannot be remedied. To minimize the stressful effects of saltwater intrusions, water quality and habitat parameters must favor healthy biological communities rather than providing additional stressors. Addressing the stressors identified in the SI process will help to provide such conditions. (All)

4. **Reduce input of winter road sand and road dirt**: many toxicants are adsorbed onto sediment particles, and enter a stream in storm runoff. A reduction in metal load by way of loose sediment could be achieved by sweeping winter road sand and road dirt. The City has a road sweeping program in place and should continue it, with special attention given to post-winter clean-up (to remove chloride). If possible, sweeper types that employ a vacuum or regenerative air system should be used for cleaning as these maximize pick-up of fines (which hold the greatest toxicant load). Businesses that do not already sweep their premises are strongly encouraged to initiate this practice. Similarly, private homes with paved driveways/parking areas also should sweep sand and dirt on a regular basis. To capture any loose sediment and attached metals that is not removed by sweeping, runoff should be guided to a treatment system as suggested above under item 1 b. (All)

5. **Natural sources**: iron and aluminum are abundant in soils, and can easily leach out and enter a waterbody. This is a natural phenomenon and cannot be remedied. To

minimize the negative impacts of natural toxicants, water quality and habitat parameters must favor healthy biological communities rather than provide additional stressors. Addressing the stressors identified in the SI process will help to provide such conditions.

6. **Atmospheric deposition**: the pollution potential from this source is difficult to assess and even more difficult to remove. Almost by definition, this type of pollution originates from very diffuse and potentially far-away and wide-spread sources and cannot be addressed by any action the City of South Portland, local businesses, or residents can take. National action is required to deal with this issue. On a local scale, however, a reduction in sources of air pollution (e.g., motor vehicles, power plants, home heating systems, any type of fume) can improve local air quality and contribute to a decrease in atmospheric deposition. (All)

7. **Eliminate sewage input from CSO**: the city has already initiated remedial actions (separation work) for this issue, and no further action beyond completion of this project is required. (City)

8. **Reduce agricultural runoff**: runoff from crop areas can contain pesticides and herbicides that are often toxic to aquatic organisms. The presence of these compounds was not investigated in this study, and it is not known whether there is any effect on macroinvertebrate communities in the stream. To reduce the pollution potential, the farm operation in the upper part of the watershed should consider the following actions:
   - planting a riparian buffer between cropland and the stream (goal: a 15 m/50 ft-wide strip of grass, shrubs, and trees between the normal bank-full water level and cropland; Agroforestry Notes 1997);
   - reducing the amount of pesticides and herbicides applied;
   - increasing the distance between the edge of fields and the stream; and
   - putting infiltration trenches between the edge of fields and the stream.

9. **Eliminate the potential for sewer/septic system leaks**: to ensure that all components of sewer system are in good working order, portions that have not recently been surveyed should be inspected, and repairs or required replacements made as allowed by budgetary constraints. For septic systems, regular maintenance and inspection are critical to ensure proper functioning. Only few homes in the watershed have septic systems, and the pollution potential from this source is deemed to be small. Home owners can ensure that they do not contribute to the toxicant load in the stream by keeping toxic substances out of the sewer/septic system. (City, public)

Goal: Improvement in Instream Habitat Quality at Late Upstream Station

During the SI process, instream habitat quality was identified as a major stressor at the late upstream station with channelization (primary source) and increased stormflow volume as likely sources. An improvement in this parameter would likely aid the recovery of the macroinvertebrate community. The following list provides BMPs and remedial actions aimed at improving instream habitat.

BMPs and remedial actions

1. **Improve channel morphology**: the channelization that occurred at and around the late upstream station resulted in an overwidened and straightened channel, leading to a reduced channel diversity, low water depth, and sedimentation problems. All of these effects cause a reduced habitat diversity and quality, which negatively influence biological communities. To improve channel morphology, the restoration suggestion included in Discussion, Geomorphological survey, above (Fig. 24), should be implemented with the help of a qualified professional such as a fluvial geomorphologist. Such restoration would markedly improve habitat quality by re-establishing channel sinuosity and the habitats associated with it, increasing water depth (and thus vertical relief), and reducing sedimentation problems. (City)

2. **Reduce stormflow volume**: the overwidened and straightened channel causes a major loss of large woody debris (LWD), and likely some scouring of the substrate during high flows. The improvement in channel morphology recommended above should help reduce LWD export but a reduction in stormflow volume would likely be required to keep LWD in place and reduce scour. Various BMPs that can aid in reducing peak flow volume are listed above in "Goal: Reduction in Toxicants", item 1. (All, but predominantly city and industry/businesses)

Goal: Improvement in Riparian Habitat Quality at Downstream Station

During the SI process, riparian habitat quality was identified as a major stressor at the downstream station with reduced riparian tree cover as the likely (primary) source. An improvement in this parameter would likely increase the recolonization potential, and aid the recovery of the macroinvertebrate community. The following list provides BMPs and remedial actions aimed at improving riparian habitat.

BMPs and remedial actions

1. **Replant the riparian buffer**: some areas around the downstream station do not have a riparian buffer, i.e., lawns reach right down to the water's edge. Many insects require an intact riparian zone to complete their reproductive cycle. In some cases, certain types of vegetation are required. Additionally, leaves and woody debris are an important food resource and habitat requirement for many of these organisms, and the shade afforded by trees helps keep the stream cool. Residents whose lawns reach to the stream should consider planting a variety of native trees and other vegetation along the stream bank so as to attract insects with aquatic life stages. Homeowners should aim for a minimum buffer width of 10 m (35 feet), but increase the width to 15 m (50 feet; CRJC, 2000) or more if possible. This BMP would also help to improve water quality (by filtering lawn runoff), provide LWD to the stream, keep the water temperature low (by providing shading), and minimize erosion problems (by stabilizing stream banks). (Public)

Goal: Restoration of Natural Hydrology

During the SI process, altered hydrology (low baseflow and high peak flow) was identified as a stressor at both stations with high percentage of impervious surfaces, stormwater outfalls, and channelization as likely sources, and increased consumptive uses as a possible source. An improvement in this parameter would likely aid the recovery of the macroinvertebrate community. The following list provides BMPs and remedial actions aimed at restoring .

BMPs and remedial actions

1. **Reduce percentage of impervious surfaces**: high watershed imperviousness alters stream hydrology by increasing runoff volume and peak discharge rate, increasing the frequency and duration of bankfull flows, and decreasing baseflow (by reducing groundwater infiltration). The BMPs and remedial actions listed in “Goal: Reduction in Toxicants”, item 1, should be implemented to address this problem. These measures are also effective for improving baseflow levels as they promote the recharge of groundwater reservoirs with precipitation. (All)

2. **Reduce effects of stormwater outfalls**: the highly localized force of water coming out of a stormwater outfall creates high shear forces that can cause localized erosion problems, and even the removal of organisms. If the removal of outfalls is not practical, the installation of BMPs suggested in “Goal: Reduction in Toxicants”, item 1, is recommended to reduce the amount of stormwater discharged through outfalls. To reduce the effect of an outfall on a stream, it should be located in an area that can withstand high erosive forces (e.g., inside a culvert), and should be designed so as to minimize the shear force (e.g., not pointed straight at a stream bank but more or less parallel to stream flow). (City)

3. **Improve channel morphology**: a straightened (and widened) stream channel tends to have a uniform, generally slow flow regime that does not promote diversity in biological communities. To improve channel morphology, the restoration suggestion included in Discussion, Geomorphological survey, above (Fig. 24), should be implemented with the help of a qualified professional such as a fluvial geomorphologist. Such restoration would help diversify the flow regime by re-establishing channel sinuosity and the associated variability in flow patterns (i.e., slow flow on inside bends *versus* fast flow on outside bends) and water depth (i.e., pools with slow flows and riffles with fast flows). (City)

4. **Minimize consumptive uses**: if Maxwell’s Farm withdraws stream water for crop irrigation, it may lead to a decrease in water levels in Trout Brook, especially during the drier summer months. Farmers should consider using irrigation practices that minimize water usage (e.g., drip irrigation, irrigating early in the day).

Goal: Improvement in Dissolved Oxygen Levels at Late Upstream Station

During the SI process, a low DO concentration in the summer was identified as a stressor at the late upstream station with perched groundwater as the likely (primary) source, and a low gradient and sewage input from CSO as possible sources. An improvement in this parameter would likely aid the recovery of the macroinvertebrate community. The following list provides BMPs and remedial actions aimed at improving the DO concentration .

BMPs and remedial actions

1. **Perched groundwater**: this is a natural situation and cannot be remedied. To minimize the negative effects of the low DO resulting from the influx of perched groundwater, the following conditions must be met:
    a) good water supply from upstream to dilute low-DO groundwater. This can only be achieved by increasing baseflow levels through promoting the infiltration of precipitation, and reducing consumptive uses (if this is a problem).
    b) water quality and habitat parameters must favor healthy biological communities rather than providing additional stressors. A reduction in toxicants, improvement in instream habitat, and restoration of a natural hydrology as described above will help to provide such conditions. (All)

2. **Low gradient**: this is a natural situation and cannot be remedied.

3. **Improve channel morphology**: channel modifications reduce the number of riffles providing re-aeration potential. They need to be reversed by implementing the restoration suggestion included in Discussion, Geomorphological survey, above (Fig. 24), with the help of a qualified professional such as a fluvial geomorphologist. (City)

4. **Eliminate sewage input from CSO**: the city has already initiated remedial actions (separation work) for this issue, and no further action beyond completion of this project is required. (City)

<u>Goal: Reduction in Nutrient Levels</u>

In the SI process, nutrients were deemed to be a minimal stressor, and were not considered extensively. However, total nitrogen and total phosphorus exceeded EPA-recommended criteria on several occasions, and these compounds may interact with other stressors to affect the macroinvertebrate community. Therefore, future increases in nutrient load should be prevented to promote the overall goal of improving aquatic life. The following list provides BMPs and remedial actions aimed at nutrient control.

BMPs and remedial actions

1. **Minimize lawn/landscaping runoff**: fertilizers applied to landscaped areas, lawns, gardens, or crops can be washed into the stream during storms. Reduction or elimination of fertilizer use is an important step in reducing the nutrient load in a waterbody. Soil tests can be a useful way to determine actual nutrient requirements. (All)

2. **Maintain/replant riparian buffer**: a densely vegetated area separating a fertilized green space or an impervious surface from the water's edge will reduce runoff of nutrient-laden water into the stream. As a rule of thumb, a riparian buffer should have a minimum width of 15 m (50 feet; CRJC, 2000), though a width of 75 feet or greater provides better treatment. Shading of the stream will also minimize the risk that

elevated nutrient loads can lead to excess algal growth and a depletion in DO. (All)

3. **Minimize impervious surface runoff**: runoff from roads and parking lots can contribute high levels of nutrients to a stream. BMPs listed above in "Goal: Reduction in Toxicants", item 1, will help to minimize the amount of nutrient-containing runoff that reaches the stream.

4. **Implement items listed under "Goal: Reduction in bacteria levels"**, below: discharges from a CSO, faulty sewer or septic systems, and pet waste as well as illicit discharges increase the nutrient load in a stream. (All)

5. **Atmospheric deposition**: studies have found that background nitrate concentrations in streams are higher in the Northeast than in other parts of the country. Almost by definition, this type of pollution originates from very diffuse and potentially far-away and wide-spread sources and cannot be addressed by any action the City of Portland or local business or residents can take. National action is required to deal with this issue. On a local scale, however, a reduction in sources of air pollution (e.g., motor vehicles, power plants burning fossil fuels) can improve local air quality and contribute to a decrease in atmospheric deposition. (All)

Goal: Reduction in Bacteria Levels

At this point, Trout Brook is not listed for bacterial violations although *E. coli* concentrations (of unknown origin) exceeded Maine's criteria for counts of bacterial colonies (of human origin) on most sampling dates (Table 5). Bacteria are not in themselves a stressor for macroinvertebrates, and thus were not included in the SI process. However, the presence of *E. coli* in the water is cause for concern because it can indicate the presence of raw sewage in the stream. Raw sewage, which can originate from the public sewer system, faulty septic systems, or illicit discharges, has the potential to also carry disease-causing organisms (as well as metals and nutrients). Therefore, elevated levels of *E. coli* in the stream suggest that a waterbody may be impaired in several ways. The following list provides BMPs and remedial actions aimed at a reduction in bacteria load.

BMPs and remedial actions

1. **Eliminate sewage input from CSO**: raw sewage can be a major contributor of bacteria to a stream. The City must continue to work towards CSO separation to eliminate this source. (City - already initiated)

2. **Eliminate potential for sewer/septic system leaks**: to ensure that all components of sewer system are in good working order, portions that have not recently been surveyed should be inspected, and repairs or required replacements made as allowed by budgetary constraints. For septic systems, regular maintenance and inspection are critical to ensure proper functioning. (All)

3. **Eliminate illicit discharges**: entities/households with an illicit discharge must eliminate it through either stopping the discharge, or routing it into a septic system/the city sewer. The Center for Watershed Protection recently developed an extensive

manual to help municipalities in the detection and elimination of illicit discharges (CWP 2004). (Industry/businesses, public)

4. **Minimize bacteria input from animals**: in many cases, *E. coli* do not originate from human sources but from warm-blooded animals, including pets, and eliminating this source would likely reduce bacteria levels. Keeping pets away from the stream and always picking up pet waste prevents waste from getting washed into the stream during a storm. Feeding of wildlife near the stream or on ponds connected to the stream is discouraged as animals (especially waterfowl) can contribute to the bacterial load in a waterbody. (Public)

5. **Be a steward of the stream**: alert city personnel if there is a sewage smell in the stream, or if signs of sewage discharge are obvious. Stream bank surveys by stream teams (see General activities that can help Trout Brook) can reveal problems without requiring costly water analyses. (Public)

6. **Eliminate septic systems in watershed**: this could be achieved by connecting residences with septic systems to the city sewer. Because of the cost, this option should be used as a last resort. (City)

General Activities that Can Help Trout Brook

1. **Invest in education and outreach efforts**: alert the public as well as industry and businesses to the role different stressors play in impairing biological communities and water quality in a stream. Encourage all concerned parties to implement BMPs and remedial actions listed here. (City, MDEP, Cumberland County Soil and Water Conservation District)

2. **Promote the formation of a Stream Team** for Trout Brook. Owing to the impaired nature of the stream at this point in time, this initiative may need to be deferred to a later date. However, once stream quality has improved, citizens and/or businesses should be encouraged to become stewards of the stream and collaborate with the City and State to improve Trout Brook's condition. (All, MDEP)

3. **Encourage responsible development**: parts of the Trout Brook watershed are not yet developed, and these wetland and forested areas have an important influence on the stream ecosystem. Future development should take into consideration the findings of this report, and be done so as to minimize the impact on the stream. Practices promoted under smart growth and low impact development (LID) guidelines should be implemented wherever possible. More information on such guidelines can be found at www.epa.gov/smartgrowth/ and www.epa.gov/owow/nps/lid/. The city should consider including such guidelines into the building code, or at least promoting their use when issuing construction permits (City, industry/businesses)

The list of BMPs and remedial actions given above provides guidance for the kinds of actions that could be taken to deal with the urban stressors the SI process identified for the lower section of Trout Brook. This list, or parts of it, will be incorporated into the TMDL plan to be developed by the Maine Department of Environmental Protection in 2005. More detailed recommendations that would be included in a restoration plan will require the input of experts from fields such as biology, geology, and engineering.

Restoring healthy aquatic communities in Trout Brook will require collaboration among several parties (regulatory agencies, the City of South Portland, businesses, concerned citizens) as well as financial resources and time. The TMDL plan will likely estimate target loads for certain pollutants, and implementation of the plan should lead to an improvement in stream health over the next several years. Future biological and water quality monitoring is advisable to determine whether the TMDL plan achieved its goal of restoring the resident aquatic communities to Class C standards, or whether additional actions are required.

Chapter 5: Barberry Creek in South Portland

Upstream Station (S672)
(June 2003)

Middle Station (S387)
(April 2003)

Below Broadway
Morse station
(June 2003)

TABLE OF CONTENTS

REPORT

FIGURES

TABLES

APPENDICES

See Table of Contents at Beginning of Report for List of Appendices.

STREAM DESCRIPTION

Barberry Creek, one of the four Urban Streams[1] in the Urban Streams Project, is located in South Portland in southern Maine (Fig. 1 in Ch. 1), and is of moderate length (~1.3 miles) and watershed size (~786 acres, excluding areas draining into downstream wetland, Fig. 1). The stream originates in a wetland in the southern part of the city in an area transected by a multitrack railway line (Springfield Terminal Railroad) and a railway yard (the Maine Central Railroad Rigby Yard). Below the wetland, the stream flows through a heavily industrialized area (along Dartmouth Street), into a wooded area with a capped landfill, and then into a residential area and another wetland before flowing through a dammed up pond into the estuarine Fore River. The Greenbelt Walkway (a paved hiking/biking path) runs parallel to the stream along the wooded and residential areas. One small tributary joins Barberry Creek at the intersection of the industrial and wooded areas, coming out of the forested area draining the landfill. The outline of the watershed as shown in Fig. 1 is based on a drainage map obtained from the City of South Portland (P. Cloutier, pers. comm.[2]), on 10 m contour lines, and actual stormwater drainage systems. In terms of water quality requirements, the Maine legislature designated Barberry Creek as Class C (see Ch. 1, Introduction).

The Maine Department of Environmental Protection (MDEP) Biological Monitoring Program has been studying three stations on Barberry Creek since 1998 (Fig. 1). The middle station above the intersection of Broadway and Evans Street (on Taylor Lane), S387, and the downstream, wetland station, W-011, are both located in the lower quarter of the watershed. The newly (2003) established upstream, algae station, S672, ~500 m above the middle station, is located in the lower half of the watershed, along the Greenbelt Walkway. All stations receive runoff from the surrounding industrial and residential areas as well as from the landfill (via the tributary). The downstream, wetland station is additionally influenced by a combined sewer overflow (CSO) located below Broadway. During baseflow conditions in the summer of 2003, the middle station had a wetted width of ~3 m, a channel width of 3.8 m, and a water depth of 5 – 8 cm with a flow velocity of 6 – 15 cm/s. At the upstream station, the stream was wider with a similar depth but lower flow velocity. Channel width on Barberry Creek is much greater than would be naturally expected for a stream of this watershed size and indicates an overwidened channel (Field 2003). The substrate at the middle station was dominated by sand (50-55 %) with some gravel (35-40 %) and silt and rubble (5 % each) mixed in. At the upstream station, only sand (90 %) and silt (10 %) were found. The riparian zone near both stream stations consisted of young trees and understory plants, which at the middle station was supplemented by an abundance of invasive Japanese Knotweed (*Polygonum cuspidatum*). Barberry Creek's surficial geology type is the "Presumpscot formation" which in this watershed is characterized by silts and clay with some sand; this suggests that fine sediment observed in the stream is partly natural in origin. From the middle station to the tributary, the Greenbelt Walkway runs along the stream and interrupts the riparian zone, which is further diminished by residential development in this area. Above the upstream station, the wooded zone is soon replaced by the industrialized area.

---

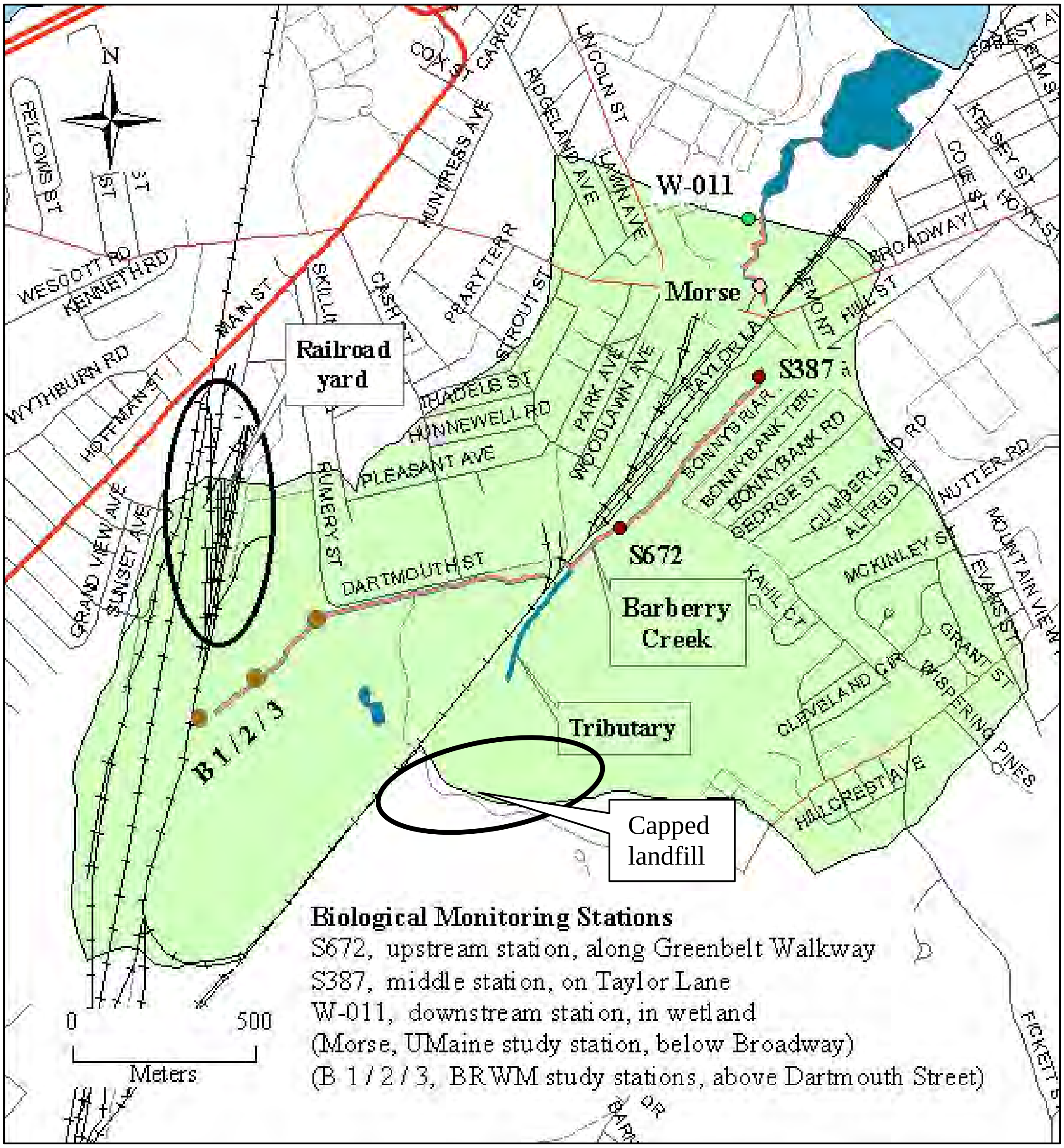
[1] Note that "Urban Streams" refers to the four streams included in this study, not to the universe of "urban streams" in Maine or elsewhere.

[2] Information on persons providing personal communications is given in the References.

The entire watershed, including the headwaters, is impacted by development (i.e., low/high intensity residential and dense residential development: 45 %; urban/industrial and commercial-industrial-transportation development: 26 %), resulting in a high percentage of the watershed being covered by impervious surfaces (23 %, calculated using the method shown in MDEP 2001b). Other landuse types are wetlands (15 %), forests (8 %), and grassland/crops/scrub-shrub (6 %). As a result of the intense urbanization surrounding the stream, Barberry Creek is affected by a variety of stressors typically associated with industrial, commercial, and residential development, and an extensive transportation system. Special concerns along Barberry Creek are the railroad and old landfill (see Previous Studies, below). Data collected by the MDEP Biological Monitoring Program in 1999 at the middle station indicated that the macroinvertebrate community did not meet the Class C aquatic life criteria (see Previous studies, below). Existing data also suggest problems with other water quality parameters (e.g., dissolved oxygen, specific conductance). Wetland data collected in 1998 and 1999 at the downstream station also indicated that biota, water, and sediments at this station were negatively impacted. In addition, Morse (2001; see Previous studies, below) found habitat degradation and impaired macroinvertebrate communities in Barberry Creek.

This report presents the data available as of December 2004, and puts them into the context of overall stream health. Information contained in this report will form the basis for the development of a stream-specific Total Maximum Daily Load (TMDL; see Ch. 1, Introduction, MDEP Urban Streams Project) plan in 2005. It is expected that the MDEP will re-sample macroinvertebrates on Barberry Creek within the next 2 - 4 years. Additional sampling events may occur in future years depending on developments in the watershed, funding availability, and program needs.

Fig. 1. Barberry Creek, South Portland. Watershed is shown in green, impaired segment in pink.



Note: Barberry Creek is culverted for ~200 m below the Broadway intersection, i.e., from just below S387 to just above “Morse” and hence is not visible as a stream in this area. The stream is also culverted and hence not visible upstream of where it crosses underneath the railroad tracks, upstream of S672.

PREVIOUS STUDIES

MDEP Biomonitoring

The Biological Monitoring Program of the MDEP’s Bureau of Land and Water Quality (BLWQ) collected macroinvertebrate data in 1999 at the middle station (S387; Fig. 1). Sample collection and processing methods are detailed in App. A i, and briefly described in Ch. 2, Methods, Biological Monitoring, item 1. Macroinvertebrate samples were identified by Freshwater Benthic Services (Petosky, MI). The MDEP analyzed taxonomic data using a statistical model which assigned samples to one of three State of Maine water quality classes (A[1], B, or C) or a Non-Attainment category. Analysis results were reported in the MDEP’s 1999 Surface Water Ambient Toxics (SWAT) Monitoring Program technical report (MDEP 2001a).

Model results indicated that the macroinvertebrate community did not meet Class C aquatic life criteria (Table 1). No sensitive taxa from the orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) were found, but some relatively tolerant caddisflies were present (*Hydropsyche*, *Limnephilus*). The community was dominated by tolerant isopods (*Caecidotea*) and chironomids (midge larvae; e.g., *Micropsectra*; Table 1). The number of organisms found was intermediate, but generic richness was quite high. The percentage of non-insects, which is a good general indicator of the quality of a macroinvertebrate community (low % = high quality), was intermediate (37 %). These tolerant non-insect organisms included isopods, worms, leeches, and amphipods. Water quality data showed a low dissolved oxygen concentration (5.6 mg/L), high conductivity (641 µS/cm), and slightly elevated water temperature (19 ºC). No continuous water temperature or water chemistry data are available for this station.

Table 1. Summary version of 1999 macroinvertebrate model report

Model variable	**Middle (S387)**
Total abundance of individuals	317
Generic richness	49
Plecoptera / Ephemeroptera abundance	0 / 0
Shannon-Wiener diversity index	3.31
Hilsenhoff biotic index	6.68
Relative abundance Chironomidae	0.50
EPT[1] generic richness	2
EP[1] generic richness/14	0
Presence of Class A indicator taxa/7	0
Five dominant taxa (%)	*Caecidotea* (32) *Micropsectra* (23) *Tanytarsus* (11) *Hydropsyche* (9) *Meropelopia* (4)
Model outcome (%)	NA (100)

[1] EPT are Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). EP are Ephemeroptera and Plecoptera.

---

[1] For the purposes of the statistical model, State of Maine water quality classes AA and A are combined.

Data collected in August 1998 and 1999 at the downstream wetland on Barberry Creek (downstream station, W-011; Fig. 1) also indicated negative impacts. Macroinvertebrate biota were impaired with low richness (18 and 19 taxa in 1998 and 1999, respectively), and low abundance (35 and 26 organisms). No sensitive organisms (mayflies, caddisflies, dragonflies) were found with the sample consisting mostly of midge larvae and isopods. Dissolved oxygen levels were very low (3.4 and 1.4 mg/L), water temperatures high (23.5 and 21.4 ºC), and conductivity levels very high (1,130 and 1,820 µS/cm). Several of the water and sediment parameters analyzed ranked among the worst 10 % of all wetlands samples collected in Maine by the biomonitoring unit (Tables 2a and b). When compared to the Sediment Quality Guidelines (SQG) published by the Ontario Ministry of the Environment (1993), most metals exceeded the Lowest Effect Level (LEL) criterion but not the Severe Effect Level (SEL) criterion (Table 2b). One exception is total organic carbon (TOC) which exceeded the LEL and SEL once each. However, TOC may be naturally elevated in wetlands compared to other waterbodies and the SQG may not apply (J. DiFranco, pers. comm.). Exceedance of criteria suggests that the contaminants may have negative long-term effects on sediment dwelling organisms, although the majority of organisms may not be affected if LELs are exceeded but not SELs.

Table 2a. Water chemistry data (in mg/L) from summer 1998 and 1999 (wetland station). Highlighted fields indicate problem parameters.

Parameters	**Downstream (W-011)**			
	1998		**1999**	
	Value	**Rank[1]**	**Value**	**Rank[1]**
Nitrate-N	0.3	5	0.05	11
Ammonia-N	0.11	10	0.02	79
Total Nitrogen	0.77	37	0.56	60
Phosphate	0.007	17	0.014	4
Total Phosphorus	0.051	30	0.063	22
Chlorophyll *a*	0.006	54	0.02	13
Sulfate	25.4	11	30.0	8
Dissolved organic carbon	6.53	114	ND	--
Calcium	32.7	4	32.4	5
Magnesium	12.9	3	21.0	1
Potassium	6.10	5	7.53	2
Sodium	105	3	178	2
Silica	4.38	9	4.60	10
Alkalinity ($CaCO_3$)	73.50	7	69.00	11
Chloride	219	3	388	1

ND, Not Detected, i.e., below stated detection limit of test.

[1] Rank out of 142 samples. Rankings in the worst 10% of each category are highlighted.

Table 2b. Sediment chemistry data (dry, in mg/Kg) from summer 1998 and 1999 (wetland station). Highlighted fields indicate problem parameters.

Parameters	**Downstream (W-011)**				**Ontario SQG[2]**	
	1998		**1999**		**SEL[2]**	**LEL[2]**
	Value	**Rank[1]**	**Value**	**Rank[1]**		
Cadmium	*3.99*	2	*3.06*	3	10	0.6
Copper	*98*	3	*79*	4	110	16
Lead	*150*	2	*163*	1	250	31
Selenium	0.66	40	0.87	35	NC	NC
Zinc	*760*	1	*573*	3	820	120
Mercury	*0.28*	7	*0.32*	6	2	0.2
Total organic carbon (%)	*8.8*	41	*10.4*	39	10	1

NC, No Criteria. Italicized values indicate exceedance of SQG criteria.

[1] Rank out of 60 samples. Rankings in the worst 10% of each category are highlighted.

[2] SQG, Ontario Sediment Quality Guidelines for freshwater; SEL, Severe Effect Level; LEL, Lowest Effect Level

A "Human Disturbance Ranking Form" also was completed at the wetland station in 1998 and 1999, and in both years resulted in a score of 19 out of a possible 125 (5 points * 5 categories * 5 sections; Table 3). This score indicated very high disturbance, and ranked as the 21st worst score recorded in the 157 wetlands assessed by the MDEP biomonitoring program to date (highest score recorded was 44). Impervious surface areas in the watershed had the highest score of the five subsections, followed by the potential for NPS pollution, and the hydrologic modifications to the wetland.

Table 3. Summary version of completed Human Disturbance Ranking Form

Factor assessed	**Score**	**Section Total**
Section 1. Hydrologic modifications to the wetland		
Man-made dikes or dams	4	4
Causeways, roads or railroad bed crossings, culverts	0	
Ditching, draining, dewatering	0	
Filling or bulldozing	0	
Other	0	
Section 2. Vegetative modifications to the wetland		
Timber harvesting in wetland	0	0
Other clearing/removal of vegetation	0	
Plowing, mowing or grazing in wetland	0	
Evidence of herbicide use in wetland	0	
Other	0	
Section 3. Evidence of chemical pollutants		
Discharge pipes	0	1
Oil, petroleum, chemicals observed, chemical odor present	0	
Soil staining, stressed/dying vegetation	0	
Trash, chemical containers, demolition debris, drums, etc.	1	
Other	0	
Section 4. Impervious surface areas in watershed		
Residential development	3	9
Commercial/industrial development and cemetery	3	
Recreational development	0	
Roads and highway bridges	3	
Other (parking lots)	0	
Section 5. Potential for NPS pollution		
Excess sediment accumulation and eroding soil from human activities	1	5
Alterations to wetland buffer	3	
Livestock, feedlots, manure piles	0	
Evidence of fertilizer or pesticide use	1	
Other (grass clippings)	0	

University of Maine Study

Chandler Morse, a graduate student at the University of Maine in Orono, studied one station on Barberry Creek in the summer and fall of 1998 and spring of 1999 (Morse, Fig. 1; Morse 2001). Like the MDEP biomonitoring studies, Morse also found that the macroinvertebrate community in Barberry Creek was degraded: taxa richness was low (10 and 15 taxa in fall 1998 and spring 1999, respectively), and there were no mayflies or stoneflies, and only 2 or 3 caddisfly taxa. The density of organisms per sample was low in fall (~148) but high in spring (~1,211). Morse noted that Barberry Creek was one of the most heavily urbanized catchments in his study ,and yielded the lowest taxa richness.

Summer temperature, predawn dissolved oxygen concentrations, and pH were adequate but conductivity levels were elevated, and total phosphorus levels exceeded the EPA-recommended criterion for ecoregion XIV once (which includes Barberry Creek; 0.031 mg/L) (Table 4). According to Morse's analysis, landuse types in the watershed of Barberry Creek were predominantly urban (58 %), with some wetlands (23 %), and little agriculture and forests (12 and 4 %, respectively; from Fig. 6 in Morse 2001). A qualitative habitat survey, which integrated 10 different metrics indicating habitat quality, resulted in a Marginal ranking (116, range is 60 – 119; ranking categories are Poor, Marginal, Suboptimal, Optimal; overall worst/best score is 0/240). A Stream Reach Inventory and Channel Stability Index assessment, which integrated 15 metrics and evaluated the channel for instability and erosion/deposition, resulted in a Fair ranking (99, range is 77 – 114; ranking categories are Excellent, Good, Fair, Poor; overall best/worst score is 33/162). Morse's conclusion from his study was that Barberry Creek, like other urban streams he studied with >6 % impervious surfaces (including Trout Brook and Birch Stream), showed a variety of impacts related to urban development, mainly declining habitat quality and decreased diversity and density of macroinvertebrate taxa (Morse 2001).

Table 4. Morse (2001) data. Highlighted fields indicate problem parameters.

Parameter	**Summer 1998**	**Fall 1998**	**Spring 1999**
Water temperature (ºC)	17.5	4.4	8.2
DO, predawn (mg/L)	7.9	11.0	8.3
pH	7.5	7.1	8.2
Specific conductance (μS/cm)	404	412	371
NO_3-Nitrogen (mg/L)	0.226	0.132	0.154
Total Phosphorus (mg/L)	0.026	0.022	0.043
Total Suspended Solids (mg/L)	4.4	4.3	9.2

MDEP BRWM study of Railroad

Staff from the Bureau of Remediation and Waste Management (BRWM) have investigated the Maine Central Railroad Rigby Yard in the upper part of the Barberry Creek watershed (Fig. 1) at various points in the past, and results of the most recent investigation were reviewed (Beneski 2000). In late 1999/early 2000, BRWM staff conducted a Mini Site Inspection (MSI) to follow up on findings from previous work, investigate potential source areas of contamination, and examine contaminant pathways. The relevant results of the MSI are summarized as follows:

- Soil samples: Diesel Range Organics (DRO), Total Petroleum Hydrocarbons (TPH), and low levels of Semi-Volatile Organic Compounds (SVOCs) were detected above background levels in the single location sampled on-site (railcar turntable, at northern end of railroad yard). No Volatile Organic Compounds (VOCs) or Polychlorinated Biphenyls (PCBs) were detected. Metals (Cr, Pb, Ba, As) were at or below background levels.

- Sediment (in surface waters): near the railroad tracks (B 1 in Fig. 1), one type of VOC (acetone) as well as several SVOCs, DRO, and TPH were detected in elevated levels. Metals were near background levels. Where Barberry Creek becomes a defined stream (B 2 in Fig. 1), two SVOCs (naphthalene, 2 methylnaphthalene) were detected above background levels. Where Barberry Creek reaches the corner of Rumery and Dartmouth Street (B 3 in Fig. 1), no SVOCs or VOCs were detected above background levels. (DRO, TPH, and metals were not analyzed at B2 and B3.)

- Groundwater samples: DRO, TPH, low levels of several PAHs (Polycyclic Aromatic Hydrocarbons, types of SVOCs), and metals (Ba, Cr, Pb, Cd, Se; above background levels) were detected in 1 to 4 samples (out of 7). No VOCs were detected.

It should be noted that only the southern part of the Railroad Yard drains directly into a ditch that becomes Barberry Creek (Fig. 1; Beneski 2000). The contaminated soil sample came from the northern part of the yard, and thus would not directly affect Barberry Creek. Sediment samples in surface waters collected just upstream of and within the stream (B 1-3 in Fig. 1) showed decreasing levels of SVOCs and VOCs with increasing distance from the railroad tracks, with the most downstream sample (B 3) showing no contamination. Note however that DRO and TPH, which were very high at B 1, were not analyzed at B 2 and B 3.

The potential effects groundwater pollutants under the yard may have on Barberry Creek cannot be assessed since groundwater flow patterns are unknown. A potential indication for polluted groundwater feeding the stream can be found in conductivity data (Figs. 4 and 9). These data show a strong drop in conductivity during storm events as stream water at baseflow conditions (i.e., groundwater-derived) is diluted with rain water.

City of South Portland Monitoring of Landfill Runoff

Runoff from a capped landfill (former South Portland Municipal Landfill) located along the south-eastern edge of the Barberry Creek watershed reaches the stream either via overland flow or the tributary (Fig. 1). The City of South Portland capped the two phases of the landfill in 1997 and 1998, with Phase 1 having been inactive for ~30 years at the time of capping, and Phase 2 for ~8 years. Surface runoff from the landfill has been monitored by the city since October 1998 and results are summarized in Table 5.

Table 5. Monitoring results of landfill runoff in surface water. Highlighted fields indicate problem parameters.

	Sampling date								
	1998	**1999**		**2000**		**2001**		**2002**	**2003**
	Oct	**Apr**	**Oct**	**Apr**	**Oct**	**Apr**	**Oct**	**Sept**	**Apr**
Field parameters (units as shown)									
pH	6.68	7.42	6.57	6.40	6.84	5.99	6.58		
SPC[1] (µS/cm)	755	638	574	608	559	1,055	646		
DO (mg/L)	2.6	8.2	10.3	8.9	9.5	6.8	5.4		
Laboratory parameters (all in mg/L)									
Iron	4.2	16	1.9	0.7	1.8	0.8	6.2	1.5	3.4
Calcium								83	94
Manganese	3.5	3.5	1.5	0.2	0.5	0.7	1.5	0.7	0.2
Magnesium								18	21
Potassium								12	11
Sodium	58	67	38	33	33	32	35	31	54
Chloride	79	71	87	58	85	45	84	59	94
Sulfate	88	51	72	108	49	991	38	28	110
Arsenic								0.007	<0.005
Alkalinity	227	212	182	171	189	134	226	230	190
TDS[1]	472	388	394	362	340	796	380	410	510
SSD[1]	11	103	<4	<4	9	<4	30	1	5
TOC[1]								14	11
COD[1]								34	24

ND, Not Detected; highlighted fields indicate exceedance of Maine SWQC (MDEP SWQC; see Table 7 for explanation).

[1] SPC, conductivity; TDS, total dissolved solids; SSD, total suspended solids; TOC, total organic carbon; COD, chemical oxygen demand.

Monitoring results indicated elevated conductivity, highly variable DO concentrations, iron concentrations that exceeded the Maine SWQC (MDEP SWQC) CCC of 1.0 mg/L (see Table 7 for explanation) on most occasions (by up to a factor of 16), some elevated SSD values (>10 mg/L), and elevated COD. Arsenic[1] concentrations did not exceed criteria (CCC: 0.19 mg/L; CMC: 0.36 mg/L; see Table 8).

---

[1] Arsenic is the only other parameter besides iron for which Maine SWQC are available.

RESULTS OF 2003 STUDY

Biological Monitoring

1. Analysis of macroinvertebrate samples collected at the middle station in August after an exposure period of four weeks in the stream showed that biota were degraded and failed to meet Class C aquatic life criteria (Table 6; full model outputs for the 2003 sampling events are shown in App. B iii). Generic richness was adequate but there was a lack of sensitive organisms (Ephemeroptera, Plecoptera, Trichoptera). Instead, tolerant organisms (e.g., *Stylodrilus*, *Caecidotea*, *Micropsectra*) dominated the community, as indicated by a high Hilsenhoff biotic index and a high percentage of non-insects (64%). Analysis results were reported in the MDEP's 2002-2003 SWAT Monitoring Program technical report (MDEP 2004c).

Table 6. Summary version of 2003 macroinvertebrate model report

Model variable	Middle (S387)
Total abundance of individuals	625
Generic richness	34
Plecoptera / Ephemeroptera abundance	0 / 0
Shannon-Wiener diversity index	3.37
Hilsenhoff biotic index	6.79
Relative abundance Chironomidae	0.31
EPT[1] generic richness	1
EP[1] generic richness / 14	0
Presence of Class A indicator taxa / 7	0
Five dominant taxa (%)	*Stylodrilus* (34) *Caecidotea* (16) *Micropsectra* (11) *Polypedilum* (11) *Eclipidrilus* (4)
Model outcome (%)	NA (100)

[1] EPT are Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). EP are Ephemeroptera and Plecoptera.

2. The fish assemblage at the middle station was investigated on June 19, and consisted of 15 American Eels (*Anguilla rostrata;* 6-14" in length).

3. The algae sample collected on July 9 off of submerged branches has not yet been analyzed for species composition and abundance. Branches were covered with a thick, orangish, flocculent layer of iron-precipitating bacteria, algae, and fungi (Fig. 2; situation was the same in 2003). It was aesthetically offensive. It is not known if the growth in Barberry Creek is natural or indirectly caused by human activities in the stream drainage. Of the 129 locations

Fig. 2. Growth on log at upstream (algae) station (June 2004)

sampled for algae statewide, similar mats have been observed only at Blood Brook, which drains historic iron deposits in Katahdin Iron Works TWP. A revisit to the site in early July 2004 showed the same conditions.

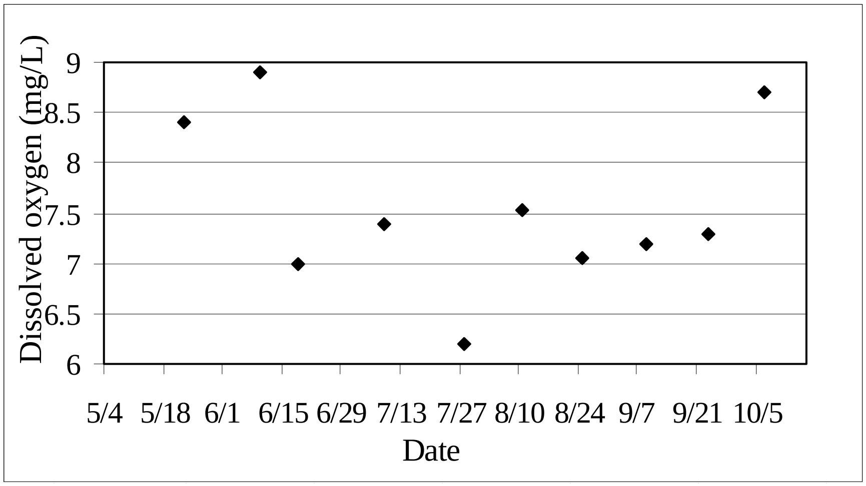
Water Quality Monitoring

1. Standard water quality parameters

a) Instantaneous dissolved oxygen

The concentrations of instantaneous dissolved oxygen (DO) at the middle station on Barberry Creek were quite variable, ranging from 6.2 - 8.9 mg/L with values generally below 7.5 mg/L in the summer (Fig. 3). Measurements taken on May 7 and July 6, 2004 were 9.0 and 5.8 mg/L, respectively.

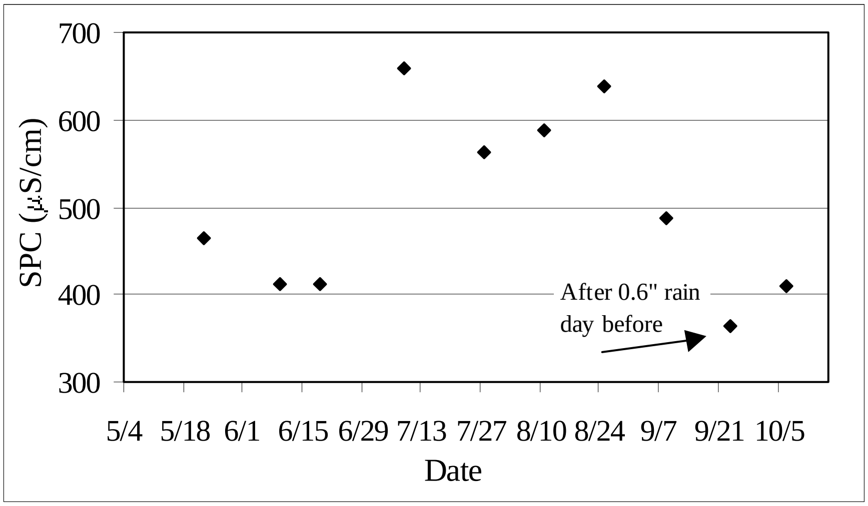
Fig. 3. Instantaneous dissolved oxygen



b) Instantaneous specific conductance

Instantaneous levels of specific conductance (also SPC or conductivity) at the middle station were quite variable throughout the sampling season, ranging from 410 - 660 μS/cm (Fig. 4). As noted on Figure 4, a value of 364 μS/cm was recorded after heavy rain (0.6”) the previous day, leading to a dilution of ions in the water and hence a lowering of the conductivity level. Measurements taken on May 7 and July 6, 2004 were 427 and 655 μS/cm, respectively.

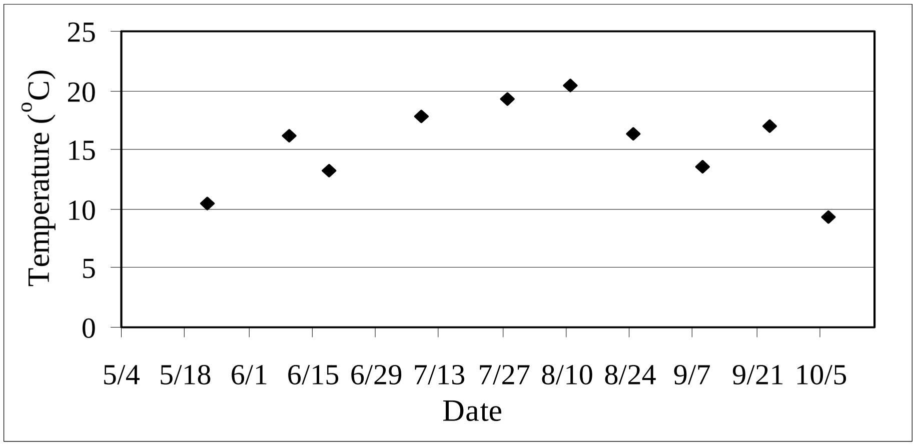
Fig. 4. Instantaneous specific conductance



c) Instantaneous water temperature

Instantaneous water temperature measured at the middle station was quite variable throughout the sampling season, ranging from 9.3 - 20.4 ºC, with summer temperatures mostly between 15 and 20 ºC (Fig. 5). Measurements taken on May 7 and July 6, 2004 were 13.2 and 18.1 ºC, respectively.

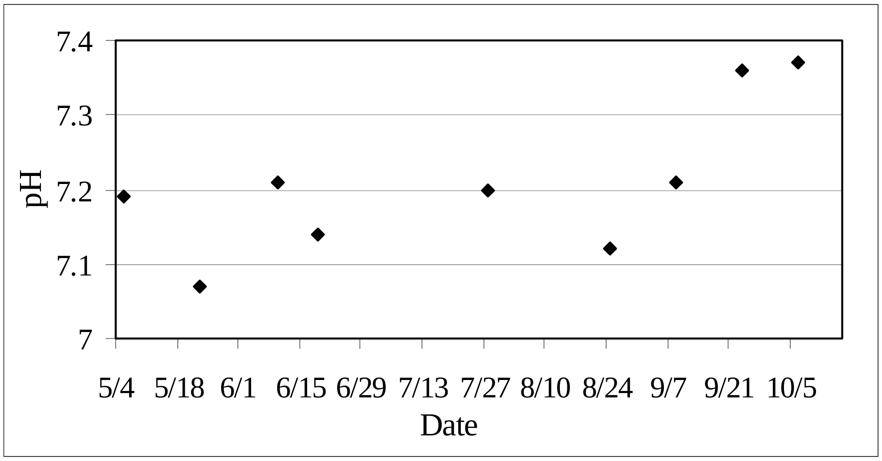
Fig. 5. Instantaneous water temperature



d) Instantaneous pH

Instantaneous measurements of pH were quite uniform at the middle station, ranging from 7.07 - 7.37 (Fig. 6). Measurements taken on May 7 and July 6, 2004 were 6.97 and 6.75, respectively.

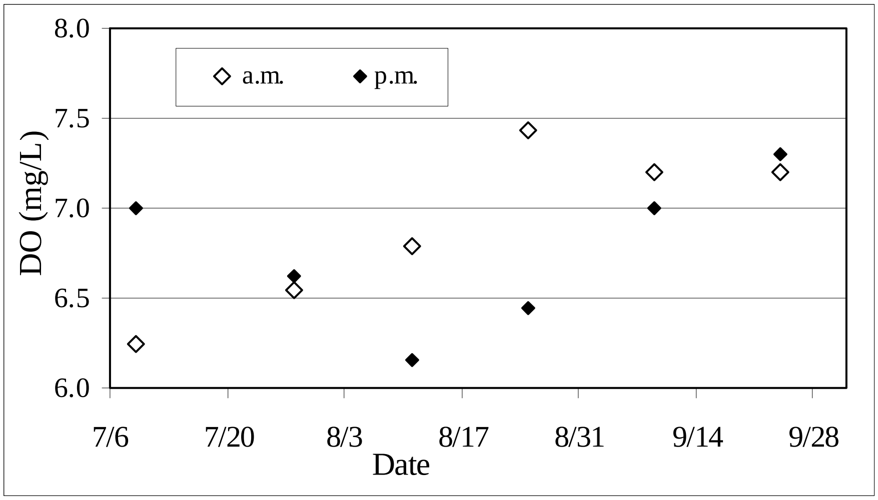
Fig. 6. Instantaneous pH



2. Diurnal dissolved oxygen

   Dissolved oxygen concentrations measured at the middle station in early morning and mid-afternoon were quite similar throughout the summer, ranging from 6.3 - 7.4 mg/L in the morning, and from 6.1 - 7.3 in the afternoon. Diurnal differences in DO were always small with a maximum of 1.0 mg/L (Fig. 7).

Fig. 7. Diurnal dissolved oxygen

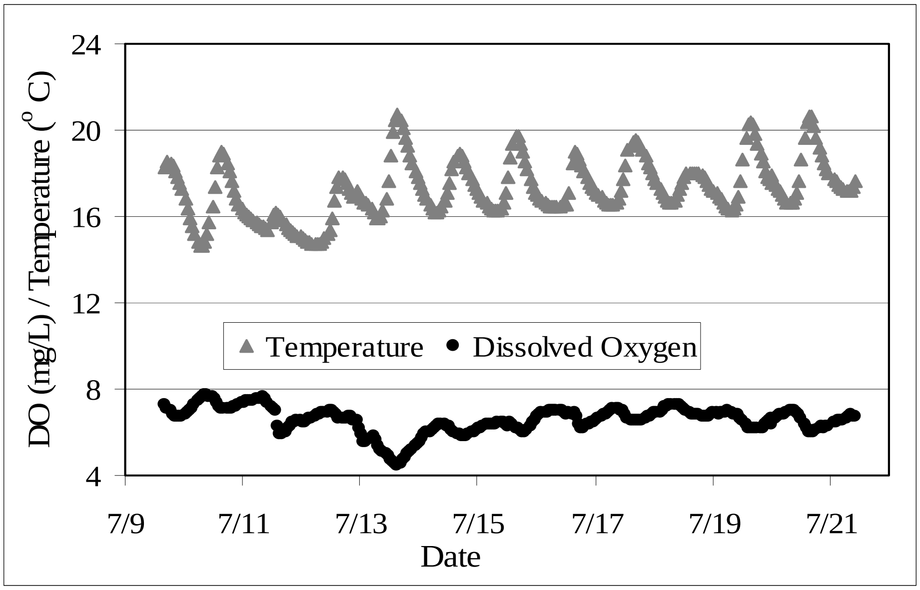


3. Continuous data collection at middle station (12 days, July 9 to 21)

   a) Continuous dissolved oxygen and water temperature

   Mean hourly dissolved oxygen (DO) and water temperature calculated from records collected every 10 min indicated that both variables showed clear diurnal fluctuations (Fig. 8). Dissolved oxygen concentrations were usually highest during the morning (7:30 – 11:30 a.m.) and lowest in late afternoon or early evening (4:30 – 8:30 p.m.; black circles in Fig. 8). Water temperatures were highest in mid to late afternoon (3:30 – 5:30 p.m.) and lowest in early morning (7:30 – 9:30 a.m.; gray triangles in Fig. 8). Dissolved oxygen concentrations were close to or below 5 mg/L (the required minimum DO concentration for a Class C stream) on several occasions. Diurnal differences were always small ranging from 0.1 - 1.0 mg/L. On July 11, (light) rain fell during most of a cool day (daytime high 17 ºC), keeping water temperatures low. The dip in DO levels on July 13 coincided with a peak in water temperature.

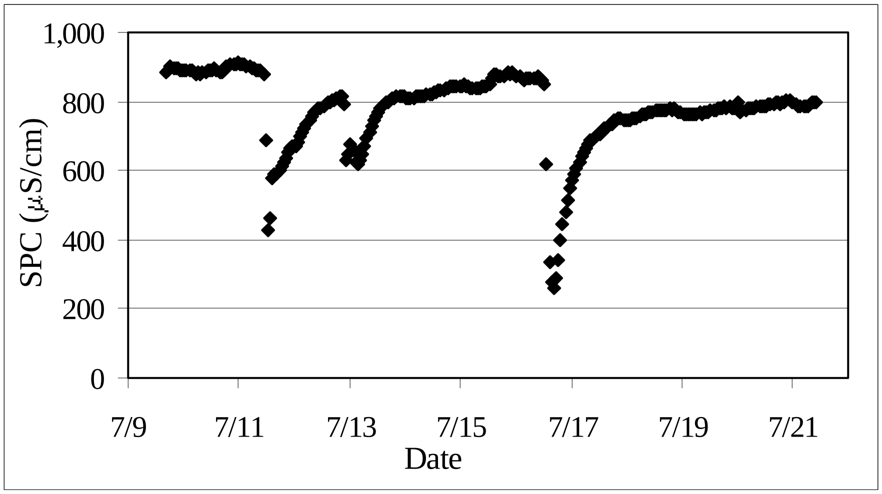
Fig. 8. Continuous dissolved oxygen and water temperature (12 days)



b) Continuous specific conductance

Mean hourly specific conductivity calculated from records collected every 10 min showed wide variation, ranging from 262 - 911 μS/cm (Fig. 9). The majority of the time, conductivity ranged from ~600 to ~900 μS/cm. Three major dips in conductivity, where SPC temporarily declined by 200 to 600 μS/cm, were recorded on July 11, 12/13, and 16/17 (Fig. 9). In all these instances, decreases were likely related to rain events (0.37", 0.08", and 0.59" on the three dates, respectively).

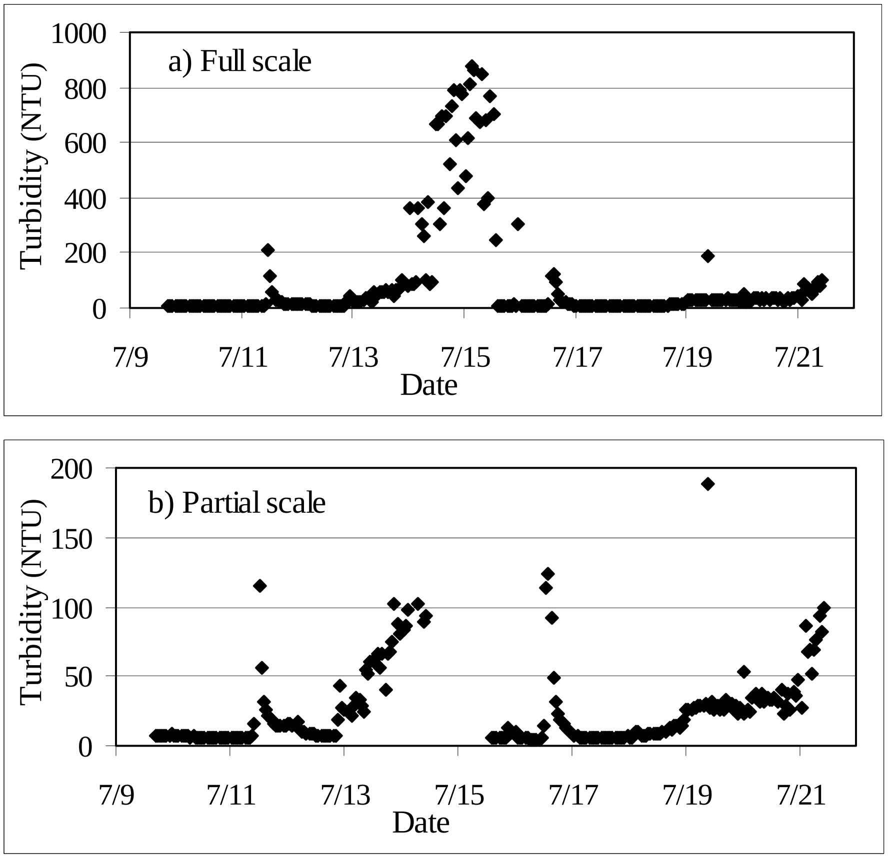
Fig. 9. Continuous specific conductance (12 days)



c) *Continuous turbidity*

Mean hourly turbidity calculated from records collected every 10 min varied widely, ranging from 4.6 - 874 NTU (Fig. 10a), thus always exceeding the EPA-recommended criterion of 3.04 NTU (EPA 2000b). The majority of the time, turbidity ranged from 5 - ~50 NTU (Fig. 10b). Small spikes recorded on July 11 and 16 (Fig. 10b) were likely related to rain events (0.37” and 0.59” on the two dates, respectively). The increase in turbidity starting on July 13 (Fig. 10b) led to a major spike where values temporarily climbed to almost 900 NTU during an ~34-h period starting at 4 a.m. on July 14 (Fig. 10a). Analysis of the raw data showed wide and random fluctuations in turbidity during that time period. There is no indication in weather data of any rain events during that time, and the reason for the observed turbidity pattern is unknown.

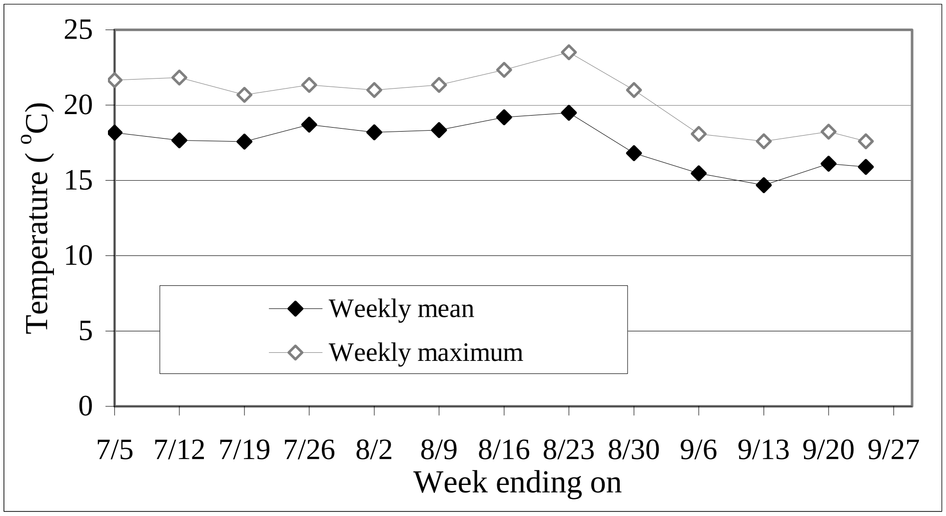
Fig. 10. Continuous turbidity (12 days)



4. Continuous water temperature (85 days, July 2 to September 24)

Continuous water temperature at the middle station (Fig. 11, measured at 20-min intervals) showed relatively constant weekly mean temperatures between 18 and 20 ºC from mid-July to mid/late August, and between 15 and 17 ºC from mid/late August to mid/late September. The weekly maximum temperature tracked the mean temperature closely but was always 2 – 4 ºC higher, i.e., always >20 ºC in the summer (Fig. 11).

Fig. 11. Continuous water temperature (85 days)



5. Water chemistry

Water chemistry data are summarized in Tables 7 and 8. Table 7 shows the results from four baseflow sampling events at the middle station. Table 8 shows the results from four stormflow sampling events at the middle station. The tables include numeric criteria for water quality where available. Criteria recommended by EPA for Region XIV present nutrient levels that protect against the adverse effects of nutrient overenrichment (USEPA 2000b). The Maine SWQC (MDEP SWQC) CMC and CCC[1] define acute (brief exposure) and chronic (indefinite exposure) levels, respectively, above which certain compounds can have detrimental effects on aquatic organisms. In general, CMC should be used to interpret results from stormflow samples while CCC should be used to interpret results from baseflow samples. Highlighted fields in the tables indicate cases where sampling results exceeded the numeric criteria, i.e., cases where negative effects may occur in aquatic organisms.

Table 7. At the middle station, Total Nitrogen (TN) exceeded EPA-recommended water quality criteria three times, and Total Phosphorus (TP) exceeded them once. Bacteria (*E. coli*) exceeded the State of Maine criterion for the mean count of bacterial colonies twice and matched it once. Note however that Maine's criteria are for *E. coli* of human origin and that the origin was not determined in this study. Iron was the only metal analyzed that exceeded any criteria although in some cases the sensitivity of the analysis was insufficient to determine whether criteria were exceeded (copper: for CMC and CCC; cadmium and lead: for CCC only). Additional data not shown in Table 7 were collected at the upstream station on July 9 during algal sampling: alkalinity, 98 mg/L, and silica (by calculation), 13 mg/L.

Table 8. During stormflow conditions at the middle station, TP exceeded recommended EPA criteria on three out of four dates. Furthermore, the following metals

---

[1] CMC, Criteria Maximum Concentration; CCC, Criteria Chronic Concentration

exceeded the CMC level of Maine SWQC (MDEP SWQC): aluminum (twice), cadmium (once), copper (twice), and zinc (twice). Zinc values recorded during stormflow conditions were 5 - 6 times higher than during baseflow conditions (aluminum was not measured at baseflow, Cd and Cu were below detection limits at baseflow; Table 7). There are no criteria for Total Suspended Solids (SSD) but SSD values at stormflows were up to 60 times higher than during baseflows.

Rainfall amounts for storm sampling events were as follows: May 26: 0.91” mostly in early evening, May 27: 0.03” at 12:30 am; November 20: 0.72” during mid to late morning, November 21: 0.28” at ~4 - 9 a.m.; February 23 - 26, 2004: no precipitation but daytime highs were 1 - 3 ºC, i.e., some melting likely occurred (Weather Underground 2003/2004).

Table 7. Water chemistry data (baseflow) from summer 2003. Highlighted fields indicate problem parameters.

Parameters	**Station (#)**	**Middle (S387)**				**Aquatic Life Criteria**	
	Sample date	**15-Jul**	**11-Aug**	**25-Aug**	**9-Sep**		
Nutrients	**Unit**						
Total Kjeldahl N	mg/L	0.5	0.5	0.4	0.4	NC	
Nitrate-Nitrite-N	mg/L	0.31	0.42	0.26	0.42	NC	
Ammonia-N	mg/L			0.04		NC	
Total Nitrogen	mg/L	0.81	0.92	0.7	0.82	0.71 [1]	
Ortho-phosphate	mg/L	0.006	0.007		~0.010	NC	
Total Phosphorus	mg/L	0.03	0.028	0.03	0.032	0.031 [1]	
Dissolved Organic Carbon	mg/L		7.6	6.5		NC	
Total Organic Carbon	mg/L		10			NC	
Chlorophyll *a*	mg/L	~0.0008	~0.0011		~0.0010	0.00375 [1]	
Total Suspended Solids	mg/L	3	ND 2	2	2	NC	
Diesel Range Organics	mg/L		83			NC	
Bacteria (*E. coli*)	# col./100 ml	161	142		236	949 [2, 3]	142 [2, 3]
Metals						**CMC**[4]	**CCC**[4]
Cadmium	mg/L	ND 0.5	ND 0.5		ND 0.5	0.64	0.32
Copper	mg/L	ND 5	ND 5		ND 5	3.89	2.99
Iron	mg/L	1,100	940		930	NC	1,000
Lead	mg/L	ND 3	ND 3		ND 3	10.52	0.41
Zinc	mg/L	10	9		9	29.9	27.1
Chromium	mg/L		ND 1			16	11
Nickel	mg/L		ND 4			363.4	40.4
Chloride	mg/L		107			860	230

NC, No Criteria; ND, Not Detected, i.e., below stated detection limit of test.

[1] Criteria recommended by EPA for Ecoregion XIV, which includes Barberry Creek. Total Nitrogen is the sum of preceding three parameters.

[2] Criteria (instantaneous/geometric mean counts of the # of *E. coli* colonies) defined by Maine's Water Classification Program for Class C waters.

[3] Results are for bacteria of any origin while Maine standards are for bacteria of **human** origin. Note that in some studies where the origin of bacteria has been investigated, the majority of bacteria were not of human origin.

[4] CMC and CCC are Maine Statewide Water Quality Criteria (SWQC; MDEP SWQC). CMC (Criteria Maximum Concentration) and CCC (Criteria Continuous Concentration) denote the level of pollutants above which aquatic life may show negative effects following brief (acute) or indefinite (chronic) exposure.

Table 8. Water chemistry data (stormflow) from 2003 and 2004. Highlighted fields indicate problem parameters.

Parameters	**Station (#)**	**Middle (S387)**				**Water Quality Criteria**	
	Date	**2003**		**2004**			
	Unit	**27-May**	**21-Nov**	**24-Feb**	**26-Feb**		
Total Phosphorus	mg/L	0.088	0.21	0.038	0.03	0.031[1]	
Total Suspended Solids	mg/L	30	120			NC	
Metals						**CMC** [2]	**CCC** [2]
Arsenic	µg/L	3	9			360	190
Aluminum	µg/L	820	2,300			750	87
Cadmium	µg/L	0.8	ND 2			0.64	0.32
Chromium	µg/L	3	4			16	11
Copper	µg/L	9	9			3.89	2.99
Iron	µg/L	2,800	8,600			NC	1,000
Lead	µg/L	4	8			10.52	0.41
Nickel	µg/L	5	7			363.4	40.4
Silver	µg/L		ND 1			0.25	NC
Zinc	µg/L	~47	60			29.9	27.1
Calcium	mg/L	21	19			NC	
Magnesium	mg/L	4.4	4.4			NC	
Potassium	mg/L	3.9	4.8			NC	
Sodium	mg/L	36	35			NC	
Manganese	mg/L	0.381	1.10			NC	

NC, No Criteria; ND, Not Detected, i.e., below stated detection limit of test.

[1] Criteria recommended by EPA for Ecoregion XIV, which includes Barberry Creek.

[2] See footnote 4 in Table 7.

Habitat Assessments

1. Flow regime

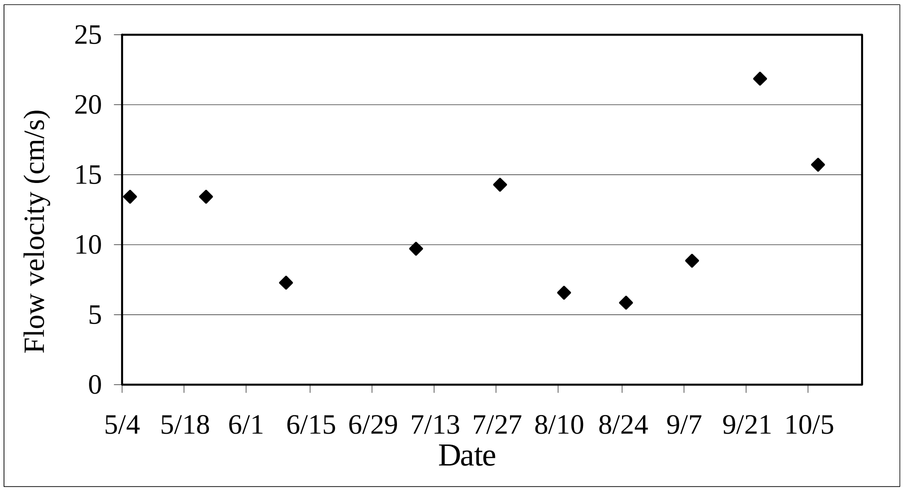
a) Instantaneous flow velocity

Instantaneous flow velocity, averaged across the stream, was quite variable at the middle station, ranging from 6 - 22 cm/s with a mean of 11 cm/s (Fig. 12; including visual estimates, which were reduced to 0.9 of observed surface flow to account for the lower velocity at mid-depth[1]).

---

[1] See Ch. 2, Methods, for further explanation.

Fig. 12. Instantaneous flow velocity

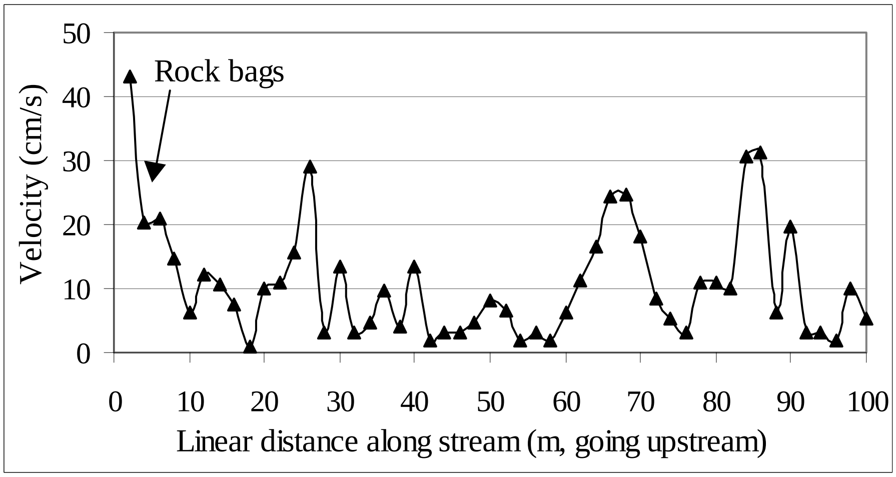


Note that first two data points are visual estimates.

b) Thalweg velocity

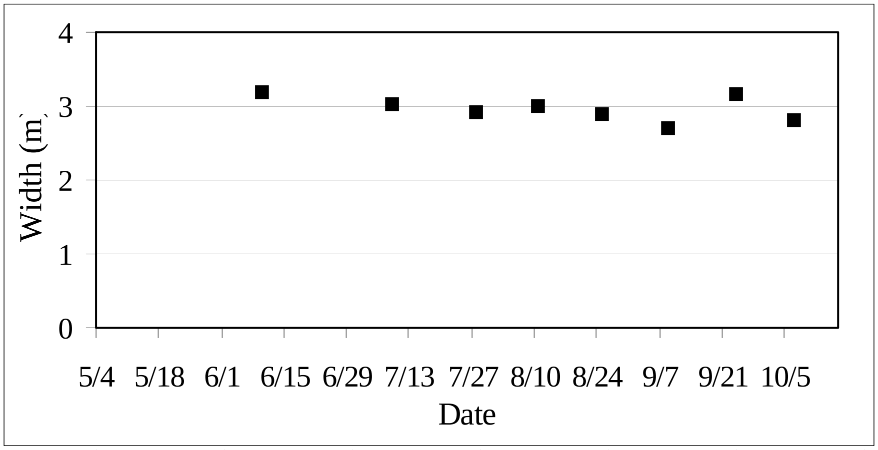
The thalweg velocity survey started just below the rock bag location and proceeded upstream. Thalweg velocity at and above the middle station was highly variable, ranging from ~1 - 43 cm/s with a mean of 13 cm/s (Fig. 13).

Fig. 13. Thalweg velocity



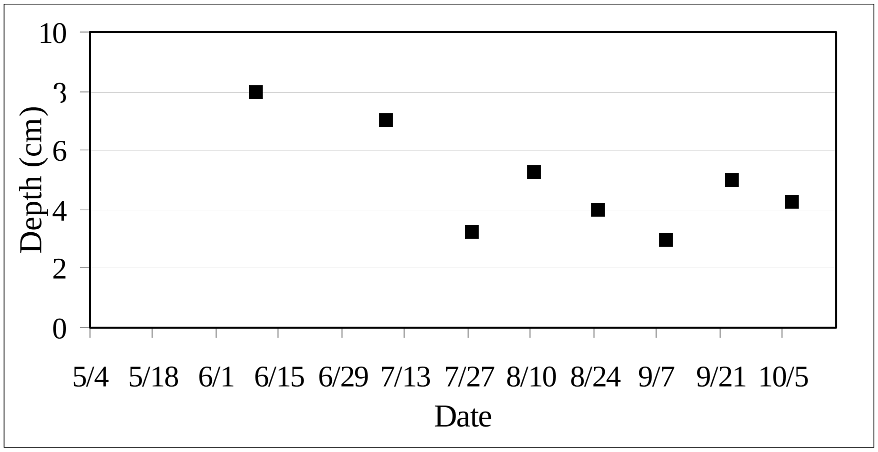
2. Mean stream width (wetted) at the middle station was quite stable throughout the sampling period, ranging from 2.7 - 3.2 m with a mean of 3.0 m (Fig. 14). Wetted width at the upstream station was 4.2 m on a single date (July 6, 2004; not measured in 2003). Bankfull width at the middle and upstream stations was similar (4.9 and 5.4 m, respectively; Field 2003, Table 2, Reaches 3 and 4).

Fig. 14. Mean stream width (wetted)



Mean stream depth at the middle station decreased noticeably during the sampling period, from a maximum of 8.0 cm in early summer to a minimum of 3.0 cm in mid and late summer (Fig. 15). Mean depth was 5.0 cm, which was very shallow given the stream width.

Fig. 15. Mean stream depth



3. Large woody debris (LWD, >5 cm mean diameter) above the middle station was abundant (46 pieces) with a good size distribution (mean diameter of 5 - 83 cm; average of 16 cm; Fig. 16). It should be noted, though, that the five large (>60 cm mean diameter) pieces found were man-made (plywood or pallets). Excluding those pieces, the size distribution is small (5 - 19 cm, average of 9 cm). Also, LWD tended to be concentrated in a few places, predominantly in debris dams. Small woody debris (2 - 5 cm diameter, >100 cm length) was very abundant at the middle station (130 pieces), and distributed fairly evenly along the section of stream studied (Fig. 17).

Fig. 16. Distribution of large woody debris (>5 cm mean diameter)

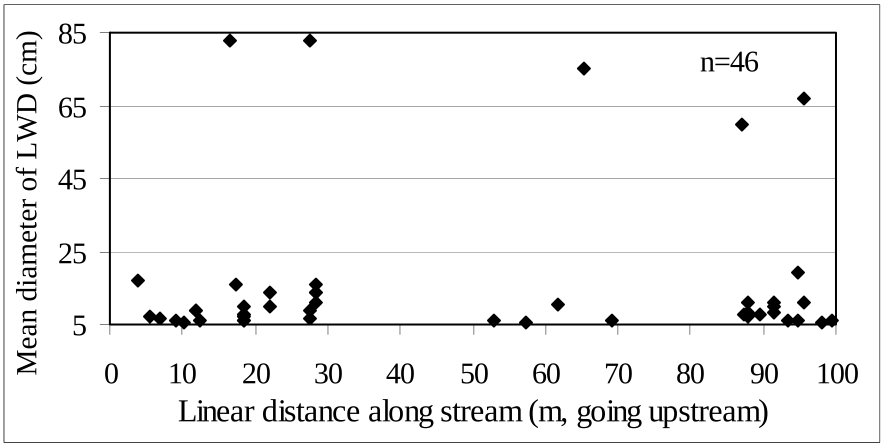
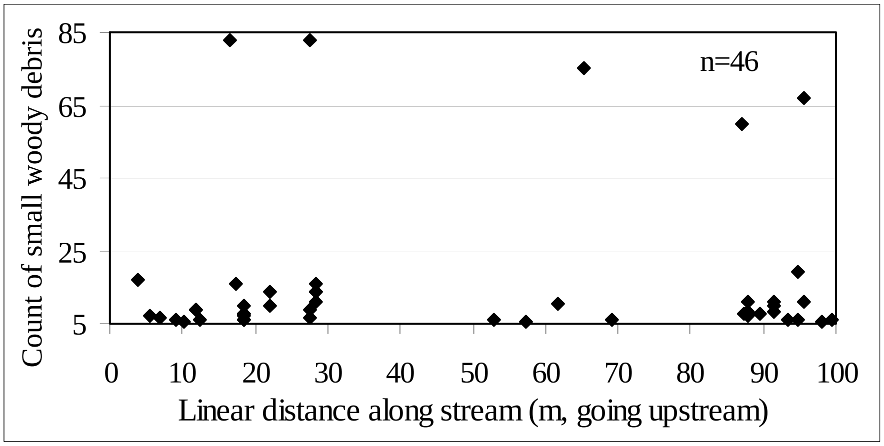
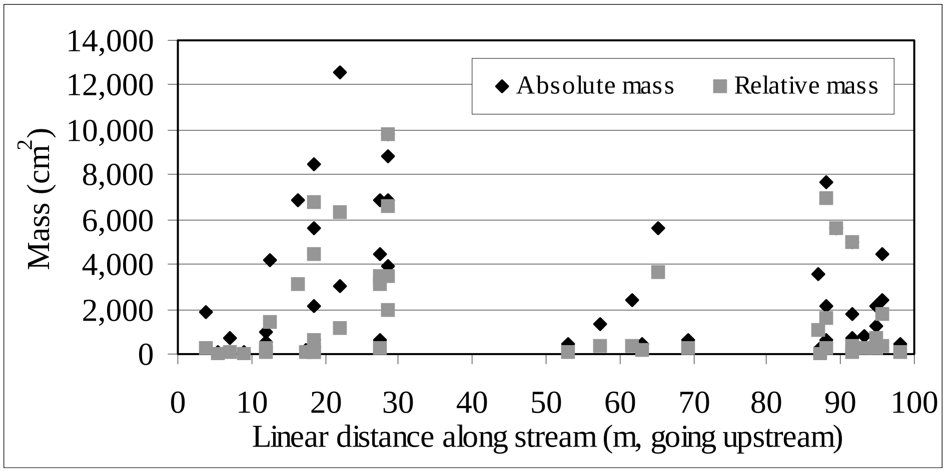


Fig. 17. Distribution of small woody debris (2 - 5 cm diameter, >100 cm length)



Absolute mass of LWD pieces (mean diameter * length) at the middle station was largely (80 %) between ~350 and 7,000 cm^2, with a few values outside this range (up to ~12,600 cm^2; black diamonds in Fig. 18). Relative mass of LWD pieces within the channel (absolute mass * % spanning channel) was largely between ~60 and 6,000 cm^2, with a few values outside this range (up to ~9,800 cm^2; gray squares in Fig. 18). There was a clear decrease from absolute to relative mass, reflecting the mean percent of the channel spanned by pieces of LWD (41 %).

Fig. 18. Absolute and relative mass of large woody debris



4. Results from the Physical Characterization assessment at the middle station are summarized in Table 9. Observed problems were moderate local watershed erosion, obvious sources of NPS pollution and channelization.

Although a Physical Characterization assessment was completed only at the middle station, observations during many visits to the stream indicated that water and sediment/substrate quality were worse in the more upstream reaches of the stream. In particular a slight oil sheen and smell, and unaesthetic appearance of the water and sediments were noted during a stream survey in June 2003 in the uppermost reach of the stream where it emerges from the wetland (Fig. 19). Furthermore, the algal survey at the upstream station also noted the objectionable appearance of the stream and substrate in that area (Fig. 2).

Fig. 19. Barberry Creek as it emerges from wetland (June 2003).

Table 9. Summary version of completed Physical Characterization form

Parameter	Sub-Parameter	Middle (S387)
Stream Characterization	Stream subsystem	Perennial
	Stream type	Coldwater
	Stream origin	Mixture of origins (swamp and bog)
Watershed Features	Predominant surrounding landuse	Commercial, industrial, residential
	Local watershed NPS pollution	Obvious sources
	Local watershed erosion	Moderate
Riparian Vegetation	Dominant type	Trees, Japanese Knotweed
Instream Features	Canopy cover	Shaded
	Proportion of reach by stream morphology types	20% Riffle, 15% Pool, 65% Run
	Channelized	Yes
	Dam present	No
Aquatic Vegetation	Dominant type (portion of reach with aquatic vegetation)	Thin layer of algae, fungi and bacteria mixed
Water Quality	Water odors	None
	Water surface oils	None
	Turbidity	Stained (little)
Sediment/ Substrate	Odors	None
	Oils	Absent
	Deposits	None
	Undersides of stones black?	No
Substrate Type	Cobble	30
	Gravel	10
	Sand	60
	Detritus (sticks, wood, coarse plant materials)	10
	Muck-mud	5

The Habitat Assessment at the middle station resulted in a total score of 94 out of a possible 200 (10 categories * 20 points) for optimal habitat, i.e., in the middle of the spectrum (Table 10). The lowest scores were recorded for channel sinuosity, sediment deposition, pool variability / bank stability / and vegetative protection , and channel flow status.

Table 10. Summary version of completed Habitat Assessment form (low gradient stream)

Habitat Parameter	**Middle (S387)**
1. Epifaunal Substrate/ Available Cover	**11**, suboptimal[1] (30-50% Mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations, presence of additional substrate in the form of newfall but not yet prepared for colonization)
2. Pool Substrate Characterization	**11**, suboptimal (Mixture of soft sand, mud or clay; mud may be dominant; some root mats and submerged vegetation present)
3. Pool Variability	**9**, marginal (Shallow pools much more prevalent than deep pools)
4. Sediment Deposition	**8**, marginal (Moderate deposition of new gravel, sand or fine sediment on old and new bars; 50-80% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent)
5. Channel Flow Status	**10**, marginal (Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed)
6. Channel Alteration	**11**, suboptimal (Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging >20 yr past, may be present but recent channelization is not present)
7. Channel Sinuosity	**5**, poor (Channel straight, waterway has been channelized for a long distance)
8. Bank Stability (score each bank, left/right)	**5/4**, marginal (Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods)
9. Vegetative Protection (score each bank, left/right)	**5/4**, marginal (50-70% of the streambank surfaces covered; by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; <1/2 of the potential plant stubble height remaining)
10. Riparian Vegetative Zone (score each bank, left/right)	**7/4**, suboptimal/ marginal (7: Width of riparian zone 12-18 m; human activities have impacted zone only minimally) (4: Width of riparian zone 6-12 m; human activities have impacted zone a great deal)

5. An analysis of historic landuse changes in the watershed undertaken as part of the geomorphological assessment found that 49 % of the watershed had been built-up by 1964; this percentage rose to 59 % by 1998 (Table 1 in Field 2003). Over the same time period, forest land declined from 40 to 35 %, agriculture remained at 0 %, and barren land declined from 10 to 5 %. No significant changes in channel position or dimension occurred during that period. All of Barberry Creek was channelized in the past (Table 11; along Dartmouth Street in 1970s, along the Greenbelt Walkway in the 1940s, D. Pineo, pers. comm.). The effect of channelization is reflected in the low entrenchment[2] ratios measured at one site (3.0 and 1.83 for two cross-sections on Site 2, in the industrialized part of the watershed; Table 6 in Field 2003). This means that flows above the bankfull stage do not spread out into a floodplain but instead remain confined within the high banks created by channelization. During high flows, this condition can create erosive forces that can cause the transport of sediment originating from the sandy substrate, stream banks or impervious surfaces. Overall, signs of entrenchment were present in all of Barberry Creek (Table 11). A notable exception to the highly entrenched channel was seen at Field's Site 1, near the upstream biomonitoring station, where the entrenchment

---

[1] For parameters 1-6, possible scores are 0-5 (poor), 6-10 (marginal), 11-15 (suboptimal), and 16-20 (optimal). For parameters 7-10, scores are given for left and right bank with bin sizes of 0-2, 3-5, 6-8, and 9-10.

[2] Entrenchment is the ratio of the channel width at two times the bankfull depth to the width at the bankfull stage (Field 2003).

ratio was >10, allowing high flows to spread out into the floodplain. However, as Field points out, the extreme width of the channel in this section allows floods to be contained within the channel (Field 2003).

Table 11. Selected results from geomorphological survey

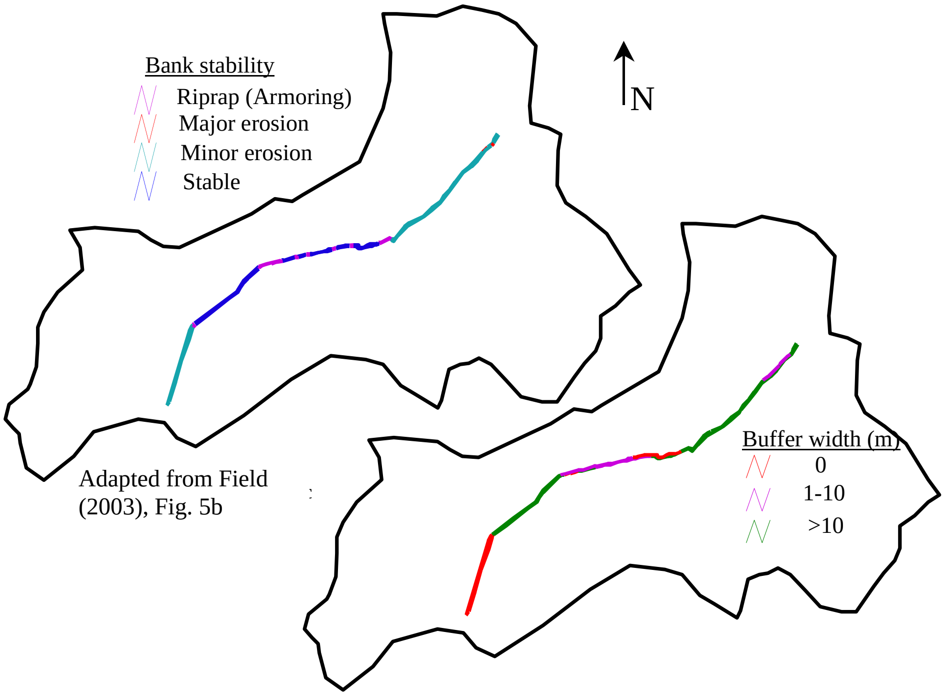
Feature		**Length (m)**	**Percent**
Channelization	Channelized	2,395	100[1]
	Encroachment	0	0
	Unaltered channel	0	0
Entrenchment (entrenchment ratio)	Deeply entrenched (<1.4)	2,246	93.8
	Slightly entrenched (1.4 - 2.2)	149	6.2
	Not entrenched (>2.2)	0	0
Bank stability	Major erosion	58	1.2
	Minor erosion	2,368	49.6
	Armoring	583	12.2
	Stable	1,766	37.0
Riparian buffer width	Absent (0 m)	1,216	25.5
	Narrow (1 - 10 m)	870	18.2
	Wide (>10 m)	2,687	56.3

The geomorphological survey showed only few areas where bank stability was identified as a problem (i.e., major erosion), but minor erosion was much more prevalent (Table 11; Fig. 20; Fig. 5b in Field 2003). Channel armoring with riprap was seen in some places, mostly at road crossings (Table 11). Buffer width was identified as a moderate problem (Table 11; Fig. 20; Fig. 5b in Field 2003). Aggradation, i.e., deposition of sediment in the channel, was identified as an issue at both survey sites (Sites 1 and 2 in Field 2003). Here the original channel was constructed too large for the dominant discharge and the channel is trying to re-establish an equilibrium through a reduction in bankfull width. Site 1, which is located in the section between Evans and Dartmouth Street, has reached Stage III of Schumm's Channel Evolution Model while Site 2, near Dartmouth Street, has reached Stage IV (see Fig. 8 and Table 6 in Field 2003). Both stations are therefore approaching the equilibrium stage (Stage V), which generally makes restoration efforts to re-establish sinuosity a good option.

---

[1] This percentage appears too high as the stream in the upstream and downstream wetlands is likely not channelized (D. Pineo, pers. comm.; pers. obs.).

Fig. 20. Bank stability and buffer width along Barberry Creek



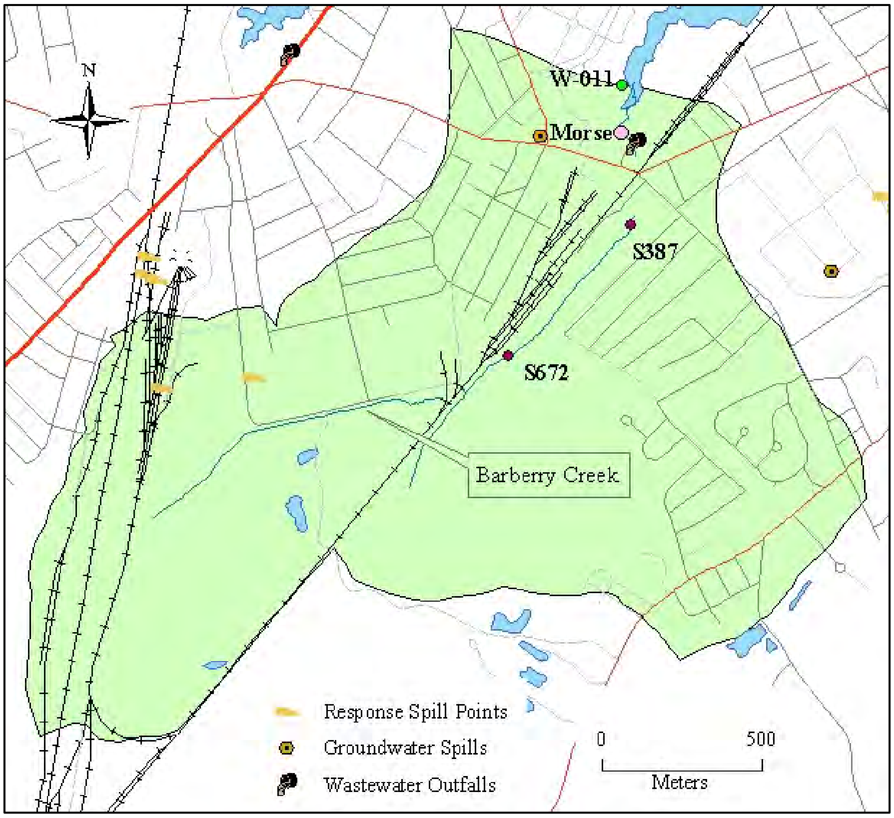
Adapted from Field (2003), Fig. 5b

The survey furthermore included two qualitative assessments of the entire stream. A Rapid Habitat Assessment (as in Table 10, above) showed that most of Barberry Creek is near the upper end of the Poor ranking, or near the lower end or middle of the Fair ranking (ranking categories are Poor, Fair, Good, Reference; top score is 200). Specifically, the stream near the upstream biomonitoring station had a Poor ranking (66, range is 0 - 70) while it had a Fair ranking (81, range is 71 - 130) near the middle station, and also a Fair ranking (117) near the downstream (wetland) station. A Rapid Geomorphic Assessment, which is used to evaluate degradation, aggradation, widening, and planform adjustment processes showed that most of Barberry Creek is near the high end of the Fair ranking, or within the Good ranking (ranking categories are Poor, Fair, Good, Reference; top score is 80). Specifically, the stream near the upstream biomonitoring station had a Fair ranking (38, range is 21 - 40) while it had a Good ranking (43, range is 41 - 60) near the middle station, and also a Good ranking (57) near the downstream (wetland) station.

6. An analysis of spills documented by the MDEP’s Bureau of Remediation and Waste Management showed that several spills occurred within the watershed between 1978 and 2003 (App. E; all spills that are not located at “Rigby Yard” plus P-402-1995 at Rigby Yard). Spatial (GIS-linked) information is currently available for only four of those spills, two of which had the potential to affect groundwater (Fig. 21). For most spills that occurred at “Rigby Yard” (App. E), the exact spill location was not indicated in the records, making it impossible to determine whether a spill occurred within the watershed or not (only part of the yard is within the watershed, see Previous Studies, BRWM study). Furthermore, in many cases the records contained no information on potential effects of a spill on nearby surface waterbodies. Most incidents concerned spills of different types of

gasoline (regular gasoline, diesel) or oil (fuel, lube, hydraulic, waste oil) with amounts ranging from <1 - 6,000 between 1978 and 2003. There was at least one case where a spilled product reached the stream, namely the largest spill (1978), where 6,000 gallons of fuel oil were spilled in the southern portion of Rigby Yard (3,000 gallons were recovered, App. E). The "Groundwater Spill" in Fig. 21 was a spill of 300 G diesel (P-58-1992).

Fig. 21. Spill points and wastewater outfalls



There is only one wastewater outfall (or combined sewer overflow, CSO, # 006; Fig. 21) in the watershed, below Broadway, near Morse's (2001) study site (see Previous Studies, University of Maine study). Discharge data for the last five years for this outfall (Table 12) show that a large amount of stormwater mixed with sewage has been discharged into the impaired segment of the stream (Fig. 1). However, as the discharge occurs below the upstream and middle stations, there is no effect on the 2003 data presented here.

Table 12. Discharge data for CSO # 006 going into Barberry Creek

Year	Number of events	Gallons discharged
2003	8	1,826,628
2002	5	1 million (estimated)
2001	7	11,236,709
2000	8	3,636,401
1999	9	8,194,061

DATA SUMMARY

The middle station studied extensively on Barberry Creek was clearly impacted, likely due to urbanization. Summary results from all sampling events and assessments are listed in Table 13 and discussed below (in the Discussion), but to summarize briefly, the station had impaired biota (macroinvertebrates, fish, algae), poor water quality (DO, conductivity, turbidity), and degraded habitat (very shallow depth, mostly small LWD, extensive channelization and entrenchment). "Conclusions and Recommendations", below, contains recommendations on how to maintain good conditions, and suggestions for remedial actions and best management practices (BMPs) aimed at improving poor conditions.

Table 13. Data summary for 2003. Problem parameters are highlighted.

Parameter	**Middle (S387)**
Biota	
Macroinvertebrates	Model result "Non-Attainment" (0 EP, 1 T, no Class A indicators, 64 % non-insects, high Hilsenhoff Index)
Fish	Only one (tolerant) species (American Eel)
Algae	Very little algal growth (but much slimy bacteria-algae-fungus mixture at upstream station)
Water Quality Parameters	
Dissolved oxygen	Quite variable (4.6-8.9 mg/L), often below 7.0 mg/L; diurnal fluctuations small (<1.0 mg/L)
Specific conductance	High (usually 500-900 µS/cm)
Summer temperature	Elevated (usually 15-20 ºC)
pH	Normal (7.1-7.4)
Turbidity/Suspended Solids	Elevated turbidity (usually 5-50 NTU); SSD ND 2-3 mg/L at baseflow, 30 and 120 mg/L at stormflow
Nutrients and bacteria (baseflow)	TN and bacteria generally exceed water quality criteria; TP right around criterion
Metals (baseflow)	Iron exceeds CCC once, just below CCC twice
Metals/Anions and cations (stormflow)	Aluminum, cadmium, copper, and zinc exceed CMC
Habitat Assessments	
Flow regime	Variable (1-43 cm/s) but mostly slow
Stream width and depth	Width stable throughout summer and into early fall; depth declined noticeably; depth shallow for stream size
Woody debris	Good abundance but limited size range of LWD, good SWD, absolute mass greater than relative mass (mean of 41% spanning channel)
Physical characterization	Qualitative assessment: predominantly urban landuses, obvious sources of NPS pollution
Habitat assessment	Intermediate score (94 out of top score 200)
Fluvial geomorphology survey	Stream is entirely channelized, most of it is deeply entrenched, half of stream has minor erosion problems, no/narrow riparian buffer along almost half of stream; Poor to Fair Habitat Assessment (score 66-121; top score is 200); Fair to Good Geomorphic Assessment (score38-57; top score is 80)
Spill points and wastewater outfalls	Several spills, one CSO in lower part (~2-11 million gallons discharged/year)

DISCUSSION

Biological Monitoring

The macroinvertebrate community observed at the middle station consisted largely of tolerant organisms, such as oligochaetes, isopods, and chironomids with an almost complete lack of sensitive organisms. Compared to macroinvertebrate data from 1999, generic richness declined (from 49 to 34, Tables 1 and 6) while the percent of non-insect taxa increased (from 37 to 64 %). Notable was the abundance of oligochaetes and taxa tolerant to sedimentation problems (*Micropsectra*, *Polypedilum*), indicating that excess sediment entering the stream may influence community composition. The only species of fish found was the American Eel, which is tolerant to water pollution. The degraded biota found in Barberry Creek are indicative of a stream that has poor water quality (reduced dissolved oxygen, high conductivity, some elevated nutrients and metals; see following section) and inadequate habitat, especially in terms of sediment load (see Turbidity and Habitat Assessments, below). In both 1999 and 2003, the middle station on Barberry Creek did not meet the required Class C aquatic life criteria , i.e. conditions were insufficient to *"maintain the structure and function of the resident biological community …" (*Maine Water Quality Criteria for Classification of Fresh Surface Waters; Title 38 MRSA §465). Maine does not yet have aquatic life criteria for algal communities in streams, and algal taxonomic data for the upstream station are as yet outstanding, but it appears that algae at that station may also be impaired as indicated by a visual assessment (see Results of 2003 Study, Biological Monitoring, item 3). Furthermore, two other studies carried out in 1998 and 1999 also found degraded macroinvertebrate communities at the downstream (wetland) station, and at a station between the middle and the downstream stations (Morse 2001; See Previous Studies). The consistent non-attainment of aquatic life criteria and generally impaired conditions are not unexpected given the predominantly urban landuse patterns in the watershed, which cause adverse effects on the stream and the biota within it. Degraded macroinvertebrate communities similar to the one found in Barberry Creek also were found in the other three streams included in the Urban Streams Project (except at the upstream station in Capisic Brook) as well as in other urban streams sampled by the MDEP's Biological Monitoring Program (unpublished data).

The data available by late May 2004 were analyzed with the goal of identifying specific stressors that are responsible for the observed impairment in the macroinvertebrate community at the middle station in Barberry Creek. The stressor identification process (see Ch. 1, Introduction, MDEP Urban Streams Project, and below) pointed to toxicants as the most likely factor to cause impairments, followed by degraded instream habitat, increased sedimentation, and low flow conditions. The Total Maximum Daily Load plan (TMDL plan; see Ch. 1, Introduction, MDEP Urban Streams Project) will need to address these factors to enable the restoration of healthy aquatic communities in Barberry Creek.

Water Quality Monitoring

Dissolved oxygen

The dissolved oxygen concentrations (instantaneous, diurnal, and continuous, Figs. 3, 7 and 8, respectively) at the middle station usually were above the Class C numeric criterion for summer DO levels (5 mg/L), although continuous data indicated that levels can come close to, or fall below, the required minimum concentration in late afternoon/early evening.

Although DO concentrations generally were >7 mg/L in spring and fall, they often fell below this level in the summer, i.e., below what is generally considered a healthy level for biota. Diurnal swings were apparent but were always well below 2 mg/L with high morning and low afternoon values. This pattern suggests that there are no negative impacts of excessive algal growth on DO concentrations in Barberry Creek.

Factors that can influence DO levels are water temperature (cold water can hold more DO than warm water), the abundance of algae (which both produce and consume oxygen, and require oxygen for decomposition by microorganisms), flow patterns (riffle sections of a stream help to re-aerate the water), and the presence of nutrients in the water (which can influence the abundance of algae). At the middle station in Barberry Creek, some of these factors are likely to impact DO concentrations. Water temperature during the summer months was somewhat elevated (Figs. 5, 8, and 11), leading to a reduction in the DO carrying capacity of stream water. Little algal growth was observed at any time at the middle station but at the upstream station, a thick film of mixed algae, bacteria and fungi was observed in July (Fig. 2). An analysis of water flow patterns at the middle station (Figs. 12 and 13) showed that the flow regime is quite variable but has a relatively low average velocity of 11 cm/s, reducing the potential for re-aeration of the water. And chemical analyses during baseflow conditions (Table 7) showed that nutrients (TN and TP) on occasion exceeded levels recommended by EPA for this region of Maine, perhaps contributing to the abundant algal growth observed in certain areas. These data and observations combined help explain the observed DO pattern at the middle station.

Dissolved oxygen is required for respiration by all aquatic animals, but some organisms, such as mayflies or trout, require relatively high oxygen concentrations for healthy functioning. Insensitive organisms like isopods, midge larvae or eels on the other hand can survive at relatively low DO concentrations. In 2003, DO concentrations were not always high enough to support healthy aquatic communities at the middle station on Barberry Creek. Indeed, macroinvertebrate data from previous years and three different stations showed that historically very few sensitive organisms were found in the stream and the wetland associated with it, which may have been partly related to reduced DO concentrations (see Previous Studies, above). To improve DO concentrations, summer water temperature and nutrient input need to be reduced, and flow patterns improved (see Water temperature, Nutrients, and Flow regime, below).

Specific conductance

The levels of conductivity (instantaneous and continuous, Figs. 4 and 9) in Barberry Creek at the middle station are similar to those found in the other three Urban Streams (except at the upstream station on Capisic Brook) as well as in other urban streams sampled by the MDEP's Biological Monitoring Program (unpublished data). These levels are much higher than those that would be encountered in minimally impacted streams in Maine, where conductivity is typically below 75 μS/cm (L. Tsomides, pers. comm.). While certain types of geological formations and certain soil types in a watershed can cause conductivity levels to be elevated naturally, it is likely that runoff from the extensive impervious surfaces above the middle station, especially runoff from the industrialized area, contributes to high conductivity levels at this station (also see discussion on Metals, below). It is noteworthy, however, that conductivity decreased substantially (by 200 - 600 μS/cm) following rain events (Fig. 9) indicating that an input of rain and stormwater temporarily diluted the ions measured with this parameter. Data from previous sampling events show that the conductivity level in the stream has increased between 1998 and 2003, and that it is lower in the stream than in the wetland section (>1,000 µS/cm). This suggests that water quality has deteriorated over the past several years, and that the wetland acts as a sink for ions (see also discussion on Metals, below).

While little is known about how conductivity in and of itself may impact biological communities, it is known that metals as well as cations and anions, all of which contribute to high conductivity levels, can have negative effects on aquatic life (see discussion on Metals, below). To reduce conductivity in Barberry Creek, it would be helpful to reduce the quantity of runoff the stream receives, or to improve runoff quality for example by channeling it through a stormwater treatment system.

Water temperature

The water temperatures (instantaneous and continuous, Figs. 5, 8, and 11) recorded in midsummer at the middle station were approaching a range that is considered stressful for some fish and aquatic invertebrates. Temperatures were at a more favorable level in spring (Fig. 5) and after late summer (Figs. 5 and 11). Compared to the other Urban Streams, temperatures in Barberry Creek were intermediate (App. C ii). Studies have shown that sensitive macroinvertebrates such as certain mayflies or stoneflies prefer temperatures below 17º C (see references in Varricchione 2002), while brook trout (a sensitive fish species) have an upper temperature limit of 20 - 24 ºC (review by McCullough 1999). Thus, the restoration of healthy biological communities in Barberry Creek would benefit from lowered summer water temperatures.

High water temperatures are often associated with open stretches of stream, where the absence of vegetation in the riparian zone leaves the water fully exposed to solar heating. This is the case in the entire upper part of the watershed, i.e., in the wetland area where the stream originates, and in parts of the industrialized section where the stream runs along roads and industrialized complexes. Heated runoff from impervious surfaces close to the stream may also increase water temperatures in the summer. To lower temperatures to a summertime level that promotes healthy biological communities, the riparian zone should be replanted wherever possible, and stormwater runoff should be diverted away from the stream.

Turbidity

Like the other urban streams studied in this project, Barberry Creek lies within the Presumpscot formation, a surficial geology type dominated by fine sediments. At all Urban Streams, silt and clay dominate over sand, contributing to an increase in turbidity due to suspended fines, especially during high flows (App. G). Analysis of the data indeed showed that high flows following rain events caused turbidity spikes on July 11 and 16 (Fig. 10b). One large turbidity spike was, however, not associated with a rain event (Fig. 10a) and it is unclear what caused it. During baseflow conditions, turbidity in Barberry Creek was relatively low (Fig. 10b), although the turbidity criterion of 3.04 NTU recommended by EPA for Ecoregion XIV (2000b), which includes Barberry Creek, was exceeded at all times. Total suspended solids were generally low during baseflow conditions (Table 7) but elevated during stormflow conditions (Table 8).

Suspended solids, which affect the turbidity of a stream, can be of natural origin (clay, silt, sand, decaying vegetation, phytoplankton) or man-made (industrial wastes, sewage, winter road sand). Land use (e.g., urban *versus* forested) and local soil type (e.g., silt and clay *versus* bedrock) are important factors that influence turbidity levels in a stream. High concentrations of suspended solids can affect streams and the resident biota in a variety of ways: by increasing sedimentation, which smothers benthic organisms (thus affecting their health) and increases substrate embeddedness (thus reducing habitat quality and diversity); by modifying light penetration, which affects plant growth; by reducing the ability of visual predators to find prey; by clogging the gills of fish; and by potentially darkening the water which may lead to an increase in temperature through increased absorption of heat from sunlight. At least one effect of suspended solids, sedimentation, was obvious in various places in the stream, for example near the upstream station where debris in the stream was embedded in a large amount of sand, and large sediment banks had accumulated along the edge of the channel (Fig. 22).

Fig. 22. Sedimentation problems at upstream station (May 2004)

Nutrients and bacteria

The surface water samples collected at the middle station during baseflow conditions exceeded EPA-recommended water quality criteria for Total Nitrogen (TN) three times, and for Total Phosphorus (TP) once (Table 7). Compared to the other impaired Urban Stream stations, Barberry Creek was similar in TN levels during baseflow (elevated; App. C iii), the abundance of algae (low), and canopy cover (high) to the stations on Trout Brook and Birch Stream. Compared to the downstream station on Capisic Brook, which had excessive algal growth and an open canopy, TN levels in Barberry Creek were ~30 % lower. During stormflows, TP exceeded the EPA-recommended criterion three out of four times (Table 8). Compared to the other impaired Urban Stream stations, Barberry Creek had an intermediate stormflow TP level in the spring of 2003 and February 2004, but the highest level in the fall of 2003 (App. C iv). At the wetland station in 1998 and 1999, several nutrients ranked very high compared to other Maine wetlands (Table 2a).

Nutrient levels are often increased in urban streams as runoff from land includes material that is high in nitrogen and phosphorus, such as animal waste, fertilizers, septic system effluent or road dirt (CWP 2003). Furthermore, many cities, including South Portland, operate a combined sewer overflow (CSO) system which may allow raw sewage to enter a stream during storm events. When this happens, the bacterial and nutrient load in the stream increases. This is also the case on Barberry Creek, but the CSO is located below the middle station and therefore does not affect water quality at this station. It would, however, affect the wetland station and may partially explain the high nutrient values recorded there. The MDEP's Biological Monitoring Program has found that, depending on site characteristics, elevated nutrient levels in urban streams may impact macroinvertebrate communities. This can occur for example when exposure of the stream to sunlight promotes excessive plant and algae growth which in turn may cause temporary DO depletion (L. Tsomides, pers. comm.).

The relatively minor exceedances of applicable water quality criteria, as well as observations on algal abundance and DO concentrations at the middle station, suggest that nutrients are likely not a significant stressor in Barberry Creek.

Maine's criterion for the mean count of bacteria (*E. coli*) colonies of human origin was exceeded twice (by 13 and 66 %) and matched once at the middle station. However, it is not known whether this constitutes a true criterion violation as the analysis performed in this study did not differentiate among various sources for bacteria (pets, wildlife, birds, leaking sewer/septic systems). Given the open nature of the wetland where Barberry Creek originates and the wooded section near the upstream station, it is likely that wildlife and birds use the stream and surrounding area as a resource, and contribute to the bacterial load. Also, residents along the middle part of the stream and people using Greenbelt Walkway in this section may contribute bacteria through pet waste that can enter the stream during storm events. According to information obtained from the City of South Portland (D. Pineo, pers. comm.), two other potential sources of bacteria (~8 homes with septic systems along Taylor Lane, and sewer pipes paralleling Barberry Creek along Dartmouth Street) are unlikely to be major issues.

Although nutrients and bacteria do not appear to be a major issue in Barberry Creek, simple measures to control them should be initiated. These measures could include keeping pets away from the stream, picking up pet waste, ensuring that any septic systems in the watershed are in good working order, and minimizing fertilizer use on lawns in the vicinity of the stream. Furthermore, the maintenance or re-planting of a vegetated riparian buffer along the stream corridor would allow for the filtration of lawn or yard runoff. Finally, separating the CSO below Broadway likely would reduce nutrient levels in the downstream wetland.

Metals and chloride

At the middle station, iron was the only metal sampled during baseflow conditions to exceed Maine's chronic Statewide Water Quality Criteria (SWQC) in 2003 (Table 7). Limited sampling in the summer of 2004 showed that aluminum exceeded the chronic criterion, that copper and chloride did not exceed any criteria, and that lead was below the acute criterion (detection limit was above chronic criterion; App. C iii). During stormflow conditions, aluminum, cadmium, copper, and zinc exceeded acute criteria (Table 8). Both sets of storm data available showed a similar pattern in criteria violations. Varricchione (2002) studied a stream (Long Creek) in a highly developed area in South Portland, and found that copper, lead, and zinc exceeded acute criteria during three storm events, i.e., a similar result to that found in Barberry Creek. Unfortunately, for some samples the detection limits for certain metals were above the water quality criteria, for example in 2003 in the case of copper for both chronic and acute criteria. Further evidence for the likely pollution of the stream with metals is found in 1998 and 1999 data from the downstream station which showed that the wetland associated with Barberry Creek had high sediment values for cadmium, copper, lead, zinc, and mercury (relative to other wetlands studied, and to the Ontario Ministry of the Environment Sediment Quality Guidelines; Table 2b). Also, monitoring results from the City of South Portland of runoff from the municipal landfill in the watershed indicated high iron values (see Previous Studies).

The metals exceeding acute or chronic aquatic life criteria likely originated as metal pollutants that had adsorbed onto particles of road dirt which were subsequently blown or washed into the stream. Beasley and Kneale (2002) and CWP (2003 and references therein) cited as sources for metal pollution in urban streams vehicles (tires, brakes, fuels, and oils), pavement (concrete, asphalt), rooftops, exterior paints, and surface debris (litter, winter road sand and salts). Given the large amount of truck traffic occurring in the industrialized part of the watershed, it is likely that vehicle wear and tear contributes substantial amounts of metals to the stream. Aluminum and iron can also occur naturally in streams as these metals are very abundant, and can leach out of soils with low pH-buffering capacity. Zinc can also originate from galvanized steel pipes used for culverts or storm drain systems. Finally, spills of hazardous substances and sediment entering the stream from construction sites, winter sanding activities, or soil erosion also may carry metals (e.g., CWP 2003). Impacts of metals on streams can occur in the form of chronic or acute toxicity to aquatic organisms, contamination of sediments, and bioaccumulation in plants or animals (CWP 2003 and references therein). Negative effects of metals on macroinvertebrates and fish have been confirmed in several studies. Effects include declines in the rates of growth and reproduction, reduced population size, changes in community structure, and death (Paul and Meyer 2001, and Beasley and Kneale 2002, and references therein). To reduce metal pollution in Barberry Creek, road runoff needs to be diverted away from the stream or treated before entering the stream. Also, sand left in parking lots and on roads after the end of the winter sanding season should be removed to reduce the sediment influx into the stream. While the City of South Portland has a road sweeping program in place (D. Pineo, pers. comm.) and is thus minimizing sand influx into the stream, it is not known whether businesses located in the watershed also remove sands from their premises. If they do not, they should be encouraged to initiate this practice. Rigorous application of BMPs by construction companies and the greening of bare surfaces also would help reduce sediment/metal input into the stream.

Chloride levels during baseflow conditions in the summers of 2003 and 2004 (Table 7 and App. C iii, respectively) were far below the chronic criterion. Chloride concentrations are expected to be low in the summer as this pollutant predominantly reaches waterbodies as road runoff during the winter and spring. No winter/spring data exist for Barberry Creek, and this data gap should be filled, preferably by deploying a continuous data sonde measuring conductivity. Conductivity is strongly affected by chloride because this anion typically occurs in high concentrations (in contrast to metals, it is measured in mg/L rather than μg/L), making SPC measurements a convenient way to determine chloride loads in winter and spring. Conductivity levels of up to ~23,000 μS/cm have been seen in studies of urban streams in the winter (S. Corsi, pers. comm.). This indicates extreme chloride toxicity as conductivities of 853 and 2,855 μS/cm correspond to the Maine SWQC (MDEP SWQC) chronic and acute criteria of 230 and 860 mg/L chloride, respectively (D. Heath, pers. comm.). According to storm drain maps obtained from the City of South Portland (D. Pineo), most snow that melts on roads, parking lots or driveways in the watershed flows into Barberry Creek either directly or via the storm drain system with outfalls located along the Greenbelt Walkway (near the upstream and middle stations). Furthermore, the City uses the old, capped landfill in the upper part of the watershed for snow disposal in the winter, and any runoff from that area would reach Barberry Creek.

Habitat Assessments

Flow regime

The variable but overall moderate flow regime (instantaneous flow velocity and thalweg velocity, Figs. 12 and 13) around the middle station likely reduces the diversity of the biological community in a number of ways. For example, organisms requiring swift flows will be absent in this environment. Furthermore, a moderate flow regime increases substrate embeddedness, and allows fine sediment to accumulate on the stream bed thus smother organisms. Finally, fast flowing areas in small streams are usually characterized by riffles which increase the re-aeration potential of the stream. Although some such areas were found in Barberry Creek, their total re-aeration potential was likely low. As shown above (Water quality monitoring, Dissolved oxygen), reduced DO concentrations were found in the stream during the summer months, and this may in part be attributable to the slow flow regime.

Urban streams often experience high and flashy peak flows due to the effects of impervious surfaces on runoff patterns. In the middle section of Barberry Creek, this is likely not a major problem (see Woody debris, below) because the channel is overwidened and capable of conveying floods efficiently (see Geomorphological survey, below). However, a negative side effect of the overwidening is the occurrence of sedimentation problems as sand and silt entering the channel are not washed out during high flows due to the reduced capacity of the stream to transport sediment.

Restoring a variable flow regime in Barberry Creek will require the expertise of a fluvial geomorphologist as many factors affecting flow velocity and stream morphology must be considered. However, as a variable flow regime would benefit aquatic communities and overall stream quality in several ways. Therefore, the restoration design for Barberry Creek described below (Fig. 23; Geomorphological survey) should be given serious consideration.

Stream width and depth

Although stream width (Fig. 14) was relatively stable at the middle station, depth was not (Fig. 15). This suggests that groundwater contributions to the stream were insufficient to maintain a constant level of baseflow from spring to fall. Furthermore, stream depth is much less than would naturally be expected for a stream the width of Barberry Creek. The shallow depth, which is largely a result of the channelization and overwidening of the stream (see Geomorphological survey, below), greatly reduces the vertical relief of the stream and hence the diversity of available habitat. The channel restoration project suggested in Fig. 23 would improve habitat conditions significantly, and should be considered as a remedial action. An additional potential factor responsible for the shallow water depth is reduced infiltration of rainwater caused by the high watershed imperviousness (23 %), which can cause reduced recharge of groundwater reserves and subsequently reduced baseflow levels (CWP 2003).

Woody debris

Although large woody debris (LWD, >5 cm mean diameter) was relatively abundant in Barberry Creek, the size distribution of natural (not man-made) material was quite small (average diameter of 9 cm; Fig. 16). This finding can be explained with the young age of trees in the riparian zone at and above the middle station (see photos on chapter title page). Small woody debris (<5 cm diameter) was very abundant (Fig. 17), reflecting the presence of much brush and Japanese Knotweed in the riparian zone amongst the young trees. The small size of most woody debris in the stream may reduce habitat diversity and food supply for aquatic organisms.

Absolute mass of LWD (diameter * length) was fairly large, mostly because many pieces measured were quite long (average of 2.6 m), while relative mass was clearly lower. Relative mass takes into account the percent of the channel LWD spans, so that a trunk lying across the entire channel (i.e., spanning 100 %) would have the same absolute and relative mass (i.e., absolute mass * 1) while a trunk lying almost parallel to the flow would have much lower relative than absolute mass (e.g., absolute mass * 0.2). The comparison between these two measures, and the average percent spanning the channel at a station (41 % for the middle station), can give an indication of flow patterns as a high maximum flow velocity tends to align LWD with the flow, thus reducing the percent spanning value. Data then suggest that maximum flows at this station may not be very large as the percent spanning value was high, second only to the upstream station in Capisic Brook (51 %), while the other Urban Streams stations analyzed in this way all had lower values (16 - 30 %). This interpretation is supported by personal observations following rain events when the riparian vegetation at this station on Barberry Creek seemed relatively unaffected while “flattened” herbaceous vegetation was observed at stations with low to intermediate percent spanning values. And yet, a visit to Barberry Creek following a large storm event (3.3” of rain in 24 h, ending shortly before visit) showed very high flows throughout the watershed (App. G, Figs. 7 - 9). These seemingly incongruous observations of a high percent spanning value, unaffected vegetation but high flows can be reconciled when considering channel width: the overwidened channel created by channelization reduces the velocity of high flows to a level where LWD is not exported and vegetation not damaged.

A comparison between LWD found in Barberry Creek and in two reference streams exemplifies the situation in Barberry Creek. For LWD >5 cm diameter, data collected in a reference stream northwest of Bangor showed that LWD abundance was similar in both streams (42 *versus* 46 pieces) but that average mean diameter was greater in the reference stream (12 cm *versus* 9 cm). Both streams had the same mean percent spanning (41 %). For this size range of LWD, Barberry Creek around the middle station appears to have a fairly natural LWD composition with a slightly smaller mean size. This finding is in line with the observation of an extensive and fairly intact riparian buffer of young trees along this section of stream. For LWD >20 cm diameter, the geomorphological survey noted an LWD abundance in Barberry Creek of 0 pieces per 100 feet of channel in 60 % of the stream, 1-2 pieces in 24 %, and >3 pieces in 16 % of the stream (Field 2003, Table 4). The corresponding percentages in a reference stream in Cape Elizabeth (adjacent to South Portland) were 18 %, 66 %, and 16 %, indicating that large-diameter LWD in Barberry Creek is less abundant than in a natural setting. This finding is not surprising given the scarcity of large trees in the riparian zone.

Woody debris enhances the habitat quality for aquatic organisms by providing stable attachment sites, providing and trapping organic materials to be used as food sources, trapping sediments, increasing habitat diversity, and being a food source in and of itself (Dolloff 1994). Trees in the riparian zone, before they become woody debris, also provide leaf litter, which is an important food source for a variety of macroinvertebrates. Because of the many advantages of a wooded riparian zone, the trees occurring along the middle section of

Barberry Creek need to be protected, and new trees should be planted in areas with a reduced riparian buffer.

Qualitative stream and habitat assessments

Qualitative assessments of the physical features of the stream and riparian area, and of the instream and riparian habitat showed that Barberry Creek suffers some of the typical problems of a stream located in a highly developed area. Problems identified near the middle station in terms of the physical character were urban development dominating landuse types and obvious sources of NPS pollution (Table 9). Only moderate erosion was observed which is likely due to a variety of reasons: dense stands of Japanese Knotweed and brush along the stream bank hold soil in place; the channel was overwidened and thus can accommodate high flow volumes without causing major erosion problems (see Geomorphological survey, below; Field 2003); and the entire stream is fairly straight, allowing water to simply rush through.

The habitat assessment (Table 10) revealed problems that are directly or indirectly a result of the channelized nature of this section of the stream [low channel sinuosity, sedimentation problems (Fig. 22), low pool variability, poor bank stability, and poor vegetative protection]. The assessment of human disturbances to the wetland (Table 3) also found evidence for the impacts of urbanization, for example a significant potential for effects of impervious surfaces in the watershed, NPS pollution, and hydrologic modifications to the wetland.

Overall, these assessments showed that the Barberry Creek watershed shows clear evidence of impacts of development on stream and wetland condition. Several of the areas of concern revealed in these assessments negatively influence aquatic biota, either directly or indirectly. For example:

- High watershed imperviousness resulting from urbanization causes an alteration in stream hydrology, an increase in pollutant concentration, a decrease in rainwater infiltration, and direct impacts on the stream channel. These factors can lead to a reduction in habitat quality and stability, in water quality, and in baseflow volume.
- Channel alterations (i.e., straightening) reduce sinuosity of the stream, thus eliminating habitat diversity.
- Clearing of vegetation along the banks and in the riparian zone reduces bank stability, decreases filtration efficiency of the soil, eliminates shading of the stream, and reduces the potential for LWD input (i.e., additional habitat). These factors can cause increased sedimentation, decreased habitat stability, increased pollutant input, elevated water temperatures, and reduced habitat diversity.

As a first step in improving riparian and instream areas, the riparian buffer should be replanted (at a minimum width of 10 - 15 m or 30 - 50 feet; CRJC, 2000) with native vegetation where open areas currently abut the stream. Issues such as the high percentage of impervious cover and channel alterations also will need to be addressed, for example through the installation of stormwater treatment systems, and the re-establishment of a natural channel morphology as described in the following section.

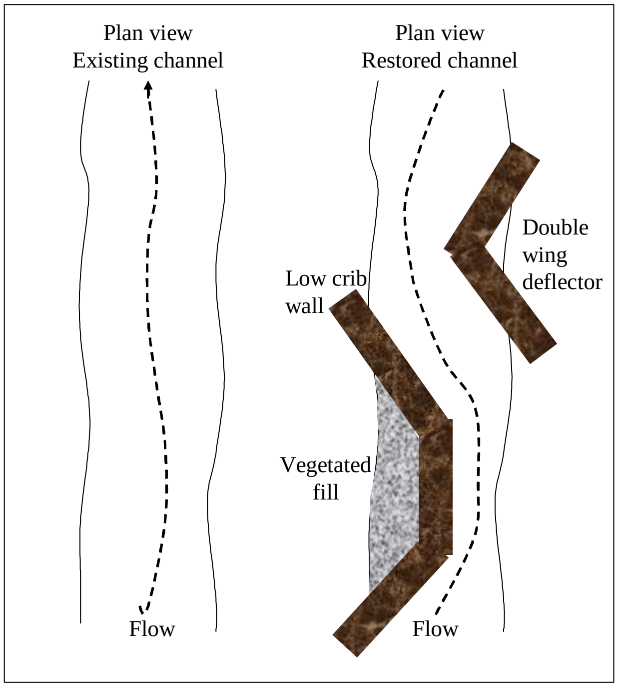
Geomorphological survey

Historical analyses of changes in watershed landuse and channel morphology as well as field work showed that the extensive urbanization in the watershed has altered stream geomorphology. Almost the entire stream has been channelized and most of it is deeply entrenched, 60 % of the stream shows signs of minor erosion or is armored, and almost half the stream has a minimal riparian buffer (Table 11, Fig. 20). Stream habitat also was impacted as shown in the Rapid Habitat Assessment. This assessment indicated that at both stations, stream habitat for biological communities is impaired in terms of physical attributes such as epifaunal substrate and available cover, sediment deposition, bank stability, or bank vegetative protection. As discussed in the preceding section, the same assessment also was carried out on a smaller scale, just around the middle station, and resulted in a similar score. The assessments documented a number of habitat problems which, in conjunction with the other data for the stream, show that available habitat in Barberry Creek does not favor healthy aquatic communities. A point worth noting is that the upstream station in Capisic Brook had a fairly low ranking in terms of its habitat with macroinvertebrate communities there attaining Class A, likely because other stressors such as toxicants, elevated temperature or depressed DO concentration were absent (see Ch. 6, Capisic Brook).

A Rapid Geomorphic Assessment showed that most of Barberry Creek is near the high end of the "Fair" or within the "Good" ranking. This type of assessment is used to document current geomorphological adjustment processes occuring in a stream in response to various watershed, floodplain, and channel modifications by evaluating channel degradation (incision or downcutting, i.e., lowering of stream bed elevation through erosion or scour of bed material), channel aggradation (i.e., raising of stream bed elevation through accumulation of sediment), channel widening, and changes in planform (i.e., the channel shape as seen from above). The assessment documented aggradation in Barberry Creek near the upstream biomonitoring station, i.e., along the Greenbelt Walkway, as well as in the heavily industrialized part of the watershed, along Dartmouth Street. This suggests that when these sections of the stream were channelized (in the 1940s and 1970s, respectively; D. Pineo, pers. comm.), the channel was constructed too large for the dominant flows thus reducing the stream's capacity to transport sediment. Aggradation is expected to continue as the stream will try to reestablish an equilibrium by reducing channel width through the accumulation of sediment (Field 2003). While a part of the accumulating sediment may be naturally derived from the underlying geology (which is dominated by sand, silt, and clay, and only very little coarser material), it is likely that some sediment enters the streams from roads, parking lots or construction sites. Channel evolution has progressed to Stage IV, i.e., close to the final stage (Stage V), in the upper part of the watershed along Dartmouth Street while it has reached Stage III in the middle part of the watershed. Given enough time, Barberry Creek will develop dimensions closer to a natural condition, i.e., a much narrower stream channel, and certain restoration actions can be taken to speed up this process.

The geomorphological report concludes with a suggestion for a restoration project to restore the middle section of Barberry Creek (i.e., around the upstream station) to a more natural morphology, i.e., a narrower, more sinuous stream channel with a faster and more varied flow regime. This could be achieved for example by installing double wing deflectors and low crib walls in the stream, and filling in and vegetating the areas behind (see Fig. 23). Because this section of the stream is wide enough allow large flood flows to spread out, the danger to of damage to the installed structures would be minimized, and this kind of restoration project should be successful (Field 2003). In addition to restoring sinuosity and improving the flow regime, such a restoration project may also alleviate sedimentation problems as faster flows would be more likely to remove excess sediment currently accumulating on the stream bed. The project could be used by the City of South Portland to educate citizens about stream restoration activities sponsored by the City and/or local businesses. Since a portion of the Greenbelt Walkway in South Portland runs along this section of Barberry Creek, this is a unique opportunity for public outreach. It should be noted that because of the highly complex nature of fluvial geomorphology, any restoration activity will require extensive involvement of a trained professional, such as a fluvial geomorphologist.

Fig. 23. Restoration design for middle section on Barberry Creek (schematic representation, after Field 2003, Fig. 9a)



Spills and CSOs

An analysis of spill points documented by the MDEP’s Bureau of Remediation and Waste Management showed that several spills have occurred in the Barberry Creek watershed (App. E, spills that are not located at Rigby Yard). Because of a lack of detail in spill records, it was not possible to determine whether certain spills shown in App. E (i.e., most of those located at Rigby Yard) indeed occurred in the watershed or, if they did, whether they affected the stream. The largest spill on record (3,000 G of fuel oil, 1978) did affect Barberry Creek and may still be contributing to the slight oil sheen and smell observed where the stream emerges from the upstream wetland (Fig. 19). Overall, the effect of spills on the stream are difficult to assess because of a lack of information on exact spill locations, weather conditions at the time of spills (rain during a spill can wash spilled products into the stream before clean-up), and groundwater drainage patterns. However, given the abundance of spills within or near the watershed, some negative effects on stream quality in Barberry Creek and the health of resident biota seem likely. To reduce the future occurrence of spills in the watershed, outreach efforts targeting businesses as well as private households should be undertaken to inform the public of the negative effects spills of any amount and product may have on stream quality. Such public outreach efforts should be accompanied by suggestions for improvements to current practices of e.g., delivering, handling, and storing fuel oil or other hazardous products. Also, storm drain stenciling has proven useful in alerting the public to the fact that any substance reaching a drain will go into a nearby waterbody where it may cause harm.

It is not known what, if any effect, discharges entering Barberry Creek from the CSO below Broadway (Table 12) have on the stream and its biota. Two studies that documented organic pollution (i.e., enrichment) in streams due to CSO influx also found evidence for DO depletion (Sztruhar et al. 1997), and an alteration in benthic community structure (Rochfort et al. 2000). In contrast, one study on CSO discharges failed to establish toxic effects on benthic communities (Rochfort et al. 2000). To eliminate any potential impacts of raw sewage, the CSO must be eliminated, and the City of South Portland has begun this process: a newly-constructed drain system (scheduled to be built in the summer/fall of 2004) will collect stormwater in the lower part of the watershed and keep it out of the sewer system. Unfortunately, the new system will route the runoff into Barberry Creek via the culvert under Broadway, thus increasing the amount of stormwater influx into the stream, and hence potentially nutrient and metal pollution. The City is aware of the issues that may arise from the sewer separation work, and is currently investigating the possibility of treating the stormwater before it reaches the stream (D. Pineo, pers. comm.).

STRESSOR IDENTIFICATION PROCESS

On May 28, 2004, the EPA Stressor Identification (SI) process was applied as described in Ch. 2. The extensive review of available data and discussion among the biologists and engineers present led to the identification of the stressors and their sources as listed below for the middle station on Barberry Creek. Although the stressors are ranked in their importance, all stressors are linked to a certain extent and their effects connected, making it difficult to apply a ranking scale. Consequently, all stressors identified may need to be addressed if the macroinvertebrate community is to recover. Similarly, although the sources for each identified stressor are listed in order of (likely) decreasing importance, sources are often interrelated, or their importance may change over space or time or depending on certain conditions, so that a ranking scale is generally difficult to apply. Where one source is of overriding importance, it is denoted below as "primary source".

Toxicants

This stressor was ranked highest (high importance), with a total of 10 "+" and 0 "-"[1] (App. D vi). The role of toxicants in impairing biological communities was indicated by violations of chronic or acute criteria for certain metals, an elevated summer level of chloride, high conductivity, and by signals from the macroinvertebrate community (App. D i). As sources for the toxicants, the conceptual model (App. D iv) identified the following:

- *Likely sources:*
  - **Railroad yard** in the upper part of watershed and railroad tracks along most of the stream: toxicants released to the environment in spills and daily operations at the yard (App. E; Previous Studies, BRWM study) as well as coal tar creosote leaching out of railroad ties can enter the stream in storm runoff or through groundwater supply to the stream. Traffic along the railroad line paralleling Barberry Creek is light (several times per year; D. Pineo, pers. comm.), and under normal circumstances should not release a significant amount of toxicants.

---

[1] "+"indicates evidence that a stressor affects macroinvertebrate community.
"-"indicates evidence that a stressor does not affect macroinvertebrate community.

  - **Runoff from local roads and parking lots**: the watershed has a dense system of roads as well as many businesses and private homes with parking areas. Much of the runoff from those impervious areas enters Barberry Creek either directly or through storm drains. As mentioned above (Discussion, Water Quality Monitoring, Metals) several studies have found elevated toxicant levels, especially metals and chloride, in urban stormwater runoff.
  - **Old, capped landfill** in upper part of the watershed: runoff from this landfill enters the stream either via overland flow or via the small tributary entering above the upstream biomonitoring station (S672, Fig. 1). Runoff may also contaminate the groundwater feeding the stream. Monitoring data from the City of South Portland indicate that runoff is high in iron and low in arsenic but no other toxicants were measured (Table 5). (Note that the existence of the landfill was unknown at the time of the SI workshop, and potential effects were therefore not discussed.)
  - **Winter road sand/road dirt**: road sand accumulations can be washed into the stream during storms, and deliver salt particles (including chloride) as well as other toxic compounds. The City sweeps road sand in the spring and also in summer and fall, but it is not known whether businesses in the upper part of the watershed do the same. Some of these businesses have large parking areas and sand/dirt from those areas can reach the stream and contribute significantly to the toxicant load.

- *Possible sources:*
  - **Documented spills**: as mentioned above (Discussion, Habitat Assessments, Spills and CSOs, and App. E), analysis of spill records indicated a significant number of spills, mostly of different types of oil or gasoline, that occurred within the surface watershed of Barberry Creek. Although groundwater drainage patterns are not fully understood in the area of the potentially largest offender, the Railroad Yard (see Previous Studies, BRWM study), it is likely that the groundwater feeding the stream has experienced a certain amount of contamination due to spills.
  - **Natural sources**, i.e., soils: iron and aluminum are very abundant in soils and, depending on the acidity of the environment, can be easily leached out and transported into streams. Cadmium, copper, lead, and zinc are far less abundant naturally, but can occur in high concentrations in some locations.
  - **Snow disposal runoff** into the stream: no snow is dumped in the stream itself but the City operates a snow dump in the area of the capped landfill in the upper part of the watershed (D. Pineo, pers. comm.). Runoff from this area reaches the stream either via overland flow or via the tributary above the upstream biomonitoring station. This runoff would contain deicing components (NaCl) as well as any materials picked up from the road surface and included in the snow (e.g., sand, debris).
  - **Atmospheric deposition**: toxicants originating from fossil fuel combustion by vehicles, industry, or power plants can be transported over large distances by air currents, and be deposited directly in a waterbody or on a pervious or impervious surface, from where they can be washed into a stream. In terms of wind patterns, Maine is downstream of many major industries in the central and eastern parts of the country, and depositions of, for example, PAHs and mercury in the state have

been attributed to atmospheric transport (see www.maine.gov/dep/air/monitoring/ Atmosdepos.htm; 2/4/2005). Overall, however, the magnitude of this source of toxicants for Barberry Creek is unknown.
  - **Septic system leaks**: a few (~8) residences in the watershed are not connected to the city sewer system and could potentially contribute toxicants via this route. City of South Portland officials indicated that this was unlikely to be a major issue (D. Pineo, pers. comm.).

<u>Degraded Instream Habitat</u>

This stressor was ranked second (high importance), with a total of 9 "+" and 0 "-" (App. D vi). The role of the habitat in impairing biological communities was indicated by a reduced habitat diversity (due to a combination of reduced sinuosity, low stream depth, a slow and homogeneous flow regime during baseflow conditions), a reduction in large woody debris, a reduction in the availability of riparian breeding habitat and thus in recruitment/ recolonization potential, and by signals from the macroinvertebrate community (App. D i). As sources for the degraded habitat, the conceptual model (App. D iv) identified the following:

- *Likely sources:*
  - **Channelization** along the majority of the stream (<u>primary source</u>): this has caused a reduction in sinuosity and a uniform flow regime, while channel overwidening has led to low stream depth, major sedimentation problems, and homogeneous habitat structure, with the overall result of a reduced habitat diversity.
  - **Low gradient**: this causes a low thalweg velocity and a generally slow flow regime.
  - **Young age of trees** in the riparian zone: this reduces the input of LWD into the stream thus lowering habitat complexity.

- *Possible source:*
  - **Increased stormflow volume**: high flows resulting from the extensive paved surfaces in the watershed can remove pieces of LWD from the stream channel thus reducing habitat complexity, and scour the substrate thus causing habitat disturbance. This is likely a minor factor in this case as the overwidened channel reduces the power of stormflows and thus does not cause much LWD export (see Discussion, Habitat Assessments, Woody debris).

<u>Increased Sedimentation</u>

This stressor was ranked third (high importance), with a total of 7 "+" and 0 "-" (App. D vi). The role of sedimentation in impairing biological communities was indicated by an increase in turbidity, high suspended solid levels during stormflows, habitat assessments giving low rankings to factors such as epifaunal and pool substrate as well as by signals from the macroinvertebrate community (App. D i), and simple observation (Fig. 22). As sources for sediments, the conceptual model (App. D iv) identified the following:

- *Likely sources:*
  - **Overwidened channel** (<u>primary source</u>): the geomorphological report found that certain sections of Barberry Creek were overwidened during channelization, reducing the capacity of the stream to move sediment downstream during baseflow conditions and causing sedimentation problems.
  - **Natural channel processes**: rivers and streams are not static but instead are constantly adjusting their morphology in response to natural or human-induced processes. Such adjustment processes include erosion and deposition of sediments (where available); they usually occur over a long time scale. Aggradation was observed in Barberry Creek in response to the overwidening of the channel as the stream is attempting to re-establish equilibrium (Field 2003).
  - **Naturally sandy/silty substrate**: this type of sediment, which is found in the Presumpscot Formation, can be easily eroded and contribute to sedimentation in a stream.

- *Possible sources:*
  - **Winter road sand/dirt**: this can accumulate along the roadside or on parking lots and be washed into the stream during snowmelt/rain events. The City sweeps road sand in the spring and also in summer and fall, but it is not known whether businesses in the watershed do the same. Some of these businesses have large parking areas and sand/dirt from those areas can reach the stream and contribute significantly to sedimentation problems.
  - **Snow dumping**: the City of South Portland operates a snow dump in the Barberry Creek watershed. Snow dumped at this location contains sand applied to roads in the winter. This sand will be released during the snow melt, and can reach the stream either via overland flow or via the tributary above the upstream biomonitoring station.
  - **High percentage of impervious surfaces**: by altering the hydrology of a stream, high imperviousness can cause an increase in stormflows leading to bank erosion problems. Approximately half of Barberry Creek showed minor erosion problems (see Geomorphological Assessment, above), and high stormflows may be partly responsible for these problems and the resulting sediment deposition in the stream.
  - **Exposed soils from landuse** (e.g., temporarily bare areas on construction sites or permanently bare areas at industrial/commercial sites): these soils can wash into a stream during storm events.

<u>Low Flow</u>

This stressor was ranked fourth (low importance), with a total of 3 “+” and 0 “-“ (App. D vi). Low flow as opposed to Altered Hydrology was chosen as a stressor because a discussion of relevant data indicated that peak flows are unlikely to be very damaging due to the ability of the overwidened channel to convey large flows. The role of low flow in impairing biological communities was indicated by reduced habitat diversity, increased sedimentation, a potential reduction in baseflow, and by signals from the macroinvertebrate community (App. D i). As sources for the low flow, the conceptual model (App. D iv) identified the following:

- *Likely source:*
    - **High percentage of impervious surfaces**: the watershed has 23 % impervious surfaces. Amongst other things, imperviousness causes low flows by reducing groundwater infiltration and thus decreasing baseflow (CWP 2003).
    - **Channelization**: this reduces channel diversity, thus promoting a uniform, and generally slow, flow regime.

- *Possible source:*
    - **Increased consumptive uses**: some businesses in the watershed (e.g., a truck washing facility on Dartmouth Street) may be using large amounts of groundwater for their operations; this needs to be investigated further.

Factors that were deemed to be minor stressors in Barberry Creek, and that were thus eliminated from further consideration were DO concentration, nutrients, and summer temperature.

CONCLUSIONS AND RECOMMENDATIONS

Study results showed that at the middle station in Barberry Creek, biological communities (macroinvertebrates and fish) were indicative of poor water and/or habitat quality. The diversity of animals present was low, and the majority of the species found are tolerant to water pollution. An analysis of general water quality indicators (dissolved oxygen, conductivity, temperature) and chemical parameters (nutrients, bacteria, metals) revealed that the middle section of Barberry Creek shows many of the effects typically encountered in urban areas. These include reduced dissolved oxygen concentrations in summer, slightly elevated water temperature, high conductivity, and elevated toxicant and nutrient levels. Habitat assessments also showed evidence of typical urban stressors, such as an altered stream morphology and hydrology, increased sedimentation, and reduced width of the riparian buffer. Data collected in other areas of the stream indicated that the entire system is degraded to some extent. The data summarized in this report formed the basis for the SI process (see previous section), which resulted in a ranking of stressors and identification of sources according to their likely importance for causing impairments. Toxicants were ranked as the most significant stressor, followed by a degraded instream habitat, increased sedimentation, and low flow conditions in summer. Factors that were deemed to be minor stressors in Barberry Creek were DO concentration, nutrients, and summer temperature. The stressors and their sources as identified during the SI process were used to develop recommendations for Best Management Practices (BMPs) and remedial actions aimed at removing or alleviating the stressors. Bacteria were not considered as a stressor during the SI process but have the potential to compromise the use of a stream for contact recreation. Therefore, BMPs for reducing bacteria levels are presented below also.

Barberry Creek is included in Maine’s 305 (b) list of impaired waters for non-attainment of the aquatic life criteria that were set for Class C streams (MDEP 2002d, 2004b). As a result, the Maine Department of Environmental Protection is required to develop a

TMDL (Total Maximum Daily Load) plan for the impaired section of the stream (namely the stream above the downstream wetland; see Fig. 1) aimed at restoring aquatic communities to Class C standards. The BMPs and remedial actions listed below will form the basis for the TMDL plan to be developed in 2005. Other data not yet available, i.e., algal taxonomy, additional water chemistry data and flow data, also will be utilized in TMDL development. While concentrating on the significant stressors, the TMDL will take into consideration all stressors because physical, chemical, and morphological features of a stream are linked and interact to affect biological communities.

The list of BMPs and remedial actions provided below is categorized by stressor and source, and provides suggestions as to which broad category of party (or parties) may be responsible for implementing BMPs (i.e., City of South Portland, industry/businesses, public, or all). Because many factors must be considered when choosing specific structural BMPs (e.g., target pollutants, watershed size, soil type, cost, runoff amount, space considerations, depth of water table, traffic patterns, etc.), the list below only suggests a variety of BMPs without proposing particular types for particular situations. For detailed information on structural BMPs, their individual effectiveness, and required planning considerations see publications by the MDEP (1995, 2003a) and the City of Nashua (2003). A summary of stressors, goals, and relevant BMPs and remedial actions as presented below and in Ch. 3, 4, and 6 can be found in App. I.

Goal: Reduction in Toxicants

During the SI process, toxicants were identified as the most important stressor in Barberry Creek with railroad facilities (primary source), runoff from impervious surfaces, the landfill, and winter road sand/road dirt as likely sources, and natural sources, documented spills, snow dispersal runoff, atmospheric deposition, and septic system leaks as possible sources. A reduction in toxicant load would likely aid the recovery of the macroinvertebrate community. The following list provides BMPs and remedial actions aimed at reducing toxicant load.

BMPs and remedial actions

1. **Reduce impact of railroad operation**: spills of toxic substances that have been documented at the Rigby Yard and toxic coal tar creosote leaching out of tracks can enter the stream in storm runoff or through groundwater supply. No corrective or remedial actions are currently planned at the yard although nine potential pollution sources were identified (Beneski 2000). Railroad operators should be encouraged to remediate those sources and to employ general BMPs at the yard and in daily operations of railroad traffic. (Industry)

2. **Reduce storm runoff from impervious surfaces**: during rain and storm events, the stream receives a large amount of runoff either directly or via the storm drain system. This runoff is contaminated with metals (aluminum, cadmium, copper, iron, lead, zinc; Table 8) that are toxic to aquatic life. Two BMPs/remedial actions can be suggested for this situation:
    a) A reduction in impervious surfaces, and thus runoff quantity, for example through the replacement of asphalt with pervious cover (e.g., porous pavement blocks, grass/gravel pave) or the replacement of conventional roofs with green roofs. In

some cases there may also be the potential for replacing impervious cover with bioretention structures (bio-islands/cells). The city could also promote shared parking areas between homes or between facilities that require parking at different times (e.g., business and church), and reconsider its minimum parking requirements for businesses. (All)

b) Channeling of runoff through a treatment system to reduce runoff quantity, control peak discharge rate, and improve runoff quality by promoting infiltration and pollutant absorption/straining/decomposition. There are several choices for such systems:
- vegetative BMPs (e.g., vegetated buffers or swales);
- infiltration BMPs (e.g., dry wells, infiltration trenches/beds/basins, driveway drainage strips, bio-islands/cells, decorative planters), which may need to be equipped with pre-treatment BMPs to filter out toxicants;
- detention BMPs (e.g., dry/wet ponds, extended detention ponds, created wetlands); and
– filter and separator BMPs (e.g., oil/grit and oil/water separators, flow splitters, Vortechnics^{TM}-type systems, water quality inlets, sand filters, leaf compost filters).

For more information on these BMPs and their effectiveness and planning considerations see MDEP 1995 and City of Nashua 2003. (All)

3. **Minimize effect of landfill runoff**: monitoring data exist for only two toxicants (iron, arsenic) and show that runoff from the landfill contains levels of iron far exceeding the Maine SWQC chronic criterion (Table 5). It is recommended that the city collects data on other metals that were found in Barberry Creek (cadmium, copper, lead, aluminum, zinc; Table 7) to help determine whether those pollutants originate from the landfill. Also, the forested area between the landfill and the stream should be protected to allow for filtration of runoff by vegetation and soil. (City)

4. **Reduce input of winter road sand and road dirt**: many toxicants are adsorbed onto sediment particles, and enter a stream in storm runoff. A reduction in metal load by way of loose sediment could be achieved by sweeping winter road sand and road dirt. The City has a road sweeping program in place and should continue it, with special attention given to post-winter clean-up (to remove chloride). If possible, sweeper types that employ a vacuum or regenerative air system should be used for cleaning as these maximize pick-up of fines (which hold the greatest toxicant load). Businesses that do not already sweep their premises are strongly encouraged to initiate this practice. Similarly, private homes with paved driveways/parking areas also should sweep sand and dirt on a regular basis. To capture any loose sediment and attached metals that is not removed by sweeping, BMPs listed below under “Goal: Reduction in Toxicants”, item 2 b (BMPs for reducing the effect of sediment leaving a site), should be considered.

5. **Reduce the incidence of spills** (both accidental and deliberate): a number of spills of hazardous substances have occurred in the watershed, largely in the area of the railroad yard (App. E). A reduction in spill frequency would likely have a beneficial effect on water quality and biological communities. Outreach efforts are useful for educating the public and businesses about safe ways for handling hazardous

substances (e.g., paint and paint thinner, motor oil, gasoline, chemicals, pesticides), and proper ways for disposal. Storm drain stenciling has been shown to be useful in informing the public that any substance reaching a drain will go into a nearby waterbody where it may cause harm. The city might also consider increasing the frequency of their hazardous waste collections. Information material listing non-hazardous alternatives to hazardous substances could also help reduce the number of spills. Finally, where it has not already been done, industry and businesses should seal up floor drains or connect them to the sewer system, as appropriate. (All, MDEP)

6. **Natural sources**: iron and aluminum are abundant in soils, and can easily leach out and enter a waterbody. This is a natural phenomenon and cannot be remedied. To minimize the negative impacts of natural toxicants, water quality and habitat parameters must favor healthy biological communities rather than provide additional stressors. Addressing the stressors identified in the SI process will help to provide such conditions.

7. **Eliminate snow disposal runoff**: the snow dump operated by the city at the site of the landfill likely contributes a significant toxicant load (e.g., chloride, metals, sediment) to the stream during snowmelt events. The city should look for an alternative site although it is acknowledged that snow melt runoff may affect a local waterbody wherever a dump site is located. Alternatively, runoff could be channeled through one of the treatment systems suggested above for runoff from impervious surfaces. At a minimum, the forested area between the dump site and the stream must be protected to allow for filtration of runoff by vegetation and soil. (City)

8. **Atmospheric deposition**: the pollution potential from this source is difficult to assess and even more difficult to remove. Almost by definition, this type of pollution originates from very diffuse and potentially far-away and wide-spread sources and cannot be addressed by any action the City of South Portland, local businesses, or residents can take. National action is required to deal with this issue. On a local scale, however, a reduction in sources of air pollution (e.g., motor vehicles, power plants, home heating systems, any type of fume) can improve local air quality and contribute to a decrease in atmospheric deposition. (All)

9. **Eliminate the potential for sewer/septic system leaks**: to ensure that all components of sewer system are in good working order, portions that have not recently been surveyed should be inspected, and repairs or required replacements made as allowed by budgetary constraints. For septic systems, regular maintenance and inspection are critical to ensure proper functioning. Only few homes in the watershed have septic systems, and the pollution potential from this source is deemed to be small. Home owners can ensure that they do not contribute to the toxicant load in the stream by keeping toxic substances out of the sewer/septic system. (City, public)

Goal: Improvement in Instream Habitat Quality

During the SI process, instream habitat quality was identified as a major stressor with channelization (primary source), a low gradient, and the young age of trees (which affects

LWD supply) in the riparian zone as likely sources, and increased stormflow volume as a possible source. An improvement in this parameter would likely aid the recovery of the macroinvertebrate community. The following list provides BMPs and remedial actions aimed at improving instream habitat.

BMPs and remedial actions

1. **Improve channel morphology**: the channelization that occurred in the 1940s and 1970s (see Results, Habitat Assessments, item 5) resulted in an overwidened and straightened channel, leading to a reduced channel diversity, low water depth, sedimentation problems, and a homogeneous and generally slow flow regime. All of these effects cause a reduced habitat diversity and quality, which negatively influence biological communities. To improve channel morphology, the restoration suggestion included in Discussion, Geomorphological survey, above (Fig. 23), should be implemented with the help of a qualified professional such as a fluvial geomorphologist. Such a restoration project would markedly improve habitat quality by re-establishing channel sinuosity and the habitats associated with it, increasing water depth (and thus vertical relief), reducing sedimentation problems, and diversifying the flow regime. (City)

2. **Low gradient**: this is a natural situation and cannot be remedied.

3. **Improve LWD quality and quantity**: large woody debris (LWD) enhances habitat quality for aquatic organisms by providing stable attachment sites, providing and trapping organic materials to be used as food sources, increasing habitat diversity (in and of itself, and by promoting the formation of pools), and being a food source. An improvement in LWD quality requires the following:
   - the preservation/development of an intact riparian buffer, preferably with large, old trees (to provide LWD), and a minimum width of 15 m (50 feet; CRJC, 2000);
   - the re-establishment of a sinuous channel (to snag LWD);
   - a reduction in stormflows (to minimize LWD export in a restored, narrower channel); and
   - the retention of LWD in the channel (i.e., the elimination of LWD removal in an effort to “clean-up” the stream).

   (All)

4. **Reduce stormflow volume**: at the moment, the overwidened channel conveys high stormflows efficiently, without causing a major loss of LWD or scouring the substrate excessively. Once channel morphology has been restored, high stormflows will tend to export LWD and scour the substrate because of their increased force. A reduction in stormflow volume would likely be required to prevent these effects. Various BMPs that can aid in reducing peak flow volume are listed above in “Goal: Reduction in Toxicants”, item 2. (All but predominantly city and industry/businesses)

Goal: Reduction in Sedimentation

During the SI process, excess sedimentation was identified as a major stressor with an overwidened channel (primary source), natural channel processes, and a naturally sandy/silty substrate as likely sources, and winter road sand/dirt, a high percentage of impervious surfaces, and exposed soils from landuse as possible sources. A reduction in sediment input would likely aid the recovery of the macroinvertebrate community. The following list provides BMPs and remedial actions aimed at reducing sedimentation problems in the stream.

BMPs and remedial actions

1. **Improve channel morphology**: the overwidened channel resulting from channelization has reduced the stream's capacity to move sediment during low flows, causing sediment to accumulate. The restoration suggestion included in Discussion, Geomorphological survey, above (Fig. 23), should be implemented with the help of a qualified professional such as a fluvial geomorphologist. A more natural flow regime would increase the stream's capacity, and hence help to export sediment from the channel. (City)

2. **Natural channel processes, and naturally sandy/silty substrate**: these are natural phenomena and cannot be remedied.

3. **Reduce input of winter road sand and road dirt**: owing to the high imperviousness in the watershed, large amounts of winter road sand and general road dirt accumulate on roads and parking lots year-round. Implementation of the BMPs listed above in "Goal: Reduction in Toxicants", item 4, can significantly alleviate sedimentation problems. (All)

4. **Eliminate snow dump runoff**: the snow dump operated by the city at the site of the landfill likely contributes a significant sediment load to the stream during snowmelt events. See "Goal: Reduction in Toxicants", item 7, for recommendations on how to deal with sedimentation effects from this source. (City)

5. **Reduce effects of high percentage of impervious surfaces**: the increased peak flows caused by high imperviousness in a watershed can lead to increased bank erosion and sediment deposition, especially where the natural substrate is sandy/silty (as in Barberry Creek). BMPs/remedial actions that reduce runoff quantity and/or velocity, and thus the erosive power of runoff, are presented above in "Goal: Reduction in Toxicants", item 2. (All)

6. **Reduce transport of exposed soils from landuse**: where soil is not stabilized by vegetation, rain (or even strong wind) will erode exposed sediment, and transport it to the nearest waterbody. If an area is temporarily bare (e.g., during construction activities), erosion controls such as mulches, grass covers, temporary diversions, silt fences, check dams, storm drain inlet protection, and sediment basins should be used (MDEP 1995 and 2003a). The city should consider starting a program to promote or enforce the conscientious use of such BMPs by construction companies.
   If an area is permanently bare and vegetating it is not practical or feasible, erosion and sediment controls (e.g., geotextiles, Super Humus, level spreaders, riprap, vegetated waterways, ditch turn-outs; MDEP 2003a) should be used to keep sediment in place. To reduce the effect of sediment that does leave a site during storm events, runoff

should be guided to a treatment system as suggested in “Goal: Reduction in Toxicants”, item 2 b. (All)

Goal: Improvement in Low Flow

During the SI process, decreased low flow was identified as a minor stressor with a high percentage of impervious surfaces and channelization as likely sources, and increased consumptive uses as a possible source. In conjunction with other stressors, both major and minor, flow patterns influence the macroinvertebrate community, and an improvement in this parameter would likely aid the recovery of the macroinvertebrate community. The following list provides BMPs and remedial actions aimed at increasing improving flow conditions in the stream.

BMPs and remedial actions

1. **Reduce percentage of impervious surfaces**: the watershed has 23 % impervious surfaces which can reduce rainwater infiltration and thus the size of groundwater reservoirs which feed baseflow. A reduction in impervious surfaces could be achieved as suggested above in “Goal: Reduction in Toxicants”, item 2 a. Also, installation of infiltration BMPs as suggested above in “Goal: Reduction in Toxicants”, item 2 b, can aid in recharging groundwater reservoirs. (All)

2. **Improve channel morphology**: a straightened (and widened) stream channel tends to have a uniform, generally slow flow regime that does not promote diversity in biological communities. To improve channel morphology, the restoration suggestion included in Discussion, Geomorphological survey, above (Fig. 23), should be implemented with the help of a qualified professional. Such restoration would help diversify the flow regime by re-establishing channel sinuosity and the associated variability in flow patterns and water depth. (City)

3. **Increased consumptive uses**: if this is confirmed to be a problem, the responsible party should be encouraged to minimize water use/loss by implementing BMPs specific to the situation.

Goal: Increase in Dissolved Oxygen Concentration

During the SI process, reduced DO concentration was identified as a minor stressor with elevated water temperature, channelization, a low gradient, the upstream wetland, and low LWD abundance as likely sources, and increased nutrients as a possible source. In conjunction with other stressors, both major and minor, DO levels influence the macroinvertebrate community, and an improvement in this parameter would likely aid the recovery of the macroinvertebrate community. The following list provides BMPs and remedial actions aimed at increasing DO levels in the stream.

BMPs and remedial actions

1. **Reduce water temperature**: cooler water temperatures in the summer would help improve the dissolved oxygen concentration as cool water can hold more oxygen than warm water. Implement BMPs and remedial actions listed under “Goal: Reduction of

water temperature”, below. (All)

2. **Improve channel morphology**: the heterogeneity in flow patterns that would result from a more natural channel morphology (Fig. 23) would naturally enhance DO levels by promoting re-aeration of stream water. (City)

3. **Low gradient**: this is a natural situation and cannot be remedied.

4. **Upstream wetland**: wetlands often have low DO levels because of their elevated water temperature (due to their unshaded nature) and very high biological activity. This is a natural phenomenon and cannot be remedied.

5. **Improve LWD abundance**: large woody debris (LWD) creates structural heterogeneity in the stream thus providing possibilities for re-aeration of the water. An improvement in LWD abundance can be achieved as suggested above in “Goal: Improvement in Instream Habitat Quality”, item 3. (All)

6. **Prevent increase in nutrient levels**: high nutrients may lead to excess algal growth and a depletion of DO. Implement BMPs and remedial actions listed under “Goal: Reduction in nutrient levels”, below. (All)

Goal: Reduction in Nutrient Levels

During the SI process, elevated nutrient levels were identified as a minor stressor with road runoff and animal waste as possible sources, and atmospheric deposition, and lawn/landscaping runoff as possible sources. In conjunction with other stressors, both major and minor, nutrient load influences the macroinvertebrate community, and an improvement in this parameter would likely aid the recovery of the macroinvertebrate community. The following list provides BMPs and remedial actions aimed at reducing nutrients in the stream.

BMPs and remedial actions

1. **Reduce nutrient load in runoff**: because nutrients were not identified as a major stressor in Barberry Creek, extensive treatment of runoff to remove nutrients is not required at this time. However, if treatment systems are installed to deal with toxicant issues, a reduction in nutrient loads could be achieved simultaneously. (City, industry/businesses)

2. **Implement BMPs and remedial actions listed under “Goal: Reduction in bacteria levels”**, below: discharges from faulty sewer or septic systems and pet waste can increase the nutrient load in a stream. (All)

3. **Atmospheric deposition**: studies have found that background nitrate concentrations in streams are higher in the Northeast than in other parts of the country. For suggestions on how to deal with atmospheric deposition see “Goal: Reduction in Toxicants”, item 8. (All)

4. **Minimize lawn/landscaping runoff**: fertilizers applied to landscaped areas, lawns or gardens can be washed into the stream during storms. Reduction or elimination of fertilizer use is an important step in reducing the nutrient load in a waterbody. Soil tests can be a useful way to determine actual nutrient requirements. (All)

5. **Maintain/replant riparian buffer**: a densely vegetated area separating a fertilized green space or an impervious surface from the water's edge will reduce runoff of nutrient-laden water into the stream. As a rule of thumb, a riparian buffer should have a minimum width of 15 m (50 feet; CRJC, 2000), though a width of ~23 m (75 feet) or greater provides better treatment. Shading of the stream will also minimize the risk that elevated nutrient loads can lead to excess algal growth and a depletion in DO. (All)

6. **Eliminate sewage input from CSO below Broadway**: although the effect of this CSO on the stream was not directly investigated in this study, it is likely that the influx of stormwater mixed with raw sewage adds significant nutrient amounts to the downstream stretch of the stream. The planned separation of this CSO will eliminate any potential effects from this source. (City)

Goal: Reduction in Water Temperature

During the SI process, elevated summer temperature was identified as a minor stressor with impervious surfaces and reduced riparian shading upstream as likely sources, and colored water as a possible source. In conjunction with other stressors, both major and minor, temperature influences the macroinvertebrate community, and an improvement in this parameter would likely aid the recovery of the macroinvertebrate community. The following list provides BMPs and remedial actions aimed at lowering water temperature.

BMPs and remedial actions

1. **Reduce temperature of road/parking lot runoff**: because water temperature was not identified as a major stressor in Barberry Creek, extensive treatment of runoff to lower temperature is not required at this time. However, if treatment systems are installed to deal with toxicant issues, a reduction in runoff temperature may be achieved simultaneously, depending on the type of treatment system used. (City, industry/businesses)

2. **Increase riparian shading**: some sections of the stream lack a riparian buffer. Tree plantings would provide shading that can aid in keeping water temperatures low. As a rule of thumb, a riparian buffer should have a minimum width of 15 m (50 feet; CRJC, 2000). (All)
   In areas where the riparian buffer currently provides adequate shading for the stream, efforts should be made to maintain this situation. (City, public)

Goal: Reduction in Bacteria Levels

At this point, Barberry Creek is not listed for bacterial violations although *E. coli* concentrations (of unknown origin) exceeded Maine's criterion for mean counts of bacterial colonies (of human origin; Table 7). Bacteria are not in themselves a stressor for macroinvertebrates, and thus were not included in the SI process. However, the presence of *E. coli* in the water is cause for concern because it can indicate the presence of raw sewage in the stream. Raw sewage, which can originate from the public sewer system, faulty septic systems, or illicit discharges, has the potential to also carry disease-causing organisms (as well as metals and nutrients). Therefore, elevated levels of *E. coli* in the stream suggest that a waterbody may be impaired in several ways. The following list provides BMPs and remedial actions aimed at a reduction in bacteria load.

BMPs and remedial actions

1. **Eliminate sewage input from CSO**: no bacteria samples were collected downstream of the CSO below Broadway but a very strong sewer smell was noticed on two visits to that area, suggesting contamination with bacteria and other materials found in sewage. The City must continue to work towards CSO separation to eliminate this source. (City - already initiated)

2. **Eliminate potential for sewer/septic system leaks**: to ensure that all components of sewer system are in good working order, portions that have not recently been surveyed should be inspected, and repairs or required replacements made as allowed by budgetary constraints. For septic systems, regular maintenance and inspection are critical to ensure proper functioning. (All)

3. **Eliminate illicit discharges**: entities/households with an illicit discharge must eliminate it through either stopping the discharge, or routing it into a septic system/the city sewer. The Center for Watershed Protection recently developed an extensive manual to help municipalities in the detection and elimination of illicit discharges (CWP 2004). (Industry/businesses, public)

4. **Minimize bacteria input from animals**: in many cases, *E. coli* do not originate from human sources but from warm-blooded animals, including pets, and eliminating this source would likely reduce bacteria levels. Keeping pets away from the stream and always picking up pet waste prevents waste from getting washed into the stream during a storm. Feeding of wildlife near the stream is discouraged as animals (especially waterfowl) can contribute to the bacterial load in a waterbody. (Public)

5. **Be a steward of the stream**: alert city personnel if there is a sewage smell in the stream, or if signs of sewage discharge are obvious. Stream bank surveys by stream teams (see below) can reveal problems without requiring costly water analyses. (Public)

6. **Eliminate septic systems in watershed**: this could be achieved by connecting residences with septic systems to the city sewer. Because of the cost, this option should be used as a last resort. (City)

General Activities that Can Help Barberry Creek

1. **Invest in education and outreach efforts**: alert the public as well as industry and businesses to the role different stressors play in impairing biological communities and water quality in a stream. Encourage all concerned parties to implement BMPs and remedial actions listed here. (City, MDEP, Cumberland County Soil and Water Conservation District)

2. **Promote the formation of a Stream Team** for Barberry Creek. Owing to the impaired nature of the stream at this point in time, this initiative should be deferred to a later date. However, once stream quality has improved, citizens and/or businesses should be encouraged to become stewards of the stream. (MDEP)

3. **Encourage responsible development**: parts of the Barberry Creek watershed are not yet developed, and these wetland and forested areas have an important influence on the stream ecosystem. Future development should take into consideration the findings of this report, and be done so as to minimize the impact on the stream. Practices promoted under smart growth and low impact development (LID) guidelines should be implemented wherever possible. More information on such guidelines can be found at www.epa.gov/smartgrowth/ and www.epa.gov/owow/nps/lid/. The city should consider including such guidelines into the building code, or at least promoting their use when issuing construction permits. (City, industry/businesses)

The list of BMPs and remedial actions given above provides guidance for the kinds of actions that could be taken to deal with the urban stressors the SI process identified for Barberry Creek. This list, or parts of it, will be incorporated into the TMDL plan to be developed by the Maine Department of Environmental Protection in 2005. More detailed recommendations that would be included in a restoration plan will require the input of experts from fields such as biology, geology, and engineering.

Restoring healthy aquatic communities in Barberry Creek will require collaboration among several parties (regulatory agencies, the City of South Portland, industry and businesses, concerned citizens) as well as financial resources and time. The TMDL plan will likely estimate target loads for particular pollutants, and implementation of the plan should lead to an improvement in stream health over the next several years. Future biological and water quality monitoring is advisable to determine whether the TMDL plan achieved its goal of restoring the resident aquatic communities to Class C standards, or whether additional actions are required.

Chapter 6: Capisic Brook in Portland

Headwaters in Evergreen Cemetery
October 2003

Upstream Station (S256)
in Evergreen Cemetery
April 2003

Mainstem in Evergreen Cemetery
May 2004

Middle section
June 2003

Downstream Station (S257)
below Lucas Street
April 2003

Wetland Station on
Capisic Pond
June 2003

TABLE OF CONTENTS

REPORT

FIGURES

TABLES

APPENDICES

See Table of Contents at Beginning of Report for List of Appendices.

STREAM DESCRIPTION

Capisic Brook, one of the four Urban Streams[1] in the Urban Streams Project, is located in Portland in southern Maine (Fig. 1 in Ch. 1), and is of moderate length (~2.2 miles, mainstem only) and watershed size (~1,290 acres excluding Capisic Pond, Fig. 1). The stream consists of several branches, with headwaters located east of Forest Avenue near the intersection with Allen Avenue (Rt. 100), in Evergreen Cemetery off of Stevens Avenue (Rt. 9), and just east of I-95 near the intersection with Warren Avenue. For the purposes of this report, the mainstem of Capisic Brook originates in a wooded area within Evergreen Cemetery. The northern branch, which originates east of Forest Avenue, flows through a residential and a commercial-industrial area before joining the mainstem just below Evergreen Cemetery. The stream then flows through a residential area and is joined by the western branch, which originates near I-95, ~1,000 m downstream of the mainstem – northern branch confluence. The western branch receives a significant amount of runoff from I-95 and development located along the highway and especially west of I-95 Exit 8. From this second confluence on, Capisic Brook continues to flow through a residential area down to Capisic Pond, which is created by the Capisic Pond dam just below Capisic Street. Below the dam, the stream flows into the estuarine Fore River, and then into Portland Harbor and Casco Bay. The outline of the watershed as shown in Fig. 1 is based information received from the City of Portland (B. Roland, pers. comm.[2]), on 10 m contour lines, and actual stormwater drainage systems. In terms of water quality requirements, the Maine legislature designated Capisic Brook as Class C (see Ch. 1, Introduction).

The Maine Department of Environmental Protection (MDEP) Biological Monitoring Program has been studying three stations on Capisic Brook since 1996 (Fig. 1). The upstream station in Evergreen Cemetery, S256, is near the headwaters of the mainstem. It is fed largely by springs within the cemetery, and receives very little runoff from the surrounding urban area (B. Roland, pers. comm.). During baseflow conditions in the summer of 2003, Capisic Brook at this station was a small, incised stream (width 0.5 m, water depth 4 - 5 cm, channel depth 0.4 m) with a flow velocity of 12 – 14 cm/s. The substratum was predominantly sand with some detritus. The riparian zone near and upstream of the station consisted of trees and understory plants, and was fairly undisturbed. A small hiking path meandered along the stream and crossed it in a few places. At the same time, Capisic Brook at the downstream station below the Lucas Street bridge and ~350 m upstream from Capisic Pond, S257, was much wider (2 m), but only slightly deeper (7 cm) and less entrenched (channel depth 0.9 m) Flow velocity was 10 –11 cm/s. The substrate at this station was composed of gravel and sand (~50 % each) but was much siltier in the past (1996: 90 % silt). The riparian zone around the station consisted of cattails, grasses and shrubs with few young trees, but further upstream, trees and understory plants were fairly common. Below this station, the stream widens and becomes marshy before widening into Capisic Pond, which is created by the Capisic Pond dam just below Capisic Street. A wetland monitoring station along the edge of the pond, W-023, was monitored in 2000 and found to have soft sediment with vegetation dominated by cattails. Capisic Brook's surficial geology type is the "Presumpscot formation"

---

[1] Note that "Urban Streams" refers to the four streams included in this study, not to the universe of "urban streams" in Maine or elsewhere.

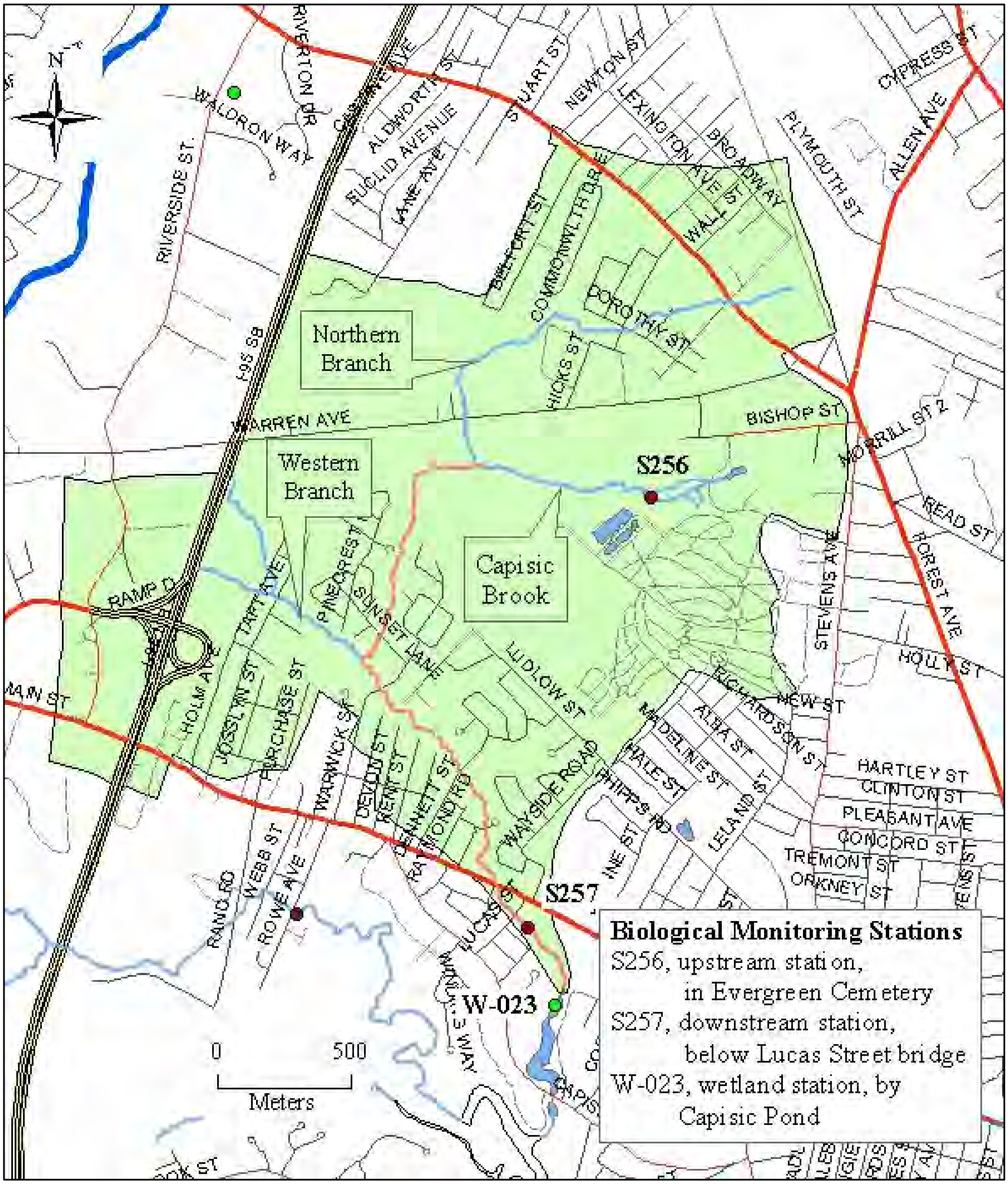
[2] Information on persons providing personal communications is given in the References.

which in this watershed is characterized by silts and clay with some sand. This suggests that any fine sediment observed in the stream is natural in origin.

The entire watershed, including all headwaters but excluding the section within Evergreen Cemetery, is impacted by development (i.e., low/high intensity residential and dense residential development: 56 %; urban/industrial and commercial-industrial-transportation development: 19 %), resulting in a high percentage of the watershed being covered by impervious surfaces (23 %; calculated using the method shown in MDEP 2001b). Other landuse types are forests (10 %) as well as grassland/crops/scrub-shrub (11 %), and wetlands (2 %). As a result, the majority of Capisic Brook is affected by a variety of urban stressors typically associated with residential and commercial development, and an extensive road system. Data collected by the MDEP Biological Monitoring Program in 1996 and 1999 at the upstream and downstream stations indicated that the upstream station in Evergreen Cemetery had a macroinvertebrate community that exceeded the Class C aquatic life criteria (see Previous studies, below). Conversely, data collected in the same years at the downstream below the Lucas Street bridge showed a consistent violation of the Class C aquatic life criteria (see Previous Studies, below) thus requiring a Total Maximum Daily Load (TMDL; see Ch. 1, Introduction, MDEP Urban Streams Project) assessment. Existing data also suggest problems with other water quality parameters (e.g., dissolved oxygen, water temperature, some nutrients). Wetland data collected in 2000 at Capisic Pond (below the downstream station) also indicated that biota, water, and sediments at this station were negatively impacted.

This report presents the data available as of December 2004, and puts them into the context of overall stream health. Information contained in this report will form the basis for the development of a stream-specific Total Maximum Daily Load (TMDL; see Ch. 1, Introduction, MDEP Urban Streams Project) plan in 2005. It is expected that the MDEP will re-sample macroinvertebrates on Capisic Brook within the next 2 - 3 years. Additional sampling events may occur in future years depending on developments in the watershed, funding availability, and program needs.

Fig. 1. Capisic Brook, Portland. Watershed is shown in green, impaired segment in pink.



Note that Capisic Brook was traced from Citipix images, requiring some inferences where the stream was obscured or running underground.

PREVIOUS STUDIES

MDEP Biological Monitoring Program

The Biological Monitoring Program of the MDEP's Bureau of Land and Water Quality (BLWQ) collected macroinvertebrate data in the summers of 1996 and 1999 at the upstream and downstream stations (S256 and S257, respectively; Fig. 1). Sample collection and processing methods are detailed in App. A i, and briefly described in Ch. 2, Methods, Biological Monitoring, item 1. Macroinvertebrate samples were identified by either Lotic, Inc (Unity, ME; 1996) or Freshwater Benthic Services (Petosky, MI; 1999). The MDEP analyzed taxonomic data using a statistical model which assigned samples to one of three State of Maine water quality classes (A[1], B, or C) or to a Non-Attainment category. Analysis results were reported in the MDEP's Surface Water Ambient Toxics (SWAT) Monitoring Program technical reports (MDEP 1999, 2001a) and in Davies et. al (1999).

Model results indicated that in both years, macroinvertebrates at the upstream station met Class A aquatic life criteria (Table 1), i.e., far exceeded the required Class C criteria. Relatively pollution-sensitive taxa from the orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) made up ~20 – 40 % of the benthic community while other, more tolerant insects (mostly Diptera, i.e., flies) accounted for most of the remaining organisms. In both years, relatively few organisms were found, possibly indicating the absence of nutrient enrichment. A good general indicator of the quality of a macroinvertebrate community is the percentage of non-insects in a sample, as this increases with decreasing water quality. The percentage of non-insects at the upstream station was low in both sampling years (2.5 and 1.1 % in 1996 and 1999, respectively). Water quality data collected at this station showed adequate dissolved oxygen concentrations (6.7 and 7.6 mg/L) and low conductivity levels (80 and 44 μS/cm). Continuous water temperature data collected between July 21 and August 20, 1999 (Fig. 2, measurements taken every 10 min) were generally low and favorable for healthy macroinvertebrate communities. Various water chemistry parameters were sampled in 1996, and results (Table 2) indicated that none of the parameters exceeded existing Water Quality Criteria.

The downstream station did not meet Class C aquatic life criteria in either sampling year (Table 1). The degraded macroinvertebrate communities in both sampling years were dominated by tolerant chironomids (midge larvae) and isopods (crustaceans). The number of organisms found was high in both years, possibly indicating nutrient enrichment. The percentage of non-insects at this station was elevated (28 and 34 % in 1996 and 1999, respectively), and included worms, leeches, and isopods. Water quality data showed low dissolved oxygen concentrations (6.4 and 3.3 mg/L), and elevated conductivity levels (195 and 386 μS/cm). Continuous water temperature data collected between July 24 and August 20, 1999 (Fig. 2, measurements taken every 10 min) were generally high, i.e., not favorable for sensitive organisms such as stoneflies. Water chemistry sampling in 1996 (Table 2) showed that Total Phosphorus exceeded the EPA-recommended Ecoregion XIV criterion, and that copper exceeded Maine Statewide Water Quality Criteria (SWQC).

---

[1] For the purposes of the statistical model, State of Maine water quality classes AA and A are combined.

Table 1. Summary version of 1996 and 1999 macroinvertebrate model reports

Model variable	**Upstream (S256)**		**Downstream (S257)**	
	1996	**1999**	**1996**	**1999**
Total abundance of individuals	91	280	1,101	1,327
Generic richness	29	54	36	51
Plecoptera / Ephemeroptera abundance	0.7 / 12	1.7 / 17.7	0 / 0	0 / 0.7
Shannon-Wiener diversity index	3.55	4.23	2.94	3.50
Hilsenhoff biotic index	3.32	4.28	6.35	6.88
Relative abundance Chironomidae	0.33	0.65	0.62	0.61
EPT[1] generic richness	6	10	2	7
EP[1] generic richness/14	0.21	0.29	0	0.14
Presence of Class A indicator taxa/7	0.14	0.14	0	0
Five dominant taxa (%)	*Brillia* (22) *Limnephilus* (18) *Parapsyche* (12) *Dicranota* (10) *Paraleptophlebia* (9)	*Micropsectra* (19) *Brillia* (15) *Dicranota* (10) *Parapsyche* (9) *Heterotrissocladius* (7)	*Rheotanytarsus* (34) *Caecidotea* (26) *Micropsectra* (8) *Hydropsyche* (8) *Thienemannimyia* (6)	*Caecidotea* (27) *Micropsectra* (17) *Rheotanytarsus* (11) *Paratanytarsus* (8) *Conchapelopia* (7)
Model outcome (%)	Class A (93)	Class A (85)	NA (100)	NA (100)

[1] EPT are Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). EP are Ephemeroptera and Plecoptera.

Fig. 2. Continuous water temperature in 1999

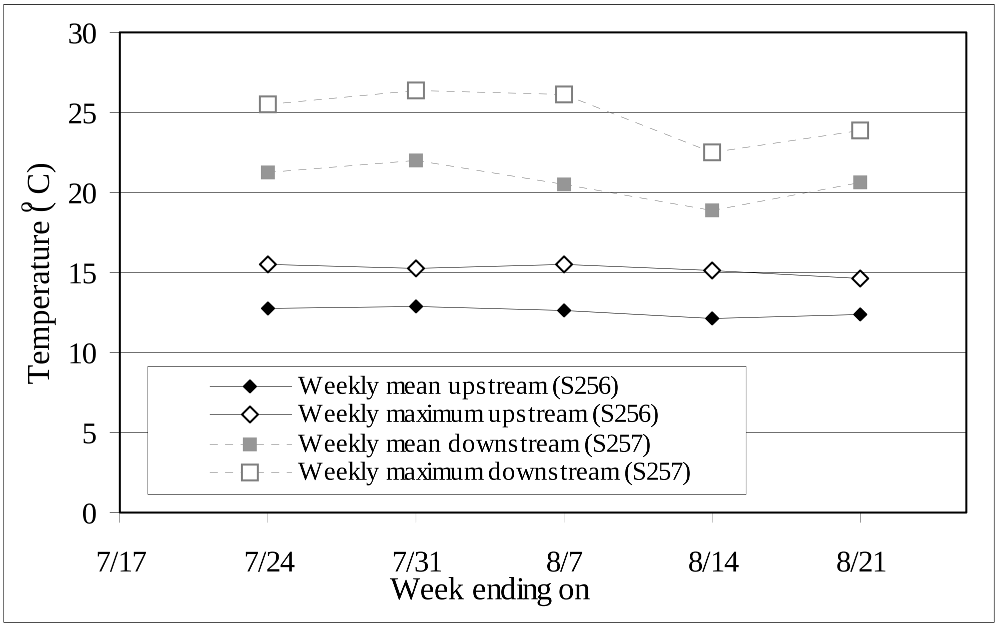


Table 2. Water chemistry data summer 1996. Highlighted fields indicate problem parameters.

Parameters (unit)	**Upstream (S256)**	**Downstream (S257)**	**Water Quality Criteria**	
Total Phosphorus (mg/L)	0.012	0.140	0.031[1]	
Total Suspended Solids (mg/L)	5.5	2.5	NC	
Metals			**CMC**[2]	**CCC**[2]
Cadmium (µg/L)	ND 0.5	ND 0.5	0.64	0.32
Copper (µg/L)	2.8	3.4	3.89	2.99
Iron (µg/L)	280	610	NC	1,000
Lead (µg/L)	< 2	< 2	10.52	0.41
Zinc (µg/L)	ND 4	ND 4	29.9	27.1
Manganese (µg/L)	13	75	NC	NC
Nickel (µg/L)	< 1	1.3	363.4	40.4

NC, No Criteria; ND, Not Detected, i.e., below stated detection limit of test.

[1] Criteria recommended by EPA for Ecoregion XIV, which includes Capisic Brook.

[2] CMC and CCC are types of Maine Statewide Water Quality Criteria (SWQC; MDEP SWQC). CMC (Criteria Maximum Concentration) and CCC (Criteria Continuous Concentration) denote the level of pollutants above which aquatic life may show negative effects following brief (acute) or indefinite (chronic) exposure, respectively.

Wetland data collected in June 2000 at Capisic Pond (below the downstream station) also indicated negative impacts. Macroinvertebrate biota were impaired (intermediate abundance of ~260 organisms, taxa richness 22; *Caenis* as the single ephemeropteran, no Trichoptera, 1 Odonata taxon), dissolved oxygen concentration was very low (3.2 mg/L), and conductivity high (434 µS/cm). Several of the water or sediment parameters analyzed ranked among the worst 10 % of all wetlands samples collected in Maine by the biomonitoring unit (Table 3). When compared to the Sediment Quality Guidelines (SQG) published by the Ontario (Canada) Ministry of the Environment (1993), most metals exceeded the Lowest Effect Level (LEL) criterion but not the Severe Effect Level (SEL) criterion (Table 3). It should be noted that Total Organic Carbon may be naturally elevated in wetlands compared to other waterbodies and that the SQG may not apply (J. DiFranco, pers. comm.). Exceedance of criteria suggests that the contaminants may have negative long-term effects on sediment dwelling organisms. However, in the case of the exceedance of LELs, the majority of organisms may not be affected.

A “Human Disturbance Ranking Form” (see Table 10) also was completed at the wetland station in 2000, and resulted in a score of 32 out of a possible 125. This score indicated very high disturbance, and ranked as the 8th worst score recorded in the 157 wetlands assessed by the MDEP biomonitoring program to date (highest score recorded was 44). The potential for NPS pollution had the highest score (12 out of 25) of the five subsections followed by impervious surfaces areas in the watershed (11), hydrologic modifications to the wetland (6), vegetative modifications to the wetland (2), and evidence of chemical pollutants (1).

Table 3. Water and sediment chemistry data summer 2000 (wetland station). Highlighted fields indicate problem parameters.

Parameters (unit)	**Downstream (W-023)**					**Ontario SQG[2]**	
Water chemistry (mg/L)	**Value**	**Rank[1]**	**Sediment chemistry (dry, mg/Kg)**	**Value**	**Rank[1]**	**SEL[2]**	**LEL[2]**
Nitrate-Nitrogen	0.038	15	Cadmium	*1.2*	8	10	0.6
Ammonia-Nitrogen	1.31	1 (of 113)	Copper	*52.5*	9 (of 113)	110	16
Total Nitrogen	1.54	3	Lead	*94.3*	3	250	31
Phosphate	0.05	1	Selenium	1.4	13	NC	NC
Total Phosphorus	0.10	3	Zinc	*356*	6	820	120
Chlorophyll *a*	0.013	26	Mercury	0.16	21	2	0.2
Sulfate	11.80	25	Total organic carbon (%)	*6.6*	49	10	1
Dissolved organic carbon	8.2	97					
Calcium	18.00	17					
Magnesium	3.56	17					
Potassium	2.42	11					
Sodium	50.60	8					
Silica	3.44	29					
Alkalinity ($CaCO_3$)	55.00	16					
Chloride	79.50	8					

NC, No Criteria. Italicized values indicate exceedance of SQG criteria

[1] Rank out of 142 samples for Water Chemistry, and out of 60 for Sediment Chemistry (except where noted). Rankings in the worst10% of each category are highlighted.

[2] SQG, Sediment Quality Guidelines for freshwater set by the Ontario Ministry of the Environment; SEL, Severe Effect Level; LEL, Lowest Effect Level

City of Portland

In 1999, the City of Portland contracted DeLuca-Hoffman Associates, Inc., a civil engineering consulting firm, to re-evaluate a watershed flood control study performed by the Natural Resources Conservation Service (NRCS) in 1995 as part of the Capisic Brook Greenbelt/Stormwater Abatement Study. This re-evaluation was precipitated by a large storm in October 1998 (8.3” of rain in 79 hours with peak flows similar to a 25-year event) which caused extensive flooding in the lower reaches of the watershed. The report by DeLuca-Hoffman (DeLuca-Hoffman 1999) had three main goals, which were resolved in the following way:

Goal 1: Validate the NRCS hydrologic and hydraulic model.
Finding: The model was found to be accurate.

Goal 2: Evaluate effectiveness of recently completed infrastructure improvements.
Finding: Recent improvements (widening of the low flow spillway of the Capisic Pond Dam; culvert enlargements at three road crossings) were found to have resulted

in increased conveyance capacity of the channel. However, DeLuca-Hoffman determined that physical constraints of the open channel system would still cause flooding above the 25-year event, and recommended further channel improvements (see Goal 3). Furthermore, DeLuca-Hoffman noted that even with such further improvements, flooding from a >25-year storm could only be achieved by reducing peak flows (see Goal 3).

Goal 3: Identify additional flood control improvements.

Finding: In addition to further culvert enlargements at four road crossings (including Lucas Street, immediately above the downstream biomonitoring station), DeLuca-Hoffman also recommended increasing channel capacity (through channel widening and straightening, and removal of obstructions such as dead or live trees or refuse) in three stream sections. They also suggested to increase the storage capacity of proposed stormwater storage facilities, and to attenuate peak flows. Implementation of such measures would result in a significant reduction of flood levels for the lower reaches of the watershed.

DeLuca-Hoffman stressed in their report that stormwater storage facilities are essential for the reduction of peak discharges, and should be implemented early in the flood control program (DeLuca-Hoffman Associates 1999). These measures, as well as further channel improvements, would alleviate the chronic flooding that has been historically experienced within the lower reaches of the Capisic Brook watershed. This flooding was primarily attributable to extensive commercial and residential development throughout the watershed in the absence of effective means for mitigating increased runoff rates. DeLuca-Hoffman also noted the negative effect of numerous developments immediately adjacent to the stream corridor, which had restricted the open channel conveyance capacity, and reduced the area available for floodwaters.

Some of the recommendations made by the consulting firm have been carried out (e.g., increase culvert capacity at Capisic Street) or are planned for the near future (e.g., increase culvert capacity at Lucas Street, scheduled for summer 2005, B. Roland, pers. comm.) while others are in the planning stage [e.g., construction of stormwater storage facilities required for combined sewer overflow (CSO) separation work]. The City has contacted the MDEP to obtain input concerning planning for future projects, especially the location, type, and size of stormwater storage facilities. In light of the separation of two CSOs entering Capisic Brook within the next 2 - 5 years, such consultation between regulatory agencies and the City is critical to ensure that the negative effect on the stream from increased stormflows or detention facilities is minimized.

RESULTS OF 2003 STUDY

Biological Monitoring

1. Analysis of macroinvertebrate samples collected from rock bags in August after an exposure period of four weeks in the stream showed that the upstream station exceeded Class C aquatic life criteria, while the downstream station failed to meet them (Table 4; full model outputs for the 2003 sampling events are shown in App. B iv). At the upstream station, the community had a number of sensitive organisms [e.g. *Eurylophella* (MDEP Class A indicator), *Parapsyche*, *Nemoura*, *Diplectrona*, *Lepidostoma*], adequate generic richness, and a low Hilsenhoff biotic index. The percentage of non-insects (19 %) was intermediate. At the downstream station, sensitive organisms (i.e., Ephemeroptera and Plecoptera) were absent and tolerant organisms (e.g., *Caecidotea*, *Slavina*, *Hyalella*) dominated the community. Generic richness was somewhat low, and the Hilsenhoff biotic index and percentage of non-insects (54 %) were high. None of the sensitive organisms seen at the upstream station (see list above) were present at the downstream station. Analysis results were reported in the MDEP's 2002-2003 SWAT Monitoring Program technical report (MDEP 2004c).

   Table 4. Summary version of 2003 macroinvertebrate model reports

Model variable	**Upstream (S256)**	**Downstream (S257)**
Total abundance of individuals	1,033	1,728
Generic richness	45	46
Plecoptera / Ephemeroptera abundance	8 / 116	0 / 0
Shannon-Wiener diversity index	4.2	3.36
Hilsenhoff biotic index	4.83	7.24
Relative abundance Chironomidae	0.44	0.44
EPT[1] generic richness	11	5
EP[1] generic richness/14	0.36	0.00
Presence of Class A indicator taxa/7	0.14	0.00
Five dominant taxa (%)	*Stylodrilus* (18) *Simulium* (14) *Micropsectra* (9) Leptophlebiidae (9) *Brillia* (9)	*Caecidotea* (37) *Micropsectra* (14) *Paratanytarsus* (10) *Tanytarsus* (9) *Slavina* (7)
Model outcome (%)	Class A (61)	NA (100)

[1] EPT are Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). EP are Ephemeroptera and Plecoptera.

2. The fish assemblage at the downstream station was investigated on June 19 and consisted of 12 American Eels (*Anguilla rostrata;* 6 - 14" in length), 14 Mummichog (*Fundulus heteroclitius*; <1 - 2"), and 4 Nine-spine Sticklebacks (*Pungitius pungitius*; 2.5"). Fish were not investigated at the upstream station.

3. The algae sample collected on July 9 from the stream bottom at the downstream station. has not yet been analyzed for species composition and abundance. A visual assessment of

the site showed excessive growth of filamentous green algae. Filamentous green algae covered almost all of the available substrate, and some strands reached 4 m in length (Fig. 20). This location had one of the most luxurious growths of filamentous green algae seen in the 129 locations where algae had been collected by May 2004. Revisits to the station in early and late July 2004 showed slightly less growth of filamentous greens than in 2003.

4. The algae samples collected on June 12 at the wetland station in Capisic Pond, ~350 m below the downstream station, have not yet been analyzed for species composition and abundance. The macroinvertebrate samples showed a low abundance (63 organisms), a preponderance of tolerant organisms (midges, isopods, tubificid worms, snails), and low number of sensitive ones (*Caenis* as the only Ephemeroptera, 2 Odonata taxa, no Trichoptera).

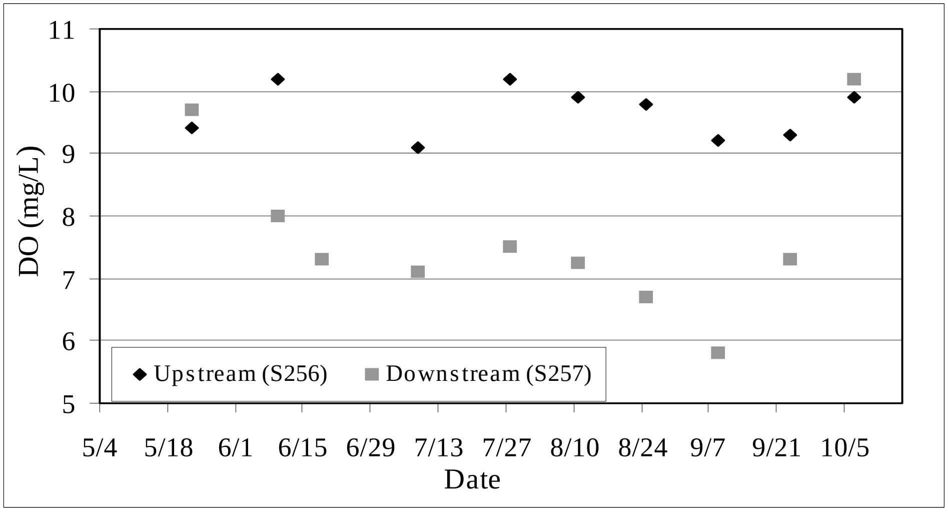
Water Quality Monitoring

1. Standard water quality parameters

a) *Instantaneous dissolved oxygen*

The concentrations of instantaneous dissolved oxygen (DO) at the upstream station on Capisic Brook were usually high, ranging from 9.1 - 10.2 mg/L (black diamonds in Fig. 3). At the downstream station, DO concentrations were quite variable, ranging from 5.8 - 10.2 mg/L (gray squares in Fig. 3). The single DO measurement taken at the wetland station on June 12 was 5.2 mg/L. Measurements taken on May 8 and July 6, 2004 at the downstream station were 9.5 and 8.5 mg/L, respectively.

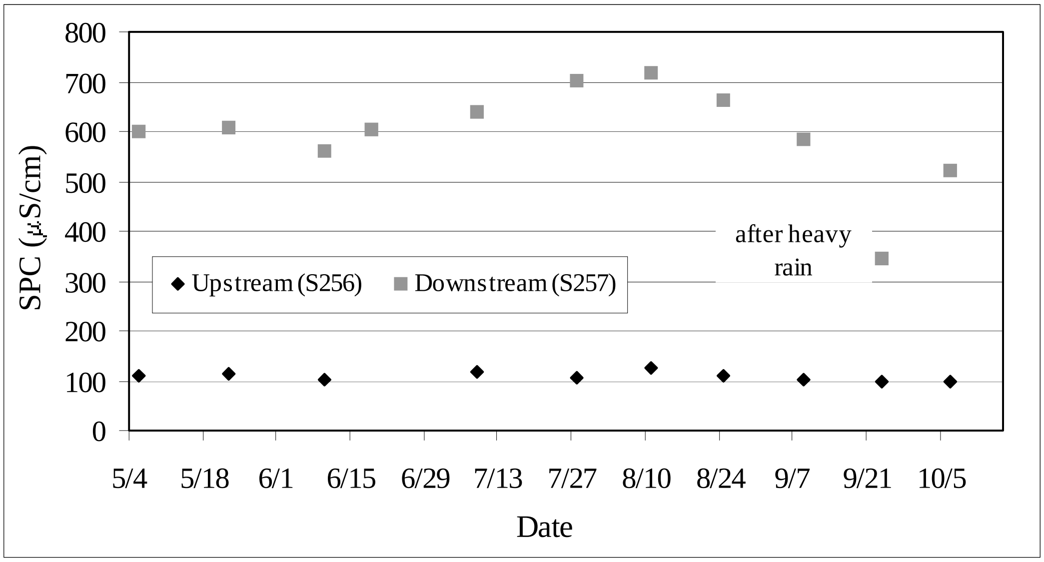
Fig. 3. Instantaneous dissolved oxygen



b) *Instantaneous specific conductance*

Instantaneous levels of specific conductance (also conductivity or SPC) at the upstream station were similar throughout the sampling season, ranging from 99 - 125 µS/cm (black diamonds in Fig. 4). At the downstream station, conductivity levels were more variable (in absolute terms), ranging from 520 - 716 µS/cm during dry conditions (gray squares in Fig. 4). As shown on Figure 4, low conductivity was recorded on September 24 after heavy rain (0.6”) the previous day had diluted the ions in the water. At the wetland station, field measured conductivity on June 12 was at 546 µS/cm. A water sample taken at that time and analyzed in the laboratory measured SPC at 703 µS/cm. Measurements taken on May 8 and July 6, 2004 at the downstream station were 542 and 669 µS/cm, respectively.

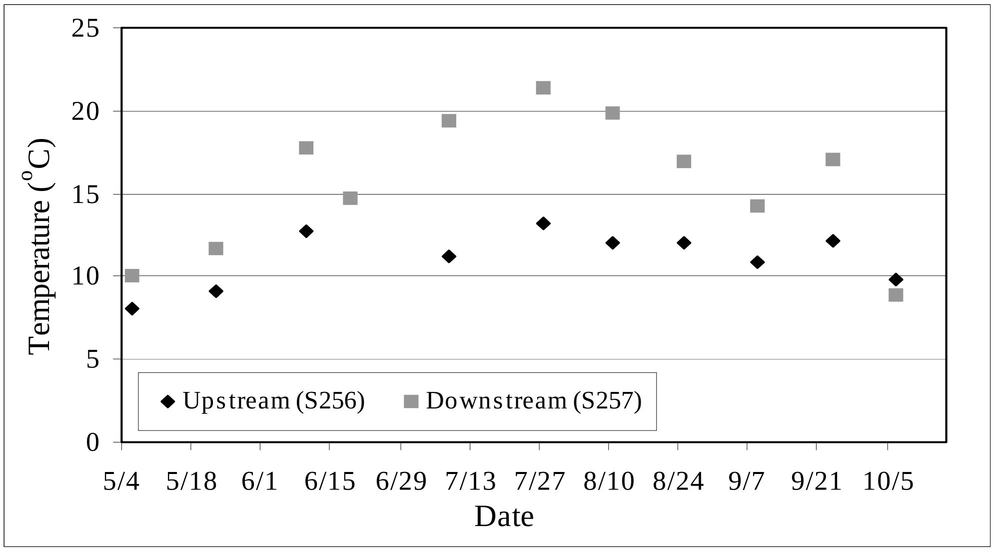
Fig. 4. Instantaneous specific conductance



c) *Instantaneous water temperature*

Instantaneous water temperature measured at the upstream station was quite uniform and low throughout the sampling season, i.e., at <10 ºC in spring and fall, and 10 - 13 ºC in summer (black diamonds in Fig. 5). At the downstream station, the temperature was highly variable with values of 10 - 12 ºC in spring and fall, and 14 - 22 ºC in summer (gray squares in Fig. 5). The single temperature measurement taken at the wetland station on June 12 was 20.1 ºC. Measurements taken on May 8 and July 6, 2004 at the downstream station were 13.6 and 18.4 ºC, respectively.

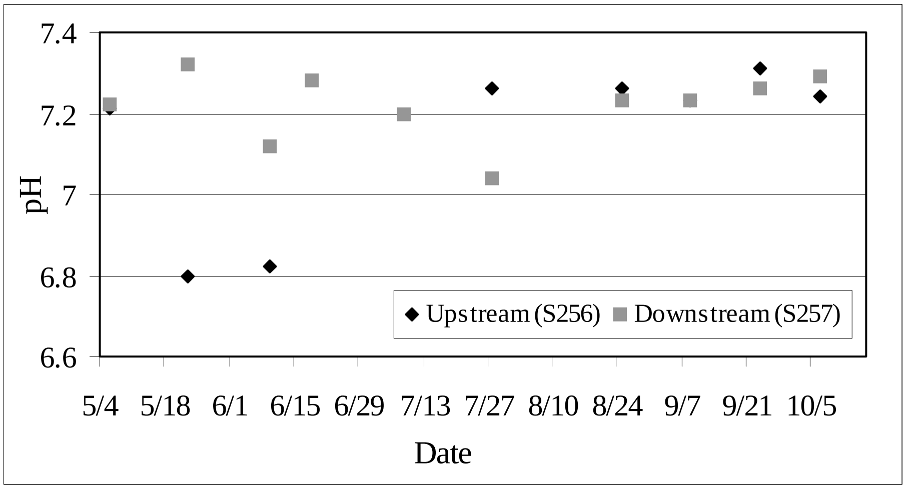
Fig. 5. Instantaneous water temperature



d) Instantaneous pH

Instantaneous measurements of pH were fairly uniform at both measurement locations. pH ranged from 6.8 - 7.3 at the upstream station, and from 7.0 - 7.3 at the downstream station (black diamonds and gray squares, respectively, in Fig. 6). The single pH measurement taken at the wetland station on June 12 was 7.03; air equilibrated pH was measured at 7.5 at this station. One measurement taken on July 6, 2004 at the downstream station was 6.7.

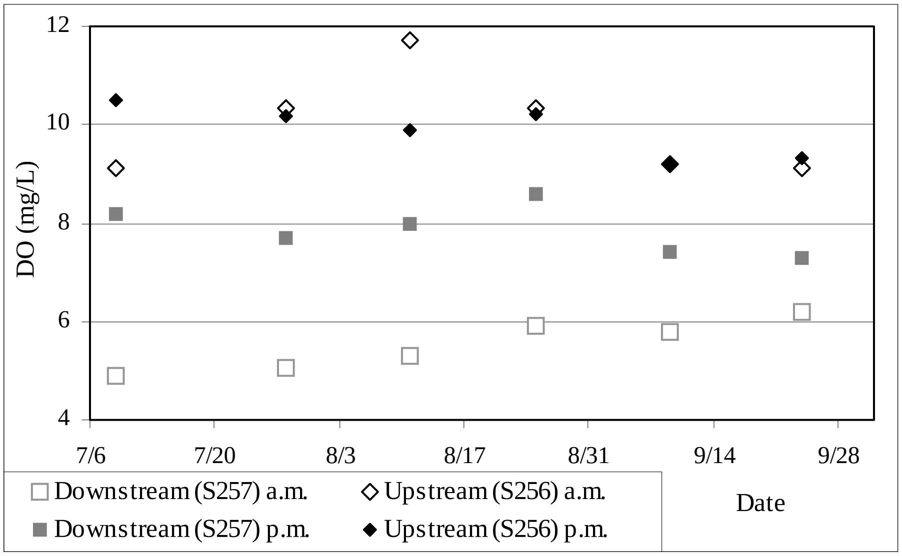
Fig. 6. Instantaneous pH



2. Diurnal dissolved oxygen

Dissolved oxygen concentrations measured at the upstream station in early morning and mid-afternoon were quite similar throughout the summer with a maximum diurnal difference of 1.4 mg/L on July 9 and 0.2 on the remaining dates[1] (diamonds in Fig. 7). At the downstream station, DO concentrations were much lower than at the upstream station, and the diurnal range was >2.0 mg/l on four of the six sampling dates (maximum difference of 3.3 mg/L; squares in Fig. 7).

Fig. 7. Diurnal dissolved oxygen



3. Continuous data collection at downstream station (8 days, July 8 to 15)

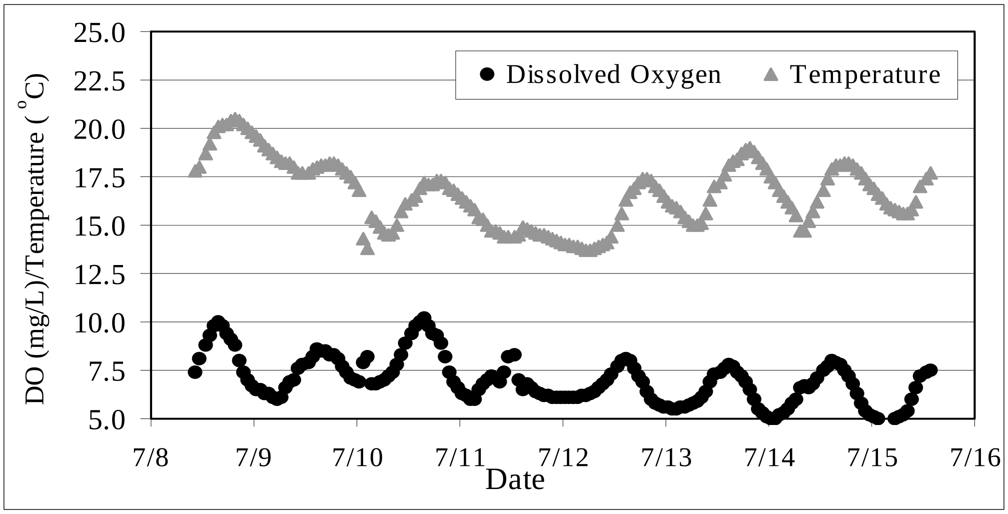
a) Continuous dissolved oxygen and water temperature

Mean hourly dissolved oxygen (DO) and water temperature calculated from records collected every 10 min indicated that both variables showed strong diurnal fluctuations (Fig. 8). Dissolved oxygen concentrations were usually highest in mid-afternoon (3 - 4 p.m.), and lowest in the middle of the night or early morning (2:30 – 6:30 a.m.; black circles in Fig. 8). Temperatures were highest in early evening (6:30 – 8:30 p.m.), and lowest in early morning (6:30 – 9:30 a.m.; gray triangles in Fig. 8a). Dissolved oxygen concentrations were close to 5 mg/L (the required minimum DO concentration for a Class C stream) on several occasions. Diurnal differences exceeded 2 mg/L every day during the measurement period (minimum/ maximum difference was 2.2/3.6 mg/L). On July 11, (light) rain fell during most of a cool day (daytime high 17 ºC), keeping DO concentrations and water temperatures low. Just prior to and at the beginning of the measurement period (July 6 – 8), daytime highs tended to be higher than during the rest of the measurement period (26 – 31 ºC compared to 17 – 27 ºC), driving initial water temperatures up.

---

[1] The measurement of 11.7 mg/L taken on the morning of August 11 seems questionable given all other measurements recorded at this station. QA/QC information (App. F i) indicates a problem with the instrument at this time.

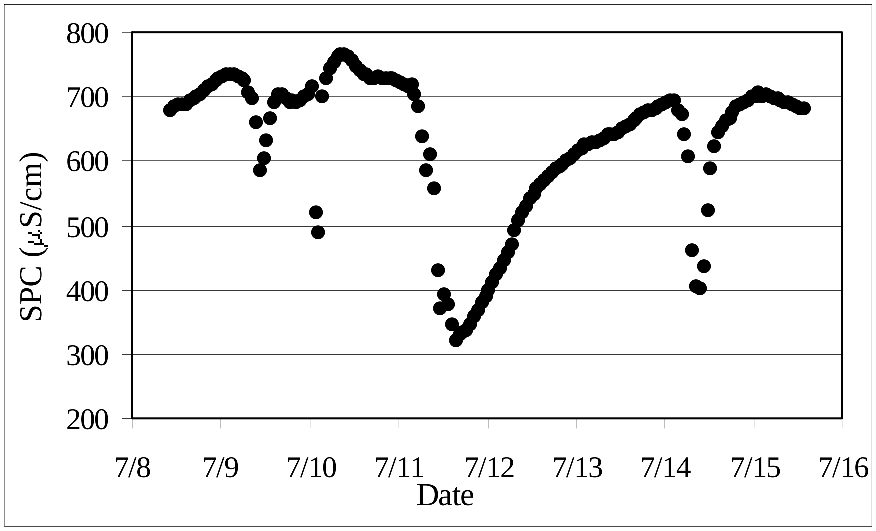
Fig. 8. Continuous dissolved oxygen and water temperature at downstream station (8 days)



b) *Continuous specific conductance*

Mean hourly conductivity calculated from records collected every 10 min showed wide variation, ranging from 321 - 766 µS/cm (Fig. 9). The majority of the time, conductivity ranged from ~600 - 770 µS/cm (Fig. 9). A strong, long-lasting (~30 hours before SPC returned to 600 µS/cm) decrease in conductivity occurred following a rain event (0.37”) during the day on July 11. The decrease in conductivity on July 14 was not associated with any precipitation.

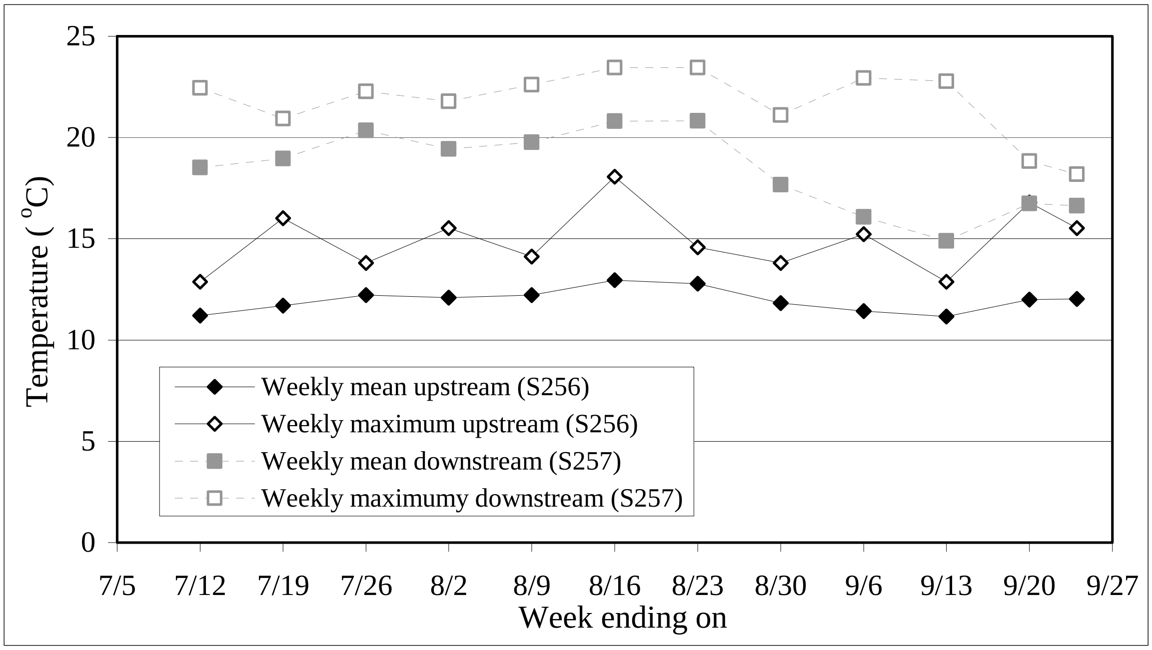
Fig. 9. Continuous specific conductance at downstream station (8 days)



4. Continuous water temperature (79 days, July 8 to September 24)

Continuous water temperature at the upstream station (black diamonds and solid lines in Fig. 10, measured at 20-min intervals) showed a relatively constant weekly mean temperature between 11 and 13 ºC throughout the recording period. In contrast, the weekly maximum temperature was quite variable, namely between 13 and 18 ºC. Further data analysis showed that in all cases the high temperatures indicated by the maximum temperature records never lasted for more than 1.5 h with temperatures before and afterwards being lower by at least 2 ºC. At the downstream station (gray squares and dashed lines in Fig. 10), the weekly mean temperature was between 18 and 21 ºC from early July to mid-August. After this, it dropped to between 15 and 18 ºC, where it stayed for the remainder of the recording period. The weekly maximum temperature at this station fluctuated between 21 and 24 ºC between early July and early September before dropping to 19 ºC in mid-September.

Fig. 10. Continuous water temperature (79 days)



5. Water chemistry

Water chemistry data are summarized in Tables 5 - 7. Table 5 shows the results from four baseflow sampling events at the upstream and downstream stations on Capisic Brook. Table 6 shows the results from two stormflow sampling events at the downstream station. Table 7 shows the results from one baseflow sampling event at the wetland station. All tables include numeric criteria for water quality where available. Criteria recommended by EPA for Region XIV present nutrient levels that protect against the adverse effects of nutrient overenrichment (USEPA 2000b). The Maine Statewide Water Quality Criteria (SWQC; MDEP SWQC) CMC and CCC[1] define acute (brief exposure) and chronic (indefinite exposure) levels, respectively, above which certain compounds can have

---

[1] CMC, Criteria Maximum Concentration; CCC, Criteria Chronic Concentration

detrimental effects on aquatic organisms. In general, CMC should be used to interpret results from stormflow samples while CCC should be used to interpret results from baseflow samples. Highlighted fields in the tables indicate cases where the sampling results exceeded the numeric criteria, i.e., cases where negative effects may occur in aquatic organisms.

Table 5. At the upstream station during baseflow conditions, only one violation was found, namely a single exceedance of the State of Maine criterion for the mean count of bacterial colonies. Note however that Maine's criteria are for *E. coli* of human origin, and that origin was not determined in this study. At the downstream station, exceedances were found for two nutrients for which recommended water quality criteria exist (Total Nitrogen, TN, and Total Phosphorus, TP) as well as for Chlorophyll *a* (one sample only). Bacteria (*E. coli*) exceeded the State of Maine criterion for the mean count of colonies three times (but see note above for the origin of bacteria). Iron was the only metal analyzed that exceeded SWQC chronic or acute criteria although in some cases the sensitivity of the analysis was insufficient to determine whether criteria were exceeded (copper: for CMC and CCC; cadmium and lead: for CCC only). Additional data not shown in Table 5 were collected at the downstream station on July 9 during algal sampling: alkalinity, 54 mg/L; and silica (by calculation), 9.2 mg/L.

Table 6. During stormflow conditions, TP consistently exceeded the EPA-recommended Ecoregion XIV criterion at the downstream station while none of the metals sampled exceeded the SWQC acute criterion (no data for the upstream station). The TP concentrations measured in May 2003 and February 2004 were similar to summer 2003 baseflow concentrations (Table 5), but concentrations in November 2003 were approximately twice as high as during baseflow conditions. There are no criteria for Total Suspended Solids (SSD) but SSD values at stormflows were up to 22 times higher than during baseflows.

Rainfall amounts for storm sampling events were as follows: May 26: 0.91" mostly in early evening, May 27: 0.03" at 12:30 am; November 20: 0.72" during mid to late morning, November 21: 0.28" at ~4 - 9 a.m.; February 23 - 26, 2004: no precipitation but daytime highs were 1 - 3 ºC, i.e., some melting likely occurred (Weather Underground 2003/2004).

Table 7. Several of the parameters analyzed for water chemistry ranked among the top 10 % of all samples ever collected in ME wetlands by the biomonitoring unit: nutrients (NO_2-NO_3-N, NH_4-N, TN, TP), anions and cations (Ca, Mg, K, NA), chloride, conductivity, alkalinity, and hardness. Total Nitrogen and TP values were slightly higher than baseflow values at the downstream station but much higher than at the upstream station (Table 5).

Table 5. Water chemistry data (baseflow) from summer 2003. Highlighted fields indicate problem parameters.

Parameters	**Station (#)**	**Upstream (S256)**				**Downstream (S257)**				**Water Quality Criteria**	
	Sample date	**15-Jul**	**11-Aug**	**25-Aug**	**9-Sep**	**15-Jul**	**11-Aug**	**25-Aug**	**9-Sep**		
Nutrients	**Unit**										
Total Kjeldahl N	mg/L		~0.1	0.1		0.5	~0.5	0.4	0.4	NC	
Nitrate-Nitrite-N	mg/L		0.21	0.22		0.72	0.73	0.78	0.89	NC	
Ammonia	mg/L			0.01				0.05		NC	
Total Nitrogen	mg/L		0.21	0.33		1.22	0.73	1.23	1.29	0.71[1]	
Ortho-phosphate	mg/L		0.004			0.015	0.019		0.016	NC	
Total Phosphorus	mg/L		0.015	0.015		0.077	0.063	0.046	0.050	0.031[1]	
Dissolved Organic Carbon	mg/L		1.3	1.9			6.4	4.6		NC	
Total Organic Carbon	mg/L		1.3				6.6			NC	
Chlorophyll *a*	mg/L		~0.0005			~0.0042	~0.0032		~0.0028	0.00375[1]	
Total Suspended Solids	mg/L		6	5		2	5	2	4	NC	
Diesel Range Organics	μg/L		<50				63			NC	
Bacteria (*E. coli*)	# col./100 ml	23	411		44	866	488		268	949[2, 3]	142[2, 3]
Metals										**CMC**[4]	**CCC**[4]
Cadmium	μg/L		ND 0.5			ND 0.5	ND 0.5			0.64	0.32
Copper	μg/L		ND 5			ND 5	ND 5			3.89	2.99
Iron	μg/L		210			1,300	860			NC	1,000
Lead	μg/L		ND 3			3	ND 3			10.52	0.41
Zinc	μg/L		ND 5			5	20			29.9	27.1
Chromium	μg/L		1				1			16	11
Nickel	μg/L		ND 4				ND 4			363.4	40.4
Chloride	μg/L		20				157			860	230

NC, No Criteria; ND, Not Detected, i.e., below stated detection limit of test

[1] Criteria recommended by EPA for Ecoregion XIV, which includes Capisic Brook. Total Nitrogen is the sum of preceding three parameters.

[2] Criteria (instantaneous/geometric mean counts of the # of *E. coli* colonies) defined by Maine's Water Classification Program for Class C waters.

[3] Results are for bacteria of any origin while Maine standards are for bacteria of **human** origin. Note that in some studies where the origin of bacteria has been investigated, the majority of bacteria were not of human origin.

[4] CMC and CCC Maine Statewide Water Quality Criteria (SWQC; MDEP SWQC). CMC (Criteria Maximum Concentration) and CCC (Criteria Continuous Concentration) denote the level of pollutants above which aquatic life may show negative effects following brief (acute) or indefinite (chronic) exposure.

Table 6. Water chemistry data (stormflow) from 2003 and 2004. Highlighted fields indicate problem parameters.

Parameters	**Station**	**Downstream (S257)**				**Water Quality Criteria**	
	Date	**2003**		**2004**			
	Unit	**27-May**[1]	**21-Nov**	**24-Feb**	**26-Feb**		
Total Phosphorus	mg/L	0.054 (0.049)	0.11	0.045	0.037	0.031[2]	
Total Suspended Solids	mg/L	10 (8)	44			NC	
Metals						**CMC** [3]	**CCC** [3]
Arsenic	µg/L	ND 3	ND 3			360	190
Aluminum	µg/L	260	590			750	87
Cadmium	µg/L	ND 0.5	ND 2			0.64	0.32
Chromium	µg/L	1	2			16	11
Copper	µg/L	ND 5	ND 5			3.89	2.99
Iron	µg/L	1,000 (1,100)	1,200			NC	1,000
Lead	µg/L	ND 3 (3)	4			10.52	0.41
Nickel	µg/L	ND 4	3			363.4	40.4
Silver	µg/L		ND 1			0.25	NC
Zinc	µg/L	~20 (~22)	22			29.9	27.1
Calcium	mg/L	23 (26)	19			NC	
Magnesium	mg/L	4.7 (5.3)	4.1			NC	
Potassium	mg/L	4.0 (4.4)	3.9			NC	
Sodium	mg/L	86 (100)	47			NC	
Manganese	mg/L	0.21 (0.24)	0.12			NC	

NC, No Criteria; ND, Not Detected, i.e., below stated detection limit of test.

[1] A duplicate sample was collected at S257 on this date. If results were the same for both analyses, only one value is given. If results differ, duplicate value is given in brackets.

[2] Criteria recommended by EPA for Ecoregion XIV, which includes Capisic Brook.

[3] See footnote 4 in Table 5.

Table 7. Water chemistry data (baseflow, wetland station) from June 2003. Highlighted fields indicate problem parameters.

Parameters	**Station (#)**	**Wetland (W-023)**	
	Unit	**Value**	**Rank[1]**
Total Kjeldahl Nitrogen	mg/L	0.9	12 (of 54)
Nitrate-Nitrite-N	mg/L	0.46	2 (of 25)
Ammonia-Nitrogen	mg/L	0.29	4 (of 113)
Total Nitrogen	mg/L	1.65	3 (of 88)
Soluble Reactive Phosphate	mg/L	0.00	--
Total Phosphorus	mg/L	0.08	12
Chlorophyll *a*	mg/L	0.008	45
Dissolved Organic Carbon	mg/L	5.90	120
Calcium	mg/L	27	10
Magnesium	mg/L	5.7	11
Potassium	mg/L	4.3	7
Sodium	mg/L	86	6
Chloride	mg/L	150	6
Conductivity	µS/cm	703	2 (of 101)
Alkalinity	mg/L	59	14
Color	PCU	38	122
Hardness[2]	mg/L	90.9	1 (of 48)

[1] Rank out of 142 samples except where noted. Rankings in the worst 10% of each category are highlighted.
[2] Water with a hardness of 0 - 60 mg/L is considered "soft"; 61 - 120 mg/L "moderately hard".

Habitat Assessments

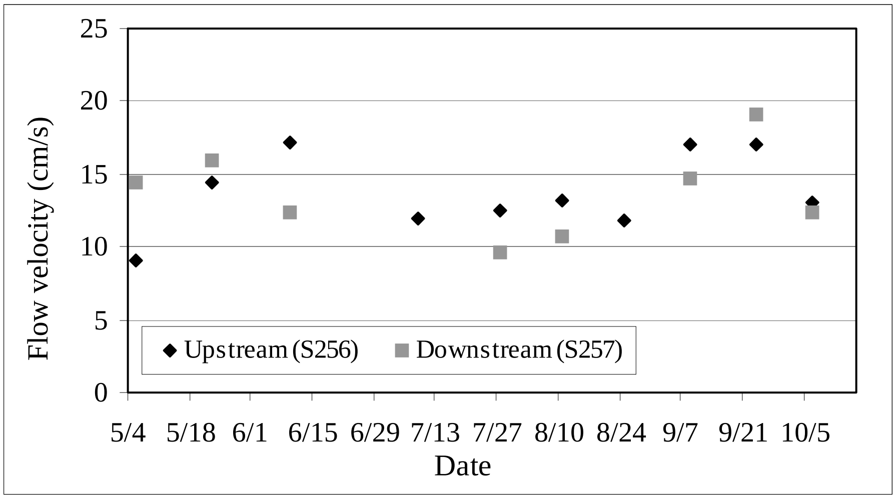
1. Flow regime
   a) *Instantaneous flow velocity*

   Instantaneous flow velocity, averaged across the stream, ranged from 9 - 17 cm/s at the upstream station, and from 10 - 19 cm/s at the downstream station. Mean velocities were 14 and 13 cm/s, respectively (black diamonds and gray squares, respectively, in Fig. 11; including visual estimates, which were reduced to 0.8 or 0.9 of observed surface flow to account for the lower velocity at mid-depth[1]).

---

[1] See Ch. 2, Methods, for further explanation.

Fig. 11. Instantaneous flow velocity

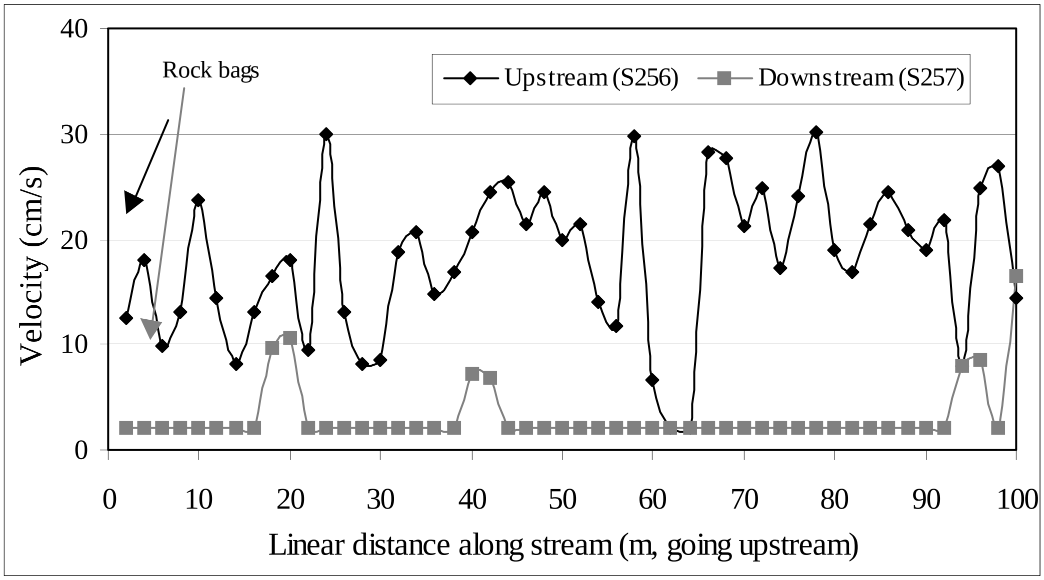


Note that first two data points at both stations are visual estimates.

b) Thalweg velocity

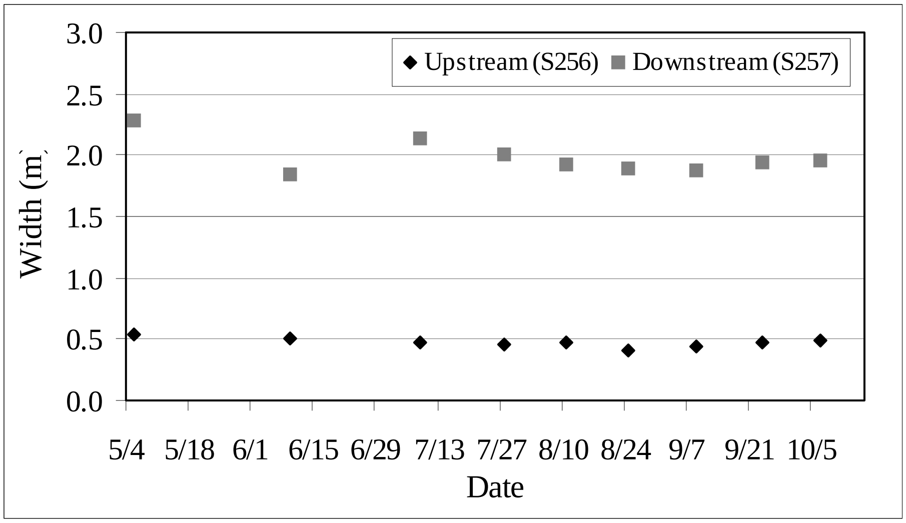
At both stations, the survey started just below the rock bag location and proceeded upstream. Thalweg velocity at the upstream station was highly variable, with velocities ranging from ~1 (non-detectable) to 31 cm/s with a mean of 18 cm/s (black diamonds in Fig. 12). At the downstream station, very little flow was measured, with velocities ranging from ~1 - 11 cm/s and a mean of 3 cm/s (gray squares in Fig. 12).

Fig. 12. Thalweg velocity



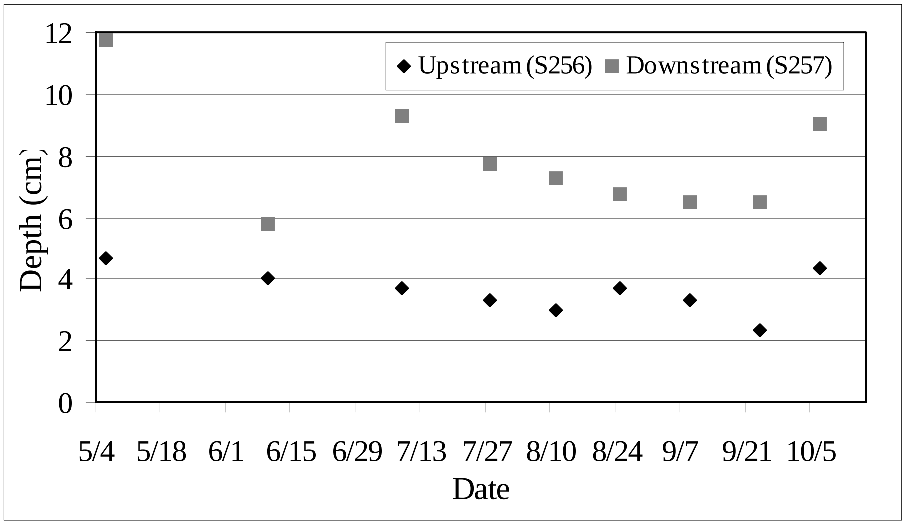
2. Mean stream width (wetted) at both stations was quite stable throughout the sampling period. It ranged from 0.41 - 0.54 m with a mean of 0.48 m at the upstream station, and from 1.8 - 2.3 m with a mean of 2.0 m at the downstream station (black diamonds and gray squares, respectively, in Fig. 13). Bankfull width at the upstream station was much smaller than at the downstream station (2.0 *versus* 4.0 m; Field 2003, Table 2, Reaches 5 and 2, respectively).

Fig. 13. Mean stream width (wetted)



Mean stream depth at the upstream station was relatively stable throughout the sampling period, ranging from 2.3 - 4.7 cm with a mean of 3.6 cm (black diamonds in Fig. 14). At the downstream station, mean stream depth was quite variable (in absolute terms), ranging from 5.8 - 11.8 cm with a mean of 7.8 cm (gray squares in Fig. 14).

Fig. 14. Mean stream depth



3. Large woody debris (LWD, >5 cm mean diameter) above the upstream station was abundant (34 pieces) with a good size distribution (mean diameter of 5 - 38 cm; black diamonds in Fig. 15) but a low average mean diameter (9 cm). Above the downstream station, fewer pieces were found (25) and the size distribution was more limited (5 - 29 cm; gray squares in Fig. 15) with a slightly larger average mean diameter (12 cm). Small woody debris (SWD, 2 - 5 cm diameter, >100 cm length) was equally abundant at the upstream and downstream stations (24 pieces each; black diamonds and gray squares, respectively, in Fig. 16) although SWD was not counted along an ~28 m-long section of stream at the downstream station.

Fig. 15. Distribution of large woody debris (>5 cm mean diameter)

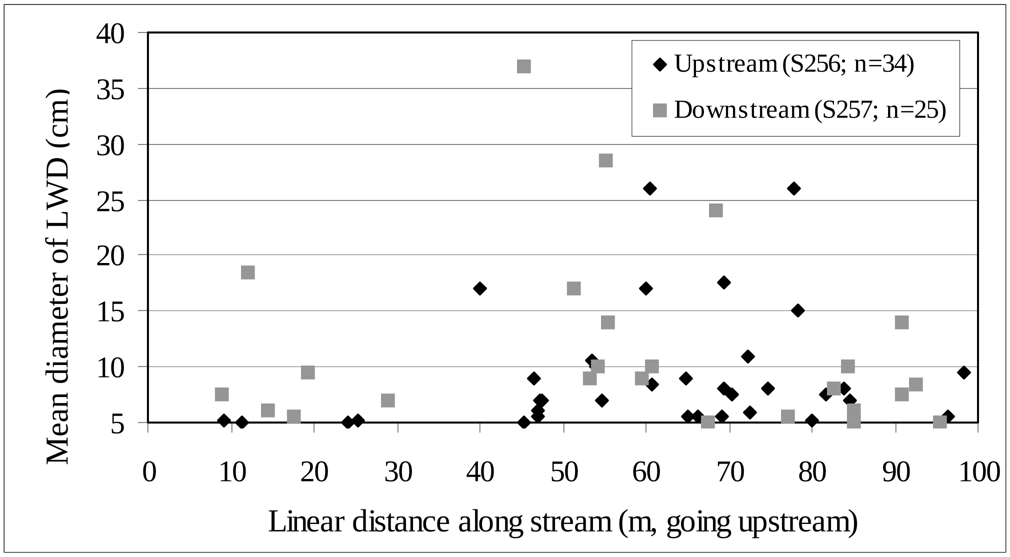
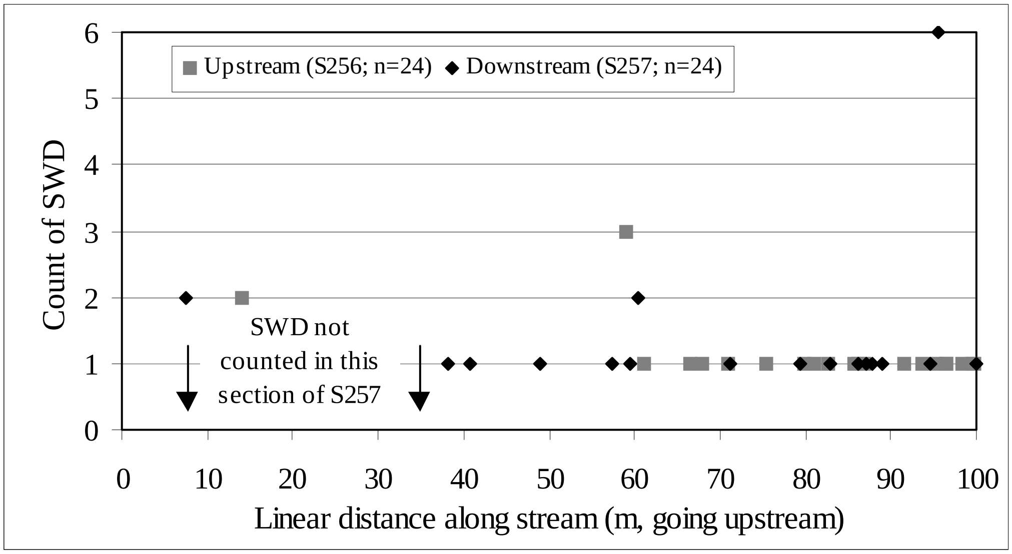
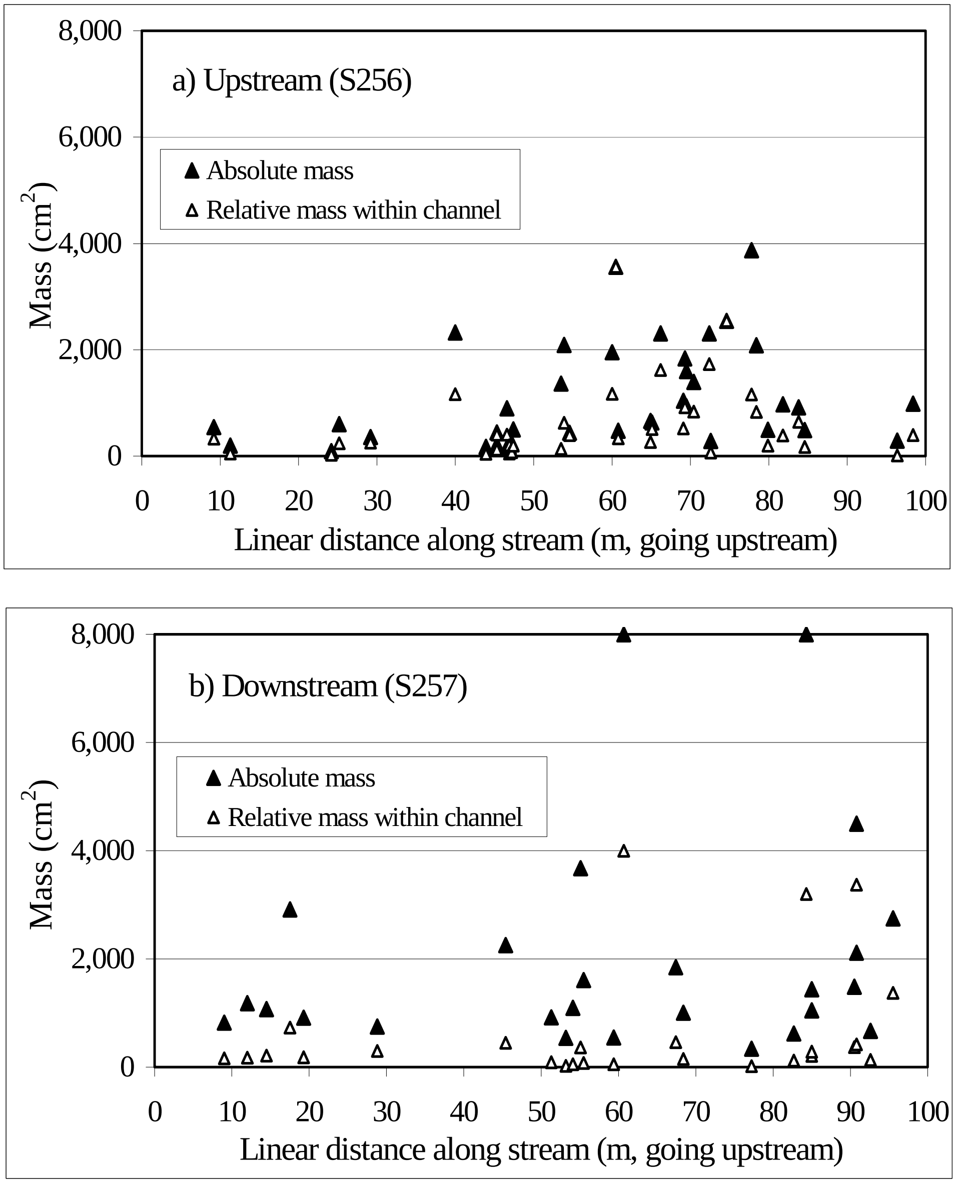


Fig. 16. Distribution of small woody debris (2 - 5 cm diameter, >100 cm length)



Absolute mass of LWD pieces (mean diameter * length) at the upstream station was largely between ~200 and 2,000 cm^2, with a few values outside this range (up to ~3,900 cm^2; black triangles in Fig. 17 a). Absolute mass of LWD pieces at the downstream station was largely between ~500 and 3,700 cm^2, with a few values outside this range (up to ~8,000 cm^2; black triangles in Fig. 17 b). Relative mass of LWD pieces within the channel (absolute mass * % spanning channel) at the upstream station was largely between ~100 and 1,100 cm^2, with a few values outside this range (up to ~3,600 cm^2; open triangles in Fig. 17 a). Relative mass of LWD pieces within the channel at the downstream station was largely between ~50 and 1,300 cm^2, with a few values outside this range (up to ~4,000 cm^2; open triangles in Fig. 17 b). The decrease from absolute to relative mass was smaller at the upstream than at the downstream station (Figs. 17 a and b), reflecting the higher mean percent of the channel spanned by pieces of LWD at the upstream station (51 *versus* 23 %).

Fig. 17. Absolute and relative mass of large woody debris



4. Results from the Physical Characterization assessment at the upstream and downstream stations are summarized in Table 8. Observed problems were moderate local watershed erosion at both stations, and obvious sources of NPS pollution and some channelization at the downstream station.

Table 8. Summary version of completed Physical Characterization form

Parameter	**Sub-Parameter**	**Upstream (S256)**	**Downstream (S257)**
Stream Characterization	Stream subsystem	Perennial	
	Stream type	Coldwater	
	Stream origin	Mixture of origins (spring-fed, swamp and bog)	
Watershed Features	Predominant surrounding landuse	Forest, cemetery	Residential, commercial
	Local watershed NPS pollution	No evidence	Obvious sources
	Local watershed erosion	Moderate	
Riparian Vegetation	Dominant type	Trees	Trees, grasses
Instream Features	Canopy cover	Shaded	Partly open
	Proportion of reach by stream morphology types	15% Riffle, 5% Pool, 80% Run	20% Riffle, 10% Pool, 70% Run
	Channelized	No	Yes (not recently)
	Dam present	No	
Aquatic Vegetation	Dominant type (portion of reach with aquatic vegetation)	None	Attached algae (100% in early summer)
Water Quality	Water odors	None	
	Water surface oils	None	
	Turbidity	Clear	
Sediment/ Substrate	Odors	None	
	Oils	Absent	
	Deposits	None	
	Undersides of stones black?	No (very few stones)	No
Substrate Type	Cobble	0	30
	Gravel	0	30
	Sand	100	30
	Silt	0	10
	Detritus (sticks, wood, coarse plant materials)	10	10
	Muck-mud	0	5

The Habitat Assessment at the upstream and downstream stations resulted in total scores of 146 and 103, respectively, out of a possible 200 (10 categories * 20 points) for optimal habitat, i.e., in the upper 25 % or the middle of the spectrum (Table 9). At the upstream station, the lowest scores were recorded for pool variability (which is naturally limited in this small channel), epifaunal substrate/available cover, and riparian vegetative zone width on right bank. At the downstream station, the lowest scores were recorded for channel sinuosity, epifaunal substrate/available cover and bank stability, pool substrate characterization, and sediment deposition, and pool variability and riparian vegetative zone width.

Table 9. Summary version of completed Habitat Assessment form (low gradient stream)

Habitat Parameter	**Upstream (S256)**	**Downstream (S257)**
1. Epifaunal Substrate/ Available Cover	**12**, suboptimal[1] (30-50% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations, presence of additional substrate in the form of newfall but not yet prepared for colonization)	**9**, marginal (10-30% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed)
2. Pool Substrate Characterization	**16**, optimal (Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common)	**10**, marginal (All mud or clay or sand bottom; little or no root mat; no submerged vegetation)
3. Pool Variability	**3**, poor (Majority of pools small-shallow or pools absent)	**11**, suboptimal (Majority of pools large-deep; very few shallow)
4. Sediment Deposition	**15**, suboptimal (Some new increase in bar formation, mostly from gravel, sand or fine sediment; 20-50% of the bottom affected; slight deposition in pools)	**10**, marginal (Moderate deposition of new gravel, sand or fine sediment on old and new bars; 50-80% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent)
5. Channel Flow Status	**15**, suboptimal (Water fills >75% of the available channel; or <25% of channel substrate is exposed)	**13**, suboptimal (as on left)
6. Channel Alteration	**19**, optimal (Channelization or dredging absent or minimal; stream with normal pattern)	**12**, suboptimal (Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, greater than past 20 yrs) may be present, but recent channelization is not present)
7. Channel Sinuosity	**17**, optimal (The bends in the stream increase the stream length 3-4 times longer than if it was in a straight line)	**6**, marginal (The bends in the stream increase the stream length 1-2 times longer than if it was in a straight line)
8. Bank Stability (score each bank, left/right)	**8/8**, suboptimal (Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion)	**4/5**, marginal (Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods)
9. Vegetative Protection (score each bank, left/right)	**9/9**, optimal (More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally)	**6/6**, suboptimal (70-90% of streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; >½ of potential plant stubble height remaining)
10. Riparian Vegetative Zone (score each bank, left/right)	**9/6**, optimal/suboptimal (9: Width of riparian zone >18 m; human activities, i.e., parking lots, clear-cuts, lawns, or crops, have not impacted zone) (6: as on right)	**5/6**, marginal/suboptimal (5: Width of riparian zone 6-12 m; human activities have impacted zone a great deal) (6: Width of riparian zone 12-18 m; human activities have impacted zone only minimally)

---

[1] For parameters 1-6, possible scores are 0-5 (poor), 6-10 (marginal), 11-15 (suboptimal), and 16-20 (optimal). For parameters 7-10, scores are given for left and right bank with bin sizes of 0-2, 3-5, 6-8, and 9-10.

The Human Disturbance Ranking Form used at the wetland station resulted in a score of 32 out of a possible 125 (5 points * 5 categories * 5 sections ;Table 10). This score indicated very high disturbance, and ranked as the 8th worst score ever recorded in wetlands assessed by the MDEP biomonitoring program (highest score recorded was 44). The potential for NPS pollution had the highest score of the five subsections, followed by impervious surfaces areas in the watershed, and hydrologic modifications to the wetland.

Table 10. Summary version of completed Human Disturbance Ranking Form

Factor assessed	**Score**	**Section Total**
Section 1. Hydrologic modifications to the wetland		
Man-made dikes or dams	3	6
Causeways, roads or railroad bed crossings, culverts	3	
Ditching, draining, dewatering	0	
Filling or bulldozing	0	
Other	0	
Section 2. Vegetative modifications to the wetland		
Timber harvesting in wetland	0	1
Other clearing/removal of vegetation	1	
Plowing, mowing or grazing in wetland	0	
Evidence of herbicide use in wetland	0	
Other	0	
Section 3. Evidence of chemical pollutants		
Discharge pipes	0	2
Oil, petroleum, chemicals observed, chemical odor present	0	
Soil staining, stressed/dying vegetation	0	
Trash, chemical containers, demolition debris, drums, etc. (litter)	2	
Other	0	
Section 4. Impervious surface areas in watershed		
Residential development	4	11
Commercial/industrial development	2	
Recreational development (park with trail along edge of wetland, dog walk area)	2	
Roads and highway bridges	3	
Other (parking lots)	0	
Section 5. Potential for NPS pollution		
Excess sediment accumulation and eroding soil from human activities (sedimentation/siltation)	3	12
Alterations to wetland buffer (houses, foot trail, lawns)	4	
Livestock, feedlots, manure piles (dog feces)	1	
Evidence of fertilizer or pesticide use (lawns)	2	
Other (stormwater drainage swale in Evergreen Cemetery)	2	

5. The fluvial geomorphology survey of Capisic Brook concentrated largely on the mainstem from Evergreen Cemetery down to Capisic Pond; it did not include the northern branch, but did include minor assessments on the western branch (Field 2003).

An analysis of historic landuse changes in the Capisic Brook watershed undertaken as part of the geomorphological assessment found that 63 % of the watershed had been built-up by 1964; this percentage rose to 76 % by 1998 (Table 1 in Field 2003). Over the same time period, forest land declined from 23 to 19 %, agriculture from 8 to 1 %, and barren land from 5 to 4 %. No significant changes in channel position or dimension occurred during that period. Only minor sections of Capisic Brook were channelized in the past (Table 11), namely a section between Lucas Street and Brighton Avenue. The effect of channelization on this section is reflected in the low entrenchment[1] ratios measured here (2.1 and 3.3 for two cross-sections on Site 1; Table 6 in Field 2003). This means that flows above the bankfull stage do not spread out into a floodplain but instead remain confined within the high banks created by channelization. During high flows, this condition can create erosive forces that can cause the transport of sediment originating from both the sandy substrate and stream banks. Overall, almost 60 % of Capisic Brook showed signs of entrenchment (Table 11).

[Note: information received from the City of Portland (B. Roland, pers. comm.) indicated that most of the stream channel was altered during the 1950s when the sewer system was put in place. Since that time, the stream has regained some of its original shape and hence does not appear channelized in most areas.)

Table 11. Selected results from geomorphological survey of Capisic Brook

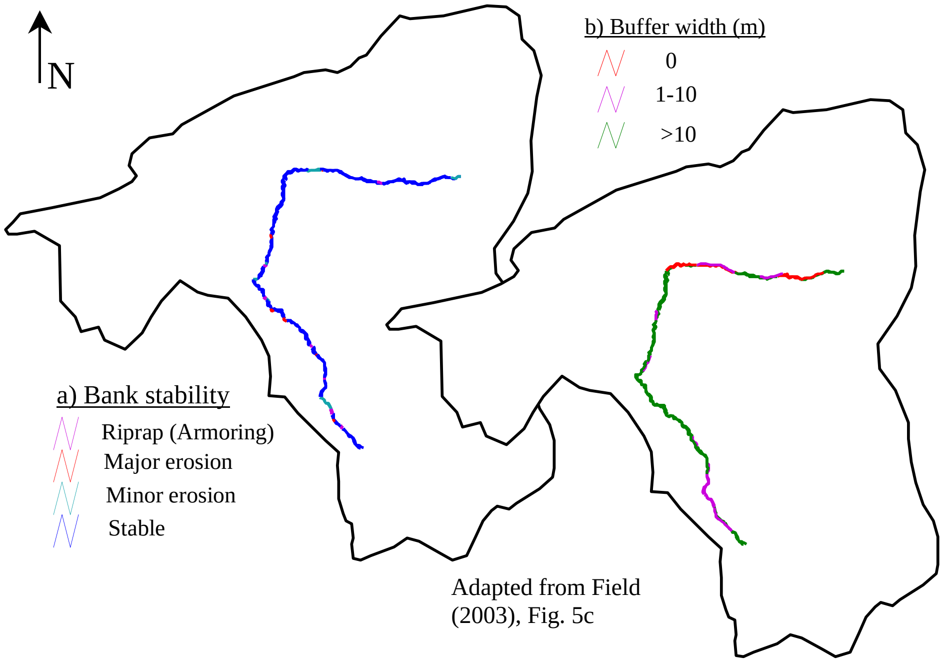
Feature		**Length (m)**	**Percent**
Channelization	Channelized	111	2.9
	Encroachment	593	15.7
	Unaltered channel	3,084	81.4
Entrenchment (entrenchment ratio)	Deeply entrenched (<1.4)	178	4.7
	Slightly entrenched (1.4 - 2.2)	2,040	53.8
	Not entrenched (>2.2)	1,571	41.5
Bank stability	Major erosion	141	2.0
	Minor erosion	513	7.2
	Armoring	312	4.4
	Stable	6,187	86.5
Riparian buffer width	Absent (0 m)	1,110	15.5
	Narrow (1-10 m)	1,498	20.9
	Wide (>10 m)	4,547	63.5

---

[1] Entrenchment is the ratio of the channel width at two times the bankfull depth to the width at the bankfull stage (Field 2003).

The geomorphological survey showed only few areas where bank stability was identified as a problem (i.e., major erosion), namely in three isolated spots in the middle part of the watershed (Table 11; Fig. 18a; Fig. 5c in Field 2003). Channel armoring with riprap was seen in a few places (Table 11), mostly at road crossings. Buffer width was identified as a moderate problem (Table 11; Fig. 18b; Fig. 5c in Field 2003). Aggradation, i.e., deposition of sediment in the channel, was identified as an issue in the section between Lucas Street and Brighton Avenue (Capisic Brook Site 1 in Field 2003). Here, the original channel was constructed too large for the dominant discharge and the channel is trying to re-establish an equilibrium through a reduction in bankfull width. This section is approaching Stage IV of Schumm's Channel Evolution Model (see Fig. 8 and Table 6 in Field 2003), i.e., is close to the equilibrium stage (Stage V), which generally makes restoration efforts to re-establish sinuosity a good option.

Fig. 18. Bank stability (a) and buffer width (b) along Capisic Brook

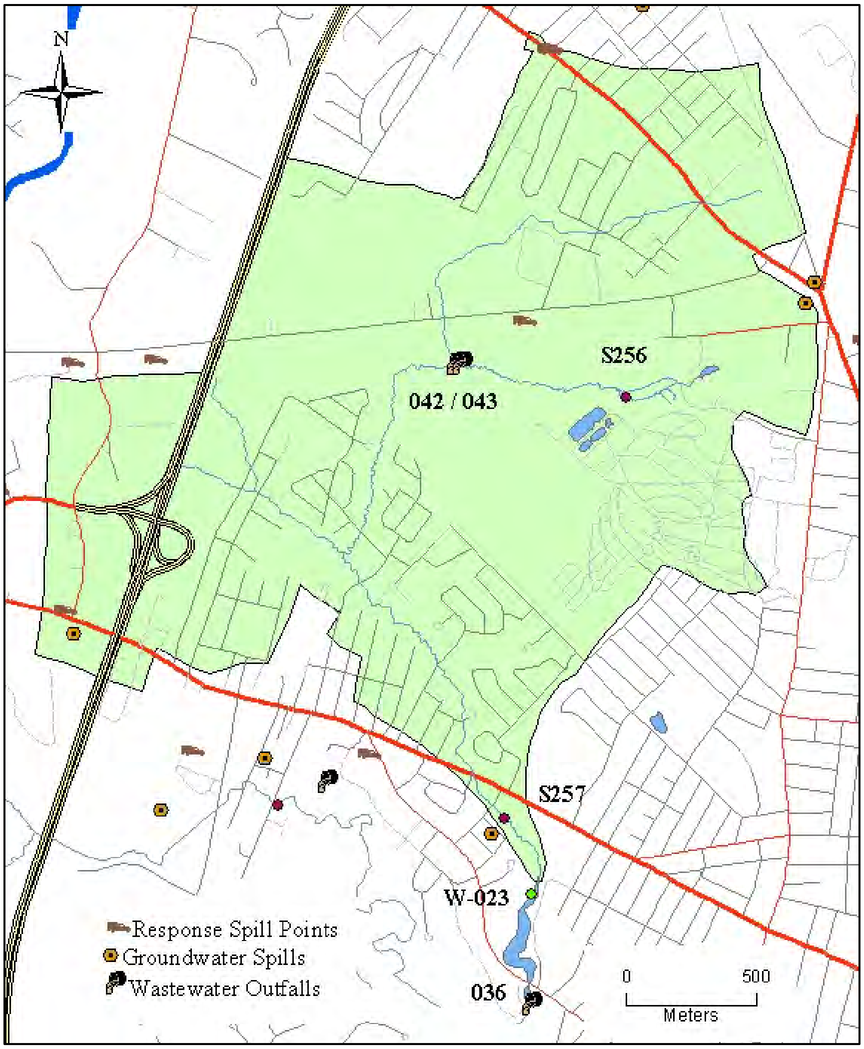


Adapted from Field (2003), Fig. 5c

The survey furthermore included two qualitative assessments of the entire stream. A Rapid Habitat Assessment (as in Table 8, above) showed that most of Capisic Brook is near the lower end of the Fair ranking (ranking categories are Poor, Fair, Good, Reference; top score is 200). Specifically, the stream near the upstream biomonitoring station in Evergreen Cemetery had a Fair ranking (79, range is 71 - 130), while it had a Poor ranking (68, range is 0 - 70) near and above the downstream station. A Rapid Geomorphic Assessment, which is used to evaluate degradation, aggradation, widening, and planform adjustment processes showed that most of Capisic Brook is near the high end of the Fair or the low end of the Good ranking (ranking categories are Poor, Fair, Good, Reference; top score is 80). Specifically, the stream near both biomonitoring stations had a Fair ranking (39 near the upstream station, 34 near the downstream station; range is 21 - 40).

6. An analysis of spills documented by the MDEP's Bureau of Remediation and Waste Management between 1976 and 2003 showed that several spills occurred within the watershed (in Portland and Westbrook; App. E). The spills were confined to the time period between 1990 and 2003. Spatial (GIS-linked) information is currently available for a few of those spills (Fig. 19). In most cases the records contained no information on potential effects of a spill on nearby surface waterbodies, and it was hence not possible to determine whether those spills affected Capisic Brook. Most incidents concerned spills of heating oil or gasoline/diesel with amounts ranging from 3 to 2,000 gallons (1,500 G of the 2,000 G spill were recovered; App. E).

Fig. 19. Spill points and wastewater outfalls (CSOs)



There are three wastewater outfalls (or combined sewer overflows, CSOs; # 036, 042, 043) in the watershed. Two are located in the upper part of the watershed near Warren Avenue (just upstream of where the northern tributary meets the mainstem), i.e., below the upstream station, and ~2,200 or ~2,600 m above the downstream or wetland stations, respectively. One CSO is located below the Capisic Pond dam (just before the stream flows into the Fore River; Fig. 19). Discharge data for the last four years for these outfalls are shown in Table 12. Note that most of the discharges occur below the Capisic Pond dam, i.e., below any of the monitoring stations, but substantial discharges also occur below the upstream station.

Table 12. Discharge data for CSOs going into Capisic Brook

Year	**CSO 036 (below dam)**		**CSO 042**		**CSO 043**	
	Number of events	**Gallons discharged**	**Number of events**	**Gallons discharged**	**Number of events**	**Gallons discharged**
2003	80	36 million	54	14 million	9	0.4 million
2002	60	49 million	52	15 million	52	~3 million
2001	32	64 million	28	21 million	28	2.4 million
2000	58	67 million	49	16 million	50	3.1 million

DATA SUMMARY

The two stations studied on Capisic Brook were very different from each other in most parameters studied. Summary results from all sampling events and assessments are listed in Table 13 and discussed below (in the Discussion). The upstream station in Evergreen Cemetery had a healthy macroinvertebrate community, good water quality and adequate habitat. The downstream station below Lucas Street and above Capisic Pond had impaired biota, poor water quality and degraded habitat. The likely reason for this difference is the difference in the type of landuse upstream of and around each station, which influences water and habitat quality, and hence biological communities. “Conclusions and Recommendations”, below, contains recommendations on how to maintain the overall good conditions at the upstream station, and suggestions for best management practices (BMPs) and remedial actions aimed at improving the poor conditions at the downstream station.

Table 13. Data summary for 2003. Highlighted fields indicate problem parameters.

Parameter	**Upstream (S256)**	**Downstream (S257)**	**Wetland (W-023)**
Biota			
Macroinvertebrates	Class A (high EPT, 19 % non-insects, low Hilsenhoff index)	Model result "Non-Attainment" (no EP, low T, 54 % non-insects, high Hilsenhoff index)	Impaired (mostly tolerant, few sensitive organisms)
Fish		Low diversity, tolerant taxa	
Algae	(observation: very little algae)	Excessive algal growth	
Water Quality Parameters			
Dissolved oxygen	Always >9 mg/L	Often <7 mg/L (down to 5 mg/L); diurnal fluctuations >2 mg/L	Low (5.2 mg/L)
Specific conductance	Relatively low (~100 µS/cm)	Relatively high (usually 600-700 µS/cm)	High (546 and 703 µS/cm)
Summer temperature	Cool (mostly 10-15 ºC)	Warm (mostly 18-22 ºC)	Warm (20 ºC)
pH	Normal	Normal	Normal
Suspended solids	5-6 mg/L at baseflow (no stormflow data)	2-5 mg/L at baseflow, 8 and 44 mg/L at stormflow	
Nutrients and bacteria	Bacteria exceed criteria once at baseflow (no stormflow data)	TP, TN, Chl *a* and bacteria exceed criteria at baseflow; TP at stormflow	Nutrients and anions/cations high compared to other ME wetlands
Metals/Anions and cations	No metal violations at baseflow (no stormflow data)	Fe exceeds criteria at baseflow; no violations at stormflow	
Habitat Assessments			
Flow regime	Swift and variable	Slow and homogeneous	
Stream width / depth	Stable throughout summer		
Woody debris (mean % spanning channel)	Good LWD and SWD, absolute mass similar to relative mass (51%)	Limited LWD, good SWD, absolute mass much greater than relative mass (23%)	
Physical characterization	Qualitative assessment: no problems	Qualitative assessment: some problems	
Habitat assessment (top score 200)	Relatively high score (146)	Intermediate score (103)	
Human disturbance (best/worst score recorded in ME is 1/44)			Relatively high level of disturbance (score of 32)
Fluvial geomorphology survey	Minor channelization, relatively high entrenchment, few erosion problems, no/narrow riparian buffer along one third of stream; Fair to Good Geomorphic Assessment (score 34-43; top score is 80); Poor to Fair Habitat Assessment (score 68-83; top score is 200)		
Spill point analysis	Few spills, mostly petroleum products		
Wastewater outfalls	2 below upstream station (<1-21 million gallons/year), 1 below Capisic Pond (36-67 million gallons/year); removal planned for 2006-2009		

DISCUSSION

Biological Monitoring

The macroinvertebrate community at the upstream station met Class A aquatic life criteria, thus exceeding the required Class C criteria (Table 4). Some sensitive organisms were present (e.g., Leptophlebiidae, *Parapsyche*) including one MDEP Class A indicator taxon (*Eurylophella*). The percent of non-insect taxa, was surprisingly high (19 %) given the Class A model outcome. The abundance of dominant organism, *Stylodrilus*, is in part attributable to the sandy substrate which constitutes the major food item for these worms. Members of the family Lumbriculidae, such as *Stylodrilus*, usually are found in streams with low organic matter (i.e., in relatively unpolluted waters), and are often common in streams (Thorp and Covich 1991). Compared to previous years (1996 and 1999, see Previous Studies, Table 1), the macroinvertebrate community achieved the same model outcome. One surprising change was the much greater number of organisms collected in 2003 (1,017 *versus* 91 and 280). This increase was related to a substantial rise in the percentage of non-insect taxa (19 % *versus* 2.5 and 1.1 %) due to the presence of *Stylodrilus*. In contrast to macroinvertebrates, macroalgae and algae at this station were in very low abundance (based on regular observations but not measured quantitatively). This finding is likely due to several factors, such as the soft (sandy) substrate, the shaded location, and the low nutrient content of the water (Table 5).

The macroinvertebrate community and fish assemblage observed at the downstream station consisted largely of tolerant organisms, such as isopods, midge larvae, and eels (Table 4). And while the macroinvertebrate community was relatively diverse (46 genera), the fish assemblage was not (3). Sensitive organisms observed at the upstream, unimpaired site, were not present downstream. The degraded biota are indicative of a stream that has poor water quality (low dissolved oxygen, elevated temperature, high nutrients; see following section), altered food supply for macroinvertebrates (a shift from allochthonous to autochthonous material), and inadequate habitat (see Habitat Assessments, below). Macroinvertebrate data from 2003 (Table 4) are quite similar to those from previous years (1996 and 1999; see Previous Studies, Table 1). The downstream station on Capisic Brook failed to meet the required Class C aquatic life criteria in all three years, i.e., conditions were insufficient to "*maintain the structure and function of the resident biological community …" (*Maine Water Quality Criteria for Classification of Fresh Surface Waters; Title 38 MRSA §465). Maine does not yet have aquatic life criteria for algal communities in streams or for wetland communities, and taxonomic algal data from this station and the wetland station ~350 m downstream are as yet outstanding. It seems clear, however, that the algal assemblage at the downstream station and the macroinvertebrate community at the wetland station also indicated an impaired condition (see Results of 2003 Study, Biological Monitoring, items 3 and 4). In 2000, the wetland station also showed impaired conditions (see Previous Studies). The consistent non-attainment of aquatic life criteria, or generally impaired conditions, is not unexpected given that the predominantly urban landuse patterns in the watershed have remained relatively constant over the last several years, resulting in adverse effects on the stream and the biota within it. Degraded macroinvertebrate communities similar to the one found at the downstream station in Capisic Brook also were found in the other three streams included in the Urban Streams Project as well as in other urban streams sampled by the MDEP's Biological Monitoring Program (unpublished data).

The data available by mid-May 2004 were analyzed with the goal of identifying specific stressors that are responsible for the observed impairment in the macroinvertebrate community at the downstream station in Capisic Brook. The stressor identification process (see Ch. 1, Introduction, MDEP Urban Streams Project, and below) pointed to a degraded instream habitat as the most likely factor to cause impairments, followed by altered hydrology, toxicants, elevated nutrient levels, elevated water temperature, low dissolved oxygen concentration, and increased sedimentation. The Total Maximum Daily Load plan (TMDL plan; see Ch. 1, Introduction, MDEP Urban Streams Project) will need to address these factors to enable the restoration of healthy aquatic communities in Capisic Brook.

Water Quality Monitoring

Dissolved oxygen

The dissolved oxygen (DO) concentrations (instantaneous and diurnal, Figs. 3 and 7, respectively) in Capisic Brook at the upstream station always were at a level that favors healthy macroinvertebrate communities. This positive finding is likely attributable to two main factors: 1) the cool temperatures existing in this stretch of the stream (see below) allow the water to hold a high concentration of dissolved oxygen; and 2) the low level of algae means that oxygen levels are not depleted due to algal respiration and decomposition.

The DO concentrations (instantaneous, diurnal, and continuous, Figs. 3, 7 and 8, respectively) at the downstream station were almost always above the Class C numeric criterion for summer DO levels (5 mg/L). However, continuous DO data indicated that levels can come close to, or fall below, that required minimum concentration during the night. Strong diurnal fluctuations were apparent in the data, with early morning concentrations usually below 7 mg/L, i.e., below what is generally considered an adequate level for biota, and afternoon concentrations near or above 8 mg/L. Diurnal swings often exceeded 2 mg/L which generally indicates an algal problem. Also noteworthy are the maximum DO concentrations measured, >10 mg/L in late afternoon on two occasions. These concentrations in conjunction with the warm water temperatures shown in Fig. 8 showed that the stream water was supersaturated with DO at times (i.e., there was more oxygen in the water than is normally possible under normal temperature and pressure; 110 and 105 % on July 8 and 10, respectively). This is a typical sign of high algal productivity.

Factors that can influence DO levels are water temperature (cold water can hold more DO than warm water), the abundance of algae (which both produce and consume oxygen, and require oxygen for decomposition by microorganisms), flow patterns (riffle sections of a stream help to re-aerate the water), and the presence of nutrients in the water (which can influence the abundance of algae). At the downstream station in Capisic Brook, all of these factors were suspected to impact DO concentrations. Water temperature during the summer months was elevated (Figs.

Fig. 20. Algae at downstream station on July 9, 2003

5, 8 and 10), leading to a reduction in the DO carrying capacity of stream water. Excessive algal growth was observed in July 2003 when the entire stream bed was covered by a thick mat of green filamentous algae (Fig. 20). A repeat visit in July 2004 showed less algal growth which, however, still far exceeded growth observed at any other Urban Stream station. An analysis of water flow patterns at this station (Fig. 12) showed that the flow regime is homogeneous with a very low velocity, all but eliminating any possibility for re-aeration of the water. And chemical analyses (Tables 5 - 6) showed that nutrients (TN and TP) are above levels recommended by EPA for this region of Maine, contributing to excessive algal growth. These data and observations combined provide a good explanation for the observed pattern of DO concentrations at the downstream station.

Dissolved oxygen is required for respiration by all aquatic animals, but some organisms, such as mayflies, stoneflies, and trout, require relatively high oxygen concentrations for healthy functioning. Insensitive organisms like isopods, midge larvae, or eels on the other hand can survive at relatively low DO concentrations. In 2003, dissolved oxygen concentrations were high enough to support healthy aquatic communities at the upstream station on Capisic Brook, but not always at the downstream station. Indeed, macroinvertebrate data from previous years showed that historically very few sensitive organisms were found at the downstream station, which may have been partly due to low DO concentrations (see Previous Studies, above). Suggestions for how to improve low DO concentrations, and some of the factors causing them, are made in Conclusions and Recommendations, below.

Specific conductance

The levels of conductivity in Capisic Brook at the upstream station (instantaneous, Fig. 4) are similar to those found by the MDEP's Biological Monitoring Program in relatively undisturbed streams in Maine (unpublished data). This suggests that this stretch of the stream is not strongly affected by human activities. The water at the upstream station is mostly derived from springs and small tributaries in Evergreen Cemetery (e.g., Fig. 21), with a small contribution from a pond upstream of the sampling location. Information obtained from the City of Portland (B. Roland, pers. comm.) indicated that, in spite of apparently extensive urbanization, the subwatershed draining into this section of Capisic Brook receives only small amounts of stormwater runoff as most of the runoff in this area is currently directed into the city sewer system. It is likely that the minimal amount of stormwater runoff is an important factor in maintaining low conductivity levels at the upstream station.

Fig. 21. Tributary in Evergreen Cemetery (May 2004)

The levels of conductivity in Capisic Brook at the downstream station (instantaneous and continuous, Figs. 4 and 9, respectively) are similar to those found in the other three streams included in the Urban Streams Project as well as in other urban streams sampled by the Biological Monitoring Program (unpublished data). These levels are much higher than typically found in minimally impacted streams in Maine, where conductivity is usually below 75 µS/cm (L. Tsomides, pers. comm.). While certain types of geological formations and certain soil types in a watershed can cause conductivity levels to be elevated naturally, it is likely that runoff from the extensive impervious surfaces near the downstream station contributes to high conductivity levels at this station. It is noteworthy, however, that conductivity decreased substantially (to ~300 μS/cm) following a rain event (Fig. 9) indicating that an input of rain and stormwater temporarily diluted the ions measured with this parameter. Data from previous sampling events show that the conductivity level has increased significantly over time, from a low of 195 μS/cm in 1996, to an intermediate value of 386 μS/cm in 1999, and a maximum of ~770 μS/cm in 2003. This suggests that water quality may have deteriorated over the past several years. At the wetland station, conductivity also increased slightly over time (2000 *versus* 2003: 434 *versus* 546 μS/cm).

While little is known about how conductivity in and of itself may impact biological communities, it is known that metals, as well as cations and anions, which contribute to high conductivity levels, can have negative effects on aquatic life (see discussion on Metals, below). To reduce conductivity levels at the downstream station in Capisic Brook, the quantity of runoff the stream receives should be reduced; alternatively, runoff quality could be improved, for example by channeling it through a stormwater treatment system.

Water temperature

The cool temperature regime generally encountered at the upstream station (continuous temperature in 1999, Fig. 2; instantaneous and short and long-term continuous temperature in 2003, Figs. 5, 8 and 10) in Capisic Brook is favorable for sensitive biota. Compared to the other Urban Streams, this station had the lowest temperatures (App. C ii). Factors responsible for this temperature regime are likely the closeness to the headwaters (springs in Evergreen Cemetery), an intact riparian zone with many trees providing good shading, and an absence of heated stormwater runoff. It is important to preserve these conditions to ensure the continued favorable temperature conditions in this stretch of Capisic Brook.

The relatively high temperatures recorded in midsummer at the downstream station (continuous temperature in 1999, Fig. 2; instantaneous and short and long-term continuous temperature in 2003, Figs. 5, 8 and 10) were in, or close to, a range that is considered stressful for many sensitive fish and aquatic invertebrates. Temperatures were at a more favorable level in spring (Fig. 5) and after late summer (Figs. 5 and 10) although the weekly maximum temperature remained above 20 ºC into early fall. Compared to the other Urban Streams, this station had the second highest temperatures (after Birch Stream; App. C ii). Studies have shown that sensitive macroinvertebrates such as certain mayflies or stoneflies prefer temperatures below 17 ºC (see references in Varricchione 2002), while Brook Trout (a sensitive fish species) have an upper temperature limit of 20 - 24 ºC (review by McCullough 1999). Thus, a lowering of summer water temperatures at the downstream station in Capisic Brook would likely aid in restoring intact biological communities.

High water temperatures are often associated with open stretches of stream, where the absence of vegetation in the riparian zone leaves the water fully exposed to solar heating. This is the case right around the downstream station in Capisic Brook, and also in some places upstream of the station. Also, heated runoff from impervious surfaces close to the stream may significantly increase water temperatures in the summer. To lower water temperatures to a summertime level that promotes healthy biological communities in the stream, a priority should be to replant the riparian zone in as many places as possible, and particularly around the sampling location. Furthermore, stormwater runoff should be diverted away from the stream wherever possible.

pH

In natural waters, pH usually falls between 6.5 and 8.5, and a range of 6.0 to 9.0 protects most aquatic life. All measurements taken on Capisic Brook were within a range that favors healthy macroinvertebrate and fish communities.

Turbidity

No turbidity data were collected at either the upstream or downstream stations but observations showed that at least following large storm events, turbidity can be easily detected visually, particularly at the downstream station (App. G, Figs. 10 - 12). Total suspended solids were generally low in Capisic Brook during baseflow conditions (Table 5) but elevated during stormflow conditions at the downstream station (Table 6).

Suspended solids, which affect the turbidity of a stream, can be of natural origin (clay, silt, sand, decaying vegetation, phytoplankton) or man-made (industrial wastes, sewage, winter road sand). Land use (e.g., urban *versus* forested) and local soil type (e.g., silt and clay *versus* bedrock) are important factors that influence turbidity levels in a stream. High concentrations of suspended solids can affect streams and the organisms living in them in a variety of ways: by modifying light penetration which affects plant growth; by smothering benthic organisms thus affecting their health; by increasing substrate embeddedness; by reducing available invertebrate living space; by reducing the flow of oxygen-rich surface water through stream gravels and cobbles where salmonid fish eggs may be incubated; by reducing the ability of visual predators to find prey; by clogging the gills of fish; and by potentially darkening the water which may lead to an increase in temperature through increased absorption of heat from sunlight. Suspended solids in Capisic Brook generally were not high enough to have a major negative effect on biota in the stream although some effects, particularly during storm events, may occur.

Nutrients and bacteria

The surface water samples collected at the upstream station on Capisic Brook showed only one violation of water quality criteria, a single exceedance of Maine's criteria for the geometric mean count of *E. coli* colonies (Table 5). All nutrients (including stormflow TP in February 2004) and two other bacteria samples were well below available criteria. As with other factors (dissolved oxygen, conductivity, temperature) this positive result is likely attributable to the undisturbed area around this station. The elevated bacterial count could be attributable to either wildlife or to pet waste being washed into the stream. A small hiking trail runs along this section of the stream, and local residents have been observed walking their dogs along the trail. To ensure pet waste does not enter the stream, owners should be encouraged to pick up after their dogs.

The surface water samples collected at the downstream station during baseflow conditions exceeded EPA-recommended water quality criteria for TN, TP, and Chlorophyll *a*, Table 5). In 1996, the EPA-recommended criterion for TP also was exceeded (Table 2) while a single sample collected in the summer of 2004 showed that TN and TP exceeded EPA criteria (App. C iii). Compared to the other impaired Urban Stream stations, this station had the highest baseflow nutrient levels in both 2003 and 2004 (App. C iii). During stormflow conditions (Table 6), the EPA-recommended criterion for TP was exceeded on all three sampling dates. This situation was similar to the other Urban Streams stations (App. C iv). Data from the wetland sampling also showed that in 2000 and 2003 several nutrients were among the highest measured in ME wetlands by the biomonitoring program (Tables 3 and 7, respectively).

Nutrient levels often are increased in urban streams as runoff from land includes material that is high in nitrogen and phosphorus, such as animal waste, fertilizers, septic system effluent, or road dirt (CWP 2003). Furthermore, many cities, including Portland, operate a combined sewer overflow (CSO) system which may allow raw sewage to enter a stream during storm events. When this happens, the bacterial and nutrient load in the stream increases (see Spills and wastewater overflows, below). The MDEP's Biological Monitoring Program has found that, depending on site characteristics, elevated nutrient levels in urban streams may impact macroinvertebrate communities. This can occur for example when exposure of the stream to sunlight promotes excessive plant and algae growth which in turn may cause temporary DO depletion (L. Tsomides, pers. comm.). The excessive algal growth and widely fluctuating DO concentrations found at the downstream station suggest that nutrients are probably a significant stressor in Capisic Brook. The relatively high Chlorophyll *a* values found at the downstream and wetland stations are likely related to high nutrient levels as the algal concentrations measured with this parameter respond favorably to nutrient input.

Maine's criterion for the mean count of bacteria (*E. coli*) colonies of human origin was exceeded at the downstream station on all sampling dates (by up to a factor of 6). However, it is not known whether this constitutes a true criterion violation as the analysis performed in this study did not differentiate among various sources for bacteria (pets, wildlife, birds, CSOs, leaking sewer systems). It is known that large amounts of storm water mixed with raw sewage enter Capisic Brook below the upstream station each year (Table 12), and constitute a potential source of bacteria. Also, further sources can be found in waterfowl that use the stream and surrounding area as a resource, and in pet waste that enters the stream during storm events.

Because nutrients appear to be an important stressor in Capisic Brook, it is important that various measures are initiated to control this stressor. Initial measures could include practices such as keeping pets away from the stream, picking up pet waste, abstaining from feeding birds in the ponds in Evergreen Cemetery, ensuring that any septic systems in the watershed are in good working order, and minimizing fertilizer use on lawns in the vicinity of the stream. Furthermore, the maintenance or re-planting of a vegetated riparian buffer along the stream corridor would allow for the filtration of lawn or yard runoff. Most of these practices also should help to reduce bacterial contamination. However, to effectively control nutrient and bacterial loads in Capisic Brook, entry of raw sewage into the stream must be prevented. To this end, the City of Portland is currently working on plans to separate (within the next 2 – 5 years, B. Roland, pers. comm.) their CSO system thus eliminating this stressor in Capisic Brook. For complete nutrient control it may furthermore be necessary to reduce the amount of stormwater runoff the stream receives, or to improve its quality. As CSO separation will likely involve the installation of two detention ponds, it is important that the city continues to consult with MDEP to minimize the effect of this work on stream quality, and maximize the removal efficiency for pollutants.

Metals and chloride

At the upstream station, none of the metals sampled during baseflow conditions (Table 5) exceeded Maine Statewide Water Quality Criteria (SWQC), again likely because of the unimpaired nature of this stretch of the stream. The same result was also found in 1996 (Table 2). A single sample collected in the summer of 2004 showed, however, that aluminum and lead exceeded chronic criteria (CCC), and that copper did not (App. C iii). In fact, the aluminum concentration measured at this station in 2004 was the highest among the 14 Urban Streams samples collected that year. It is unknown what caused the high value but natural sources are one possibility.

At the downstream station, iron was the only metal sampled during baseflow conditions to exceed chronic Maine SWQC in 2003 (Table 5), and the same was true for copper in 1996 (Table 2). In the summer of 2004, aluminum and lead exceeded the CCC once, while copper was below the CCC (App. C iii). During stormflow conditions, no metals exceeded acute SWQC (Table 6). Both sets of storm data available showed a similar pattern in criteria violations, which were less severe than those documented by Varricchione (2002) in Long Creek, South Portland (copper, lead, and zinc exceeded CMC during three storm events). Unfortunately, for some samples the detection limits for certain metals were above the water quality criteria, for example in 2003 in the case of copper for both chronic and acute criteria. One indication of potential metal pollution in the Capisic Brook watershed is found in the 2000 wetland data for sediments. These samples showed that cadmium, copper, lead, and zinc all were in the upper 10 % of wetland samples collected by the biomonitoring unit in Maine. Samples also exceeded the Ontario Ministry of the Environment Sediment Quality Guidelines LELs (Table 3). Likewise, in 2003 and in 2000, anions and cations in the water column were in the upper 10 % of wetlands samples (Tables 3 and 7).

The metals detected in Capisic Brook (Tables 5 and 6) likely originated as metal pollutants that had adsorbed onto particles of road dirt which were subsequently blown or washed into the stream. Beasley and Kneale (2002) and CWP (2003 and references therein) cited as sources for metal pollution in urban streams vehicles (tires, brakes, fuels, and oils), pavement (concrete, asphalt), rooftops, exterior paints, and surface debris (litter, winter road sand and salts). Lead may also enter the stream from CSO pipes (J. True, pers. comm.). Aluminum and iron can also occur naturally in streams as these metals are very abundant, and can leach out of soils with low pH-buffering capacity. Zinc can also originate from galvanized steel pipes used for culverts or storm drain systems. Sediment entering the stream from construction sites, winter sanding activities, or soil erosion also may carry metals (e.g., CWP 2003). Finally, spills of hazardous substances and CSO input also can add metals to a waterbody. Impacts of metals on streams can occur in the form of chronic or acute toxicity to aquatic organisms, contamination of sediments, and bioaccumulation in plants or animals (CWP 2003 and references therein). Negative effects of metals on macroinvertebrates and fish have been confirmed in several studies. Effects include declines in the rates of growth and reproduction, reduced population size, changes in community structure, and death (Paul and Meyer 2001, Beasley and Kneale 2002, and Lydersen et al. 2002, and references therein). To reduce metal pollution in Capisic Brook, road runoff needs to be diverted away from the stream or treated before entering the stream. Also, sand left in parking lots and on roads after the end of the winter sanding season should be removed to reduce the sediment influx into the stream. While the City of Portland has a road sweeping program in place (B. Roland, pers. comm.) and is thus minimizing sand influx into the stream, it is not known whether businesses located in the watershed also remove sands from their premises. If they do not, they should be encouraged to initiate this practice. Rigorous application of BMPs by construction companies and the greening of bare surfaces also would help reduce sediment/metal input into the stream.

Chloride levels at the upstream station during baseflow conditions in the summers of 2003 and 2004 were far below the chronic criterion, and indeed were the lowest among all Urban Streams stations (App. C iii). At the downstream station, chloride were higher than at the upstream station, but still below the chronic criterion. Chloride concentrations are expected to be low in the summer as this pollutant predominantly reaches waterbodies as road runoff during the winter and spring. No winter/spring data exist for Capisic Brook, and this data gap should be filled, preferably by deploying a continuous data sonde measuring conductivity at the downstream station[1]. Conductivity is strongly affected by chloride because this anion typically occurs in high concentrations (in contrast to metals, it is measured in mg/L rather than µg/L), making SPC measurements a convenient way to determine chloride loads in winter and spring. Conductivity levels of up to ~23,000 µS/cm have been seen in studies of urban streams in the winter (S. Corsi, pers. comm.). This indicates extreme chloride toxicity as conductivities of 853 and 2,855 µS/cm correspond to the Maine SWQC (MDEP SWQC) chronic and acute criteria of 230 and 860 mg/L chloride, respectively (D. Heath, pers. comm.). According to information from the City of Portland (B. Roland, pers. comm.), snow that melts on roads, parking lots or driveways within the watershed flows untreated into the stream either directly or via the storm drain system.

Habitat Assessments

Flow regime

The relatively swift and highly variable flow regime found at and above the upstream station (instantaneous flow velocity and thalweg velocity, Figs. 11 and 12) on Capisic Brook is yet another positive feature of this stretch of the stream. It provides aquatic organisms with a wide variety of environments to occupy and thus increases the potential for a diverse biological community. The continued existence of the large pervious surface (forest and cemetery) around this station will ensure continued groundwater supply to the stream, and maintenance of the positive flow regime.

In contrast, the relatively slow and homogeneous flow regime found at and above the downstream station (instantaneous flow velocity, thalweg velocity, Figs. 11 and 12) does not favor a diverse biological community because of reduced habitat diversity. In such an environment, organisms requiring swift flows, for example for feeding, will be absent. Furthermore, a slow flow regime increases substrate embeddedness, and allows fine sediment

---

[1] The upstream station receives very little road runoff and chloride pollution is not considered a serious threat.

to accumulate on the stream bed thus smother organisms. Finally, fast flowing areas in small streams are usually characterized by riffles which increase the re-aeration potential of the stream. As shown above (Water quality monitoring, Dissolved oxygen), low DO concentrations, perhaps in part caused by the absence of riffles, were identified as a likely factor impacting macroinvertebrate communities at this station.

Restoring a more natural channel morphology and hence a variable flow regime in the lower section of Capisic Brook will require the expertise of a fluvial geomorphologist as many factors affecting stream morphology and flow velocity will need to be considered. However, a variable flow regime would benefit aquatic communities and overall stream quality in several ways. Therefore, the restoration design for this section of Capisic Brook described below in the section on the geomorphological survey results should be given serious consideration.

Stream width and depth

Stream width and depth (Figs. 13 and 14, respectively) were relatively stable at both stations suggesting that groundwater contributions to the stream are sufficient to maintain a relatively even baseflow from spring to fall. This is a positive factor as it means that total habitat availability does not vary greatly during the warmer parts of the year, thus providing biota with relatively constant area available for colonization.

Woody debris

The abundance and size distribution of large woody debris (LWD, >5 cm mean diameter) in Capisic Brook reflects the availability of wood in the riparian zone. In Evergreen Cemetery above the sampling location, the riparian zone consists of many trees. Trees also are present in the riparian zone above the Lucas Street bridge (starting at ~40 m in Fig. 15), causing a relatively favorable abundance and size distribution of woody debris in this stretch of the stream. Immediately above the downstream station (from 0 to ~35 m in Fig. 15), however, the riparian zone is essentially bare of trees or other woody plants, with cattails as well as grasses and other annuals accounting for the large majority of vegetation. The absence of trees and hence woody debris significantly reduces the habitat quality for aquatic organisms in this stretch of Capisic Brook in terms of habitat diversity and food supply.

Absolute mass of LWD (diameter * length) was similar at both stations, but relative mass was lower at the downstream station. Relative mass takes into account the percent of the channel LWD spans, so that a trunk lying across the entire channel (i.e., spanning 100 %) would have the same absolute and relative mass (i.e., absolute mass * 1) while a trunk lying almost parallel to the flow would have much lower relative than absolute mass (e.g., absolute mass * 0.2). The comparison between these two measures, or the average percent spanning the channel at each station (51 and 23 % at the upstream and downstream stations, respectively), can give an indication of flow patterns as a high maximum flow velocity tends to align LWD with the flow, thus reducing the percent spanning value. Data then suggest that maximum flows are much greater at the downstream station, a conclusion that is supported by personal observations following rain events when much of the herbaceous riparian vegetation was “flattened” by high flows at the downstream station (Fig. 22) while no such observations

Fig. 22. “Flattened” vegetation at downstream station (May 2004)

were made at the upstream station[1]. A visit to both stations following a large storm event (3.3” of rain in 24 h, ending shortly before visit) showed very high flows at the downstream station but only somewhat increased flow at the upstream station (App. G, Figs. 10 - 11). Another factor influencing the percent spanning value is bankfull width as LWD is more likely to get snagged in a narrower channel, leading to a higher percentage. As the channel at the upstream station is much narrower than at the downstream station (2.0 *versus* 4.0 m bankfull width; Field 2003, Table 2, reaches 5 and 2, respectively), the percent spanning value would be expected to be higher upstream even if maximum flow velocity was not lower.

A comparison between LWD found in Capisic Brook and in two reference streams exemplifies the situation in Capisic Brook. For LWD >5 cm diameter, data collected in a reference stream northwest of Bangor showed that LWD abundance was greater in the reference stream than at the upstream or downstream station on Capisic Brook (42 *versus* 34 *versus* 25 pieces) but that average mean diameter was similar (12 cm *versus* 9 cm *versus* 12 cm). The mean percent spanning value was highest at the upstream station in Capisic Brook (51 %), intermediate in the reference stream (41 %), and lowest at the downstream station in Capisic Brook (23 %). This shows that the upstream station on Capisic Brook has a more natural LWD composition than the downstream station, a finding that is in line with the difference in the riparian buffer between these two stations. For LWD >20 cm diameter, the geomorphological survey noted an LWD abundance in Capisic Brook overall of 0 pieces per 100 feet of channel in 41 % of the stream, 1 - 2 pieces in 59 %, and >3 pieces in 0 % of the stream (Field 2003, Table 4). The corresponding percentages in a reference stream in Cape Elizabeth (adjacent to South Portland) were 18 %, 66 %, and 16 %, indicating that large LWD in Capisic Brook is much less abundant than in a natural setting.

Woody debris enhances the habitat quality for aquatic organisms by providing stable attachment sites, providing and trapping organic materials to be used as food sources, trapping sediments, increasing habitat diversity, and being a food source in and of itself (Dolloff 1994). Trees in the riparian zone, before they become woody debris, also provide leaf litter, which is an important food source for a variety of macroinvertebrates. Because of the many advantages of a wooded riparian zone, it is advisable to plant trees along Capisic Brook below the Lucas Street bridge, both to increase woody debris and food supply, and to provide more shading for the stream.

Qualitative stream/wetland and habitat assessments

Few problems were observed at the upstream stations in terms of the physical character (Table 8) or the habitat quality (Table 9). The only physical problem encountered was modest bank erosion occurring in some places, largely at bends in the stream. Minor erosion problems are probably normal at this station as the sandy substrate and soil in the area

---

[1] Although the picture shows dead, “flattened” vegetation, live cattails similarly flattened were observed on a number of visits in the summer of 2003.

erode easily. In terms of habitat quality, the uniformly sandy substrate caused an intermediate score in the epifaunal substrate/available cover category, but again this represents the natural condition. Pool variability was very low which is not surprising given the small size of the stream in Evergreen Cemetery.

More problems in terms of the physical character were encountered at the downstream station, where urban development dominated the landuse types and obvious sources of NPS pollution were seen (Table 8). Only moderate erosion was observed which is likely due to a variety of reasons: very dense stands of cattails and grasses along the stream bank hold soil in place; the channel in this section is fairly straight, allowing water to simply rush through the stream; and the banks are low and sloping gently, allowing easy access to the floodplain. The habitat assessment (Table 9) revealed problems that are directly or indirectly a result of the channelized nature of this section of the stream (low channel sinuosity, low pool variability, reduced bank stability, sedimentation problems) as well as an impacted riparian buffer. The restoration suggestion made by the geomorphologist (see next section) would help remove or at least alleviate most of those problems.

The assessment of human disturbances to the wetland (Previous Studies, MDEP Biological Monitoring Program, and Table 10) also found evidence for the impacts of urbanization, for example a significant potential for NPS pollution, effects of impervious surfaces in the watershed, and human modifications to the wetland. Overall, these assessments showed that the lower half of the Capisic Brook watershed shows evidence of impacts of development on stream and wetland condition.

Several of the areas of concern revealed in these assessments are known to negatively influence aquatic biota, either directly or indirectly. For example:

- High impervious surface cover in a watershed causes an alteration in stream hydrology, an increase in pollutant concentration, a decrease in rainwater infiltration and direct impacts on the stream channel. These factors can lead to a reduction in habitat quality and stability, in water quality, and in baseflow volume.
- Channel alterations (i.e., straightening) reduce sinuosity of the stream, thus eliminating habitat diversity.
- Clearing of vegetation along the banks and in the riparian zone reduces bank stability, decreases filtration efficiency of the soil, and eliminates shading of the stream. These factors can cause increased sedimentation, decreased habitat stability, increased pollutant input, and elevated water temperatures.

Some of the problems identified could be remedied, for example by increasing sinuosity in previously straightened section of the stream (see next section) and by replanting the riparian buffer where lawns or areas with grasses/annuals currently abut the stream. Other problems, however, such as the high percentage of impervious surfaces, will be difficult to address, especially around Capisic Brook where many impervious surfaces are rooftops or small local roads as opposed to large parking lots or highways (where stormwater treatment systems could be installed). Suggestions for a reduction in impervious surfaces are made in Conclusions and Recommendations, Goal: Reduction in sedimentation, Reduce effects of high percentage of impervious surfaces, below. As a first measure, the already planned or easily achieved improvements listed above should be made, before installation of expensive stormwater treatment facilities is considered. However, when detention facilities are installed in preparation for CSO separation, options providing an improvement in hydrology should be considered.

Geomorphological survey

Historical analyses of changes in watershed landuse and channel morphology as well as extensive field work showed that in spite of 76 % of the watershed being built-up (see Results, Habitat Assessments, item 5, above), stream geomorphology has not suffered severely from human intervention. Only small stretches have been channelized[1], few areas are deeply entrenched, most of the stream is stable, and more than half the stream has a riparian buffer of >10 m (Table 11, Fig. 18). The problems that were documented tended to occur in the lower part of the watershed. In contrast to stream morphology, stream habitat was more impacted as shown in the Rapid Habitat Assessment. This assessment indicated that at both stations, stream habitat for biological communities is not ideal in terms of physical attributes such as epifaunal substrate and available cover, sediment deposition, bank stability, or bank vegetative protection. As discussed in the preceding section, the same assessment also was carried out on a smaller scale, just around each station, with better results for both stations. This difference could be attributable to the different extent assessed each time but is probably also related to the qualitative, somewhat subjective nature of this assessment. Overall, the assessments documented habitat problems which were more pronounced at the downstream station. This result in conjunction with the other data for the downstream station shows that the lower stretch of Capisic Brook does not favor healthy aquatic communities. At the upstream station, most other data collected indicated a relatively healthy system, suggesting that habitat problems at this station do not impair biological communities or water chemistry parameters.

A Rapid Geomorphic Assessment showed that most of Capisic Brook is near the high end of the Fair or the low end of the Good ranking (ranking scale is Poor, Fair, Good, Reference). This type of assessment is used to document current geomorphological adjustment processes occuring in a stream in response to various watershed, floodplain, and channel modifications by evaluating channel degradation (incision or downcutting, i.e., lowering of stream bed elevation through erosion or scour of bed material), channel aggradation (i.e., raising of stream bed elevation through accumulation of sediment), channel widening, and changes in planform (i.e., the channel shape as seen from above). This assessment documented active incision near the upstream biomonitoring station. While incision is often caused by increased flow volumes resulting, for example, from urbanization, this particular instance of incision seems unrelated to development and may instead be natural, albeit unexpected for this location (Field 2003). The assessment furthermore documented aggradation in Capisic Brook above the downstream biomonitoring station, i.e., between Lucas Street and Brighton Avenue. This suggests that when this section of the stream was channelized, the channel was constructed too large for the dominant flows, and that subsequently the stream has been trying to reestablish an equilibrium by reducing channel width through the accumulation of sediment (Field 2003). While at least part of the accumulating sediment may be naturally derived from the underlying geology (see below), it is likely that some sediment enters the streams from roads, parking lots, or construction sites.

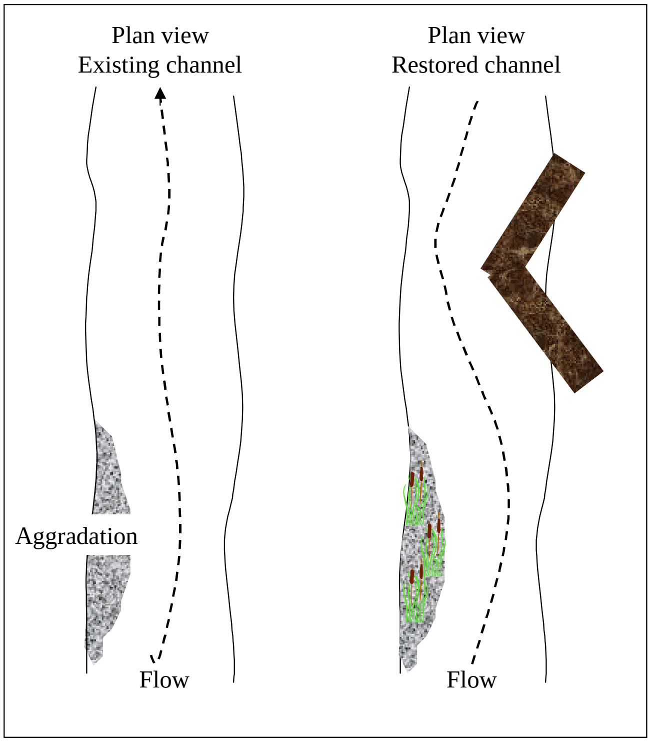
---

[1] See note in Results, Habitat Assessments, item 5, above.

The geomorphological report includes one cautionary note based on the analysis of the surficial geology of Capisic Brook (Field 2003). Like other streams in this region, Capisic Brook lies within the Presumpscot Formation where the stream substrate consists of sand, silt, and clay, and only very little coarser material. Because of this dominance of fine sediments, any increase in the dominant discharge due to additional runoff, be it from increased impervious surfaces or greater diversion of runoff into the stream, could cause the erosion of accumulated sediment above the downstream biomonitoring station. This would lead to a reversion of the documented aggradation (see previous paragraph), and the formation of a newly enlarged channel able to convey the increased discharge (Field 2003). Furthermore, an increase in the dominant discharge also may cause erosion in other parts of Capisic Brook that have adjusted to the current flow patterns. Depending on extent and location, erosion may endanger man-made structures such as bridges and buildings, and impair water quality for biological communities by increasing suspended sediment load and sediment deposition on the stream bed as well as disturbing benthic habitat.

The geomorphological report concludes with a suggestion for restoring the lower section of Capisic Brook, where channelization and aggradation were documented, to a more natural morphology, i.e., a narrower, more sinuous stream channel with a varied flow regime. This could be achieved by installing double wing deflectors in the stream, and vegetating the bars formed by accumulating sediment (see Fig. 23). Because this section of the stream was channelized many years ago (in the 1950s, B. Roland, pers. comm.), the stream has had time to adjust to the alteration, and it is now approaching a new equilibrium condition. As a result, little future change should be expected, and a restoration project should be successful if no significant changes in the dominant peak discharge occur (Field 2003). Because of the highly complex nature of fluvial geomorphology, any restoration activity will require the extensive involvement of a trained professional.

Fig. 23. Restoration design for downstream station on Capisic Brook (schematic representation, modified from Field 2003, Fig. 9a)



The report submitted by DeLuca-Hofman Associates, Inc. to the City of Portland (see Previous Studies; DeLuca-Hofman Associates 1999) recommends certain engineering activities that would result in channel modifications which are counter to the recommendations made by the fluvial geomorphologist (Field 2003). For example, DeLuca Hoffman recommends straightening of the channel while Field recommends re-establishing sinuosity and a more natural channel. The city would be well advised to seek the guidance of a fluvial geomorphologist to ensure that any planned channel modifications do not result in a patchwork of band-aids without regard for the natural, physical progression of channel evolution. Such guidance would likely result in a more successful, cost-efficient, and long-term resolution of the flooding problems affecting the lower part of the Capisic Brook watershed.

Spills and CSOs

An analysis of spill points documented by the MDEP's Bureau of Remediation and Waste Management showed that several spills have occurred in the Capisic Brook watershed (App. E). Because of a lack of detail in spill records, it was not possible to determine whether certain spills shown in App. E affected the stream. Two spills are known to have reached the stream via storm drains discharging into Capisic Brook (20 gallons diesel, of which 5 gallons were recovered, in 1999; 15 gallons diesel, most of which was recovered, in 2002). Also, low level effects of contaminated runoff into Capisic Brook cannot be excluded. The extensive residential development throughout the watershed also suggests that undocumented spills of substances used in private households (e.g., automobile oil, paint or paint thinners, cleaning agents) may occur in the watershed and may impact water quality in Capisic Brook. Indeed, a stream walk in June 2003 revealed the remains of hazardous materials in or near the stream (e.g., paint cans, radios, tires; pers. obs.). Overall, spills may have impacted stream quality and the health of resident biota. Further (indirect) evidence for a possible effect of spills on water quality in Capisic Brook is that spill records included several instances where contaminated soil was found during construction or tank removal activities, suggesting the potential for groundwater pollution. To reduce the future occurrence of spills in the watershed, outreach efforts targeting private households as well as businesses should be undertaken to inform the public of the negative effects spills of any amount and product may have on stream quality. Such public outreach efforts should be accompanied by suggestions for improvements to current practices of delivering, handling, and storing fuel oil or other hazardous products. Also, storm drain stenciling has proven useful in alerting the public to the fact that any substance reaching a drain will go into a nearby waterbody where it may cause harm.

While it is not possible to link the observed impairment in the macroinvertebrate community at the downstream station directly to an influx of combined stormwater and raw sewage (Table 12), it seems likely that a connection exists. Two studies that documented organic pollution (i.e., enrichment) in streams due to CSO influx also found evidence for DO depletion (Sztruhar et al. 1997), and an alteration in benthic community structure (Rochfort et al. 2000). Indications that enrichment effects are occurring in Capisic Brook were seen in the elevated nutrient levels, excess algal growth (see Fig. 20) and large diurnal DO swings as well as in the macroinvertebrate community (App. D i). One study on CSO discharges failed to establish toxic effects on benthic communities (Rochfort et al. 2000) and it is unknown whether this is a problem in Capisic Brook. It must be noted that the two CSOs above the downstream station are 2.2 km away so that any possible effect is mitigated by distance. To eliminate any impacts of raw sewage, CSOs must be eliminated and the City of Portland is in the planning stages for CSO separation (B. Roland, pers. comm.). As previously mentioned, the city should continue consultations with MDEP to ensure that this work does not result in an increase in nutrient and metal pollution or peak flows.

STRESSOR IDENTIFICATION PROCESS

On May 17, 2004, the EPA Stressor Identification (SI) process was applied as described in Ch. 2. The extensive review of available data and discussion among the biologists and engineers present led to the identification of the stressors and their sources as listed below for the downstream station on Capisic Brook. Although the stressors are ranked in their importance, all stressors are linked to a certain extent and their effects connected, making it difficult to apply a ranking scale. Consequently, all stressors identified may need to be addressed if the macroinvertebrate community is to recover. Similarly, although the sources for each identified stressor are listed in order of (likely) decreasing importance, sources are often interrelated, or their importance may change over space or time or depending on certain conditions, so that a ranking scale is generally difficult to apply. Where one source is of overriding importance, it is denoted below as "primary source".

Degraded Instream Habitat

This stressor was ranked highest (high importance, even with altered hydrology) with a total of 5 "+" and 0 "-"[1] (App. D vi). The role of the habitat in impairing biological communities was indicated by a reduced habitat diversity (due to a combination of reduced sinuosity, low stream depth, and a slow and homogeneous flow regime during baseflow conditions), and by a reduction in large woody debris. As sources for the impaired instream habitat at the downstream station, the conceptual model (App. D iv) identified the following:

- *Likely sources:*
    - **Channelization** in this section of the stream: the reduced sinuosity and homogeneous flow regime caused by channelization as well as the overwidening of the channel and resulting low stream depth lead to reduced habitat diversity.
    - **Low gradient**: this can cause a low thalweg velocity and homogeneous flow regime.
    - **Decreased riparian tree cover**: this reduces the input of LWD into the stream thus lowering habitat complexity.
    - **Increased stormflow volume**: high flows resulting from the extensive paved surfaces in the watershed can remove pieces of LWD from the stream channel thus reducing habitat complexity.

Altered Hydrology

This stressor was ranked highest (high importance, even with degraded instream habitat) with a total of 5 "+" and 0 "-" (App. D vi). Both low baseflow and high peak flows were identified as potential problems. The role of altered hydrology in impairing biological communities was indicated by reduced channel and habitat diversity, observations indicating high peak flows, a potential reduction in baseflow, a slow and homogeneous flow regime, and by signals from the macroinvertebrate community (App. D i). As sources for the altered hydrology, the conceptual model (App. D iv) identified the following:

---

[1] "+"indicates evidence that a stressor affects macroinvertebrate community.
"-"indicates evidence that a stressor does not affect macroinvertebrate community.

- *Likely sources:*
    - **High percentage of impervious surfaces**: the watershed has ~23 % impervious surfaces. Imperviousness causes changes in hydrology by increasing runoff volume, increasing peak discharge and flashiness (i.e. rise-to-peak-rate), increasing the frequency and duration of bankfull flows, and decreasing baseflow by reducing groundwater infiltration (CWS 2003).
    - **Channelization**: this reduces channel diversity, thus promoting a uniform flow regime.
    - **Low gradient**: this causes a reduced thalweg velocity and generally slow flow regime.

- *Possible sources:*
    - **Stormwater outfalls**: these can increase erosion and scour problems leading to a reduced channel diversity and homogeneous flow regime. In extreme cases, high flow from outfalls can cause the removal of organisms. Outfalls are located above Brighton Avenue and near Sunset Lane (on western branch). It is currently not known whether erosion problems are evident at those locations.

Toxicants

This stressor was ranked second highest (medium importance, even with elevated nutrient levels), with a total of 3 "+" and 0 "-" (App. D vi). The role of toxicants in impairing biological communities was indicated by elevated concentrations of certain metals and chloride (in summer), high conductivity, and by signals from the macroinvertebrate community (App. D i). As sources for the toxicants (metals, ions), the conceptual model (App. D iv) identified the following:

- *Likely sources:*
    - **Sewage input from two CSOs** below Evergreen Cemetery, ~2.2 km above downstream station: sewage containing household waste and a limited amount of business/industrial waste can contain toxic compounds.
    - **Winter road sand/road dirt**: road sand accumulations can be washed into the stream during storms, and deliver salt particles (including chloride) as well as other toxic compounds. The City sweeps road sand in the spring and also in summer and fall, but it is not known whether businesses in the lower part of the watershed do the same. Some of these businesses have large parking areas and sand/dirt from those areas can reach the stream and contribute significantly to the toxicant load.
    - **Runoff from local roads and parking lots**: the lower half of the watershed has a dense system of roads and residences, most with paved parking areas, as well as a number of businesses with parking lots. Much of the runoff from those impervious areas enters Capisic Brook either directly or through storm drains. As mentioned above (Discussion, Water Quality Monitoring, Metals) several studies have found elevated toxicant levels, especially metals and chloride, in urban stormwater runoff.

- *Possible sources:*
    - **Dumping**: instances of illegal dumping of materials were noted in a stream survey in June 2003 (done as part of the geomorphological survey) and on other occasions, and included empty oil and paint containers, yard waste, old bicycles and radios, tires, and other refuse discarded in or near the stream.
    - **Natural sources**, i.e., soils: iron and aluminum are very abundant in soils and, depending on the acidity of the environment, can be easily leached out and transported into streams. Cadmium, copper, lead, and zinc are far less abundant naturally, but can occur in high concentrations in some locations.
    - **Atmospheric deposition**: toxicants originating from fossil fuel combustion by vehicles, industry, or power plants can be transported over large distances by air currents, and be deposited directly in a waterbody or on a pervious or impervious surface, from where they can be washed into a stream. In terms of wind patterns, Maine is downstream of many major industries in the central and eastern parts of the country, and depositions of, for example, PAHs and mercury in the state have been attributed to atmospheric deposition (see www.maine.gov/dep/air/ monitoring/Atmosdepos.htm; 2/4/2005). Overall, however, the magnitude of this source of toxicants for Capisic Brook is unknown.
    - **Documented spills**: several spills have occurred in the watershed over the last ~25 years (see Discussion, Water Quality Monitoring, Spills, above), and some of these spills may have affected Capisic Brook. The effect of spills on the groundwater feeding Capisic Brook is unknown.
    - **Sewer or septic leaks**: the city sewer system runs along most of Capisic Brook (including western and northern branch but excluding the mainstem within Evergreen Cemetery) and crosses it in several places. A recent infiltration study showed problems in a number of areas and the city has carried out the necessary repairs (B. Roland, pers. comm.). Several homes, predominantly near the edges of the watershed, have septic systems. The city receives notification of septic leaks once or twice per year and always follows up on those problems (B. Roland, pers. comm.) Overall, the potential for sewer and septic leaks seems minimal.

<u>Elevated Nutrient Levels</u>

This stressor was ranked second highest (medium importance, even with toxicants), with a total of 3 "+" and 0 "-" (App. D vi). The role of nutrients in impairing biological communities was indicated by exceedances of EPA-recommended nutrient criteria, excessive algal growth causing DO depletion, and by signals from the macroinvertebrate community (App. D i). As sources for the nutrients (nitrogen, phosphorus), the conceptual model (App. D iv) identified the following:

- *Likely source:*
    - **Sewage discharge from two CSOs** below Evergreen cemetery, ~2.2 km above downstream station (<u>primary source</u>): this is likely a major source of high nitrogen and phosphorus loads in the stream, especially given the frequency of discharge events (see Table 12).

- *Possible sources:*
    - **Runoff from local roads and parking lots**: the lower half of the watershed has a dense system of roads and residences, most with paved parking areas, as well as a number of facilities with parking lots. Studies have shown that runoff from such impervious surfaces can be high in nutrients (CWP 2003).
    - **Lawn/landscaping runoff**: the high density of residential and commercial development in the watershed suggests that at least some fertilizers are used on lawns or other landscaped areas. Storm runoff from these areas would carry nutrients, mostly nitrogen and phosphates, into the stream.
    - **Animal waste from pets and wildlife**: this contributes significant amounts of nitrogen and phosphates to a stream. A path running along Capisic Brook between Lucas Street and Capisic Pond is used by locals to walk their dogs, suggesting a high potential for contamination with nutrients (and bacteria).
    - **Reduced riparian buffer**: in the absence of a densely vegetated area separating a fertilized green space or an impervious surface from the water's edge, runoff of nutrient-laden water from those areas will enter the stream directly.
    - **Sewer or septic system leaks**: this source can add high concentrations of nitrogen and phosphorus to a stream. Overall, the potential for sewer and septic leaks seems minimal (see Toxicants, Sewer or septic leaks, above).
    - **Atmospheric deposition**: the National Water-Quality Assessment (NAWQA) program of the US Geological Survey (USGS 1996) and other studies have found that background nitrate concentrations in streams are higher in the Northeast than in other parts of the country. These elevated levels were attributed to nitrogen in rainfall, i.e., "acid rain". It is not known how important the contribution of acid rain is to the nutrient load in Capisic Brook.

Elevated Water Temperature

This stressor was ranked third (medium importance), with a total of 3 "+" and 1 "-" (App. D vi). The role of an elevated temperature in impairing biological communities was indicated by high summer, daytime temperatures and signals from the macroinvertebrate community (App. D i). As sources for the elevated temperature, the conceptual model (App. D iv) identified the following:

- *Likely sources:*
    - **Impervious surfaces**: parking lots, roofs, roads, etc. are exposed to direct sunlight and thus heat up. This heat is transferred to rainwater running off the impervious surfaces and into a stream. This effect is particularly pronounced in the summer, when the sun is strongest and air temperatures are warm. This is also the time when aquatic communities are already stressed due to low flow conditions and naturally elevated water temperatures, making the effect of heated run-off even more deleterious.
    - **Locally reduced riparian shading**: removal of the riparian buffer exposes the water surface to more direct sunlight, leading to an increase in water temperature.

Low Dissolved Oxygen

This stressor was ranked fourth (medium to low importance), with a total of 2 “+” and 1 “-“ (App. D vi). The role of low DO in impairing biological communities was indicated by measurements of low DO concentrations, excessive algal growth, and by signals from the macroinvertebrate community (App. D i). As sources for the depressed DO concentrations, the conceptual model (App. D iv) identified the following:

- *Likely sources:*
  - **Sewage input from two CSOs** below Evergreen cemetery, ~2.2 km above downstream station (primary source): sewage containing nutrients can lead to excess algal growth and elevated BOD, which can cause a decrease in DO levels due to algal respiration and decomposition.
  - **Nutrients**: high nitrogen and phosphorus levels promote algal growth which can lead to a depletion in DO concentrations due to algal respiration and decomposition.
  - **Reduced riparian shading**: this increases exposure of the stream to the sun and contributes to a decrease in DO in two ways: 1) directly, by increasing water temperature, which reduces the capacity of water to hold dissolved oxygen; and 2) indirectly, by promoting algal growth, which can lead to a depletion in DO concentrations due to algal respiration and decomposition.

- *Possible sources:*
  - **Low channel gradient and channel modifications**: these can reduce the number of riffles in a stream thus reducing the potential for re-aeration.
  - **Reduced riparian shading**: this suggests that the amount of LWD in the stream is reduced, and thus also the occurrence of turbulent areas.

One factor that was deemed to be of minimal importance in Capisic Brook, and that was thus eliminated from further consideration, was increased sedimentation.

CONCLUSIONS AND RECOMMENDATIONS

Study results show that the macroinvertebrate community at the upstream station in Capisic Brook is in surprisingly good condition, far exceeding the aquatic life criteria of its assigned water quality class. Furthermore, water quality and most habitat indicators also indicate a relatively healthy system. In order to maintain this situation, it is important that runoff entering the stream from impervious surfaces upstream of this sampling station is kept to a minimum, and that a large riparian zone with an intact forest is preserved.

At the downstream station in Capisic Brook, biological communities (macroinvertebrates and fish) were indicative of poor water and/or habitat quality. Although macroinvertebrate diversity was intermediate, fish diversity was very low, and the majority of the species found are known to be tolerant to water pollution. An analysis of general water quality indicators (dissolved oxygen, conductivity, temperature) and chemical parameters (nutrients, bacteria, metals) revealed that the lower section of Capisic Brook shows many of the effects typically encountered in urban areas, such as depressed dissolved oxygen concentrations in summer, elevated water temperature, high conductivity, and elevated nutrient and toxicant levels. Habitat assessments also showed evidence of typical urban stressors, such as an altered stream morphology and hydrology, and reduced width of the riparian buffer. The data summarized in this report formed the basis for the SI process (see previous section), which resulted in a ranking of stressors and identification of sources according to their likely importance for causing impairments. A degraded instream habitat and altered hydrology were ranked as the most significant stressors, followed by toxicants, elevated nutrient levels, elevated water temperature, low DO concentration and increased sedimentation. The stressors and their sources as identified during the SI process were used to develop recommendations for Best Management Practices (BMPs) and remedial actions aimed at removing or alleviating the stressors. Bacteria were not considered as a stressor during the SI process but have the potential to compromise the use of a stream for contact recreation; therefore, BMPs for reducing bacteria levels are presented below also.

Capisic Brook is included in Maine’s 305 (b) list of impaired waters for non-attainment of the aquatic life criteria that were set for Class C streams (MDEP 2002d, 2004b). As a result, the Maine Department of Environmental Protection is required to develop a TMDL (Total Maximum Daily Load) plan for the impaired section of the stream (namely the section from Capisic Pond upstream to the wastewater outfalls below Evergreen Cemetery; see Fig. 1) aimed at restoring aquatic communities to Class C standards. The BMPs and remedial actions listed below will form the basis for the TMDL plan to be developed in 2005. Other data not yet available, i.e., algal taxonomy, additional water chemistry data and flow data, also will be utilized in TMDL development. While concentrating on the significant stressors, the TMDL will take into consideration all stressors because physical, chemical, and morphological features of a stream are linked and interact to affect biological communities.

The list of BMPs and remedial actions provided below is categorized by stressor and source, and provides suggestions as to which broad category of party (or parties) may be responsible for implementing BMPs (i.e., City of Portland, industry/businesses, public, or all). Because many factors must be considered when choosing specific structural BMPs (e.g., target pollutants, watershed size, soil type, cost, runoff amount, space considerations, depth of water table, traffic patterns, etc.), the list below only suggests a variety of BMPs without proposing particular types for particular situations. For detailed information on structural BMPs, their individual effectiveness, and required planning considerations see publications by the MDEP (1995, 2003a) and the City of Nashua (2003). A summary of stressors, goals, and relevant BMPs and remedial actions as presented below and in Ch. 3 - 5 can be found in App. I.

Goal: Improvement in Instream Habitat Quality

During the SI process, instream habitat quality was identified as the most important stressor with channelization, a low gradient, decreased riparian tree cover, and increased stormflow volume as likely sources. An improvement in this parameter would likely aid the recovery of the macroinvertebrate community. The following list provides BMPs and remedial actions aimed at improving instream habitat.

BMPs and remedial actions

1. **Improve channel morphology**: the channelization that occurred at and upstream of the station resulted in a straightened and in parts overwidened channel, leading to a reduced channel diversity, low water depth, and sedimentation problems. All of these effects cause a reduced habitat diversity and quality, which negatively influence biological communities. To improve channel morphology, the restoration suggestion included in Discussion, Geomorphological survey, above (Fig. 22), should be implemented with the help of a qualified professional such as a fluvial geomorphologist. Such restoration would markedly improve habitat quality by re-establishing channel sinuosity and the habitats associated with it, increasing water depth (and thus vertical relief), and reducing sedimentation problems. (City)

2. **Low gradient**: this is a natural situation and cannot be remedied.

3. **Improve riparian tree cover**: trees in the riparian zone provide large woody debris (LWD) which helps to create a diversity of habitats. The riparian buffer around the downstream station should be replanted with native trees which, over time, will form LWD. As a rule of thumb, a riparian buffer should have a minimum width of 15 m (50 feet; CRJC, 2000). Also, attempts to clear fallen trees out of the stream channel should be discouraged. (City, public)

4. **Reduce stormflow volume**: the straightened and in parts overwidened channel causes a significant loss of LWD, and likely some scouring of the substrate during high flows. The improvement in channel morphology recommended above should ameliorate those problems as would a reduction in stormflow volume. The following BMPs/remedial actions are aimed at reducing the percentage of impervious surfaces and/or alleviating negative effects such as high stormflows:
    a) Replacement of asphalt with pervious cover (e.g., porous pavement blocks, grass/gravel pave) or replacement of conventional roofs with green roofs directly reduces the percentage of impervious surfaces. In some cases there may also be the potential for replacing impervious cover with bioretention structures (bio-islands/cells). The city could also promote shared parking areas between homes or between facilities that require parking at different times (e.g., business and church), and reconsider its minimum parking requirements for businesses. (All)
    b) Channeling of runoff through a type of treatment system that promotes infiltration and/or allows temporary runoff detention reduces runoff quantity, and controls peak discharge rate. There are several choices for such systems:
    - vegetative BMPs (e.g., vegetated buffers or swales);
    - infiltration BMPs (e.g., dry wells, infiltration trenches/beds/basins, driveway drainage strips, bio-islands/cells, decorative planters), which may need to be equipped with pre-treatment BMPs to filter out toxicants; and
    - detention BMPs (e.g., dry/wet ponds, extended detention ponds, created wetlands).

    For more information on these BMPs and their effectiveness and planning considerations see MDEP 1995 and City of Nashua 2003. (All)

Goal: Restoration of Natural Hydrology

During the SI process, altered hydrology (low baseflow and high peak flow) was identified as the most important stressor with high percentage of impervious surfaces, channelization, and a low gradient as likely sources, and stormwater outfalls as a possible source. An improvement in hydrology would likely aid the recovery of the macroinvertebrate community. The following list provides BMPs and remedial actions aimed at restoring a natural hydrology .

BMPs and remedial actions

1. **Reduce percentage of impervious surfaces**: high imperviousness alters stream hydrology by increasing runoff volume and peak discharge rate, increasing the frequency and duration of bankfull flows, and decreasing baseflow (by reducing groundwater infiltration). Various BMPs that can aid in reducing peak flow volume are listed above in “Goal: Improvement in Instream Habitat Quality”, item 4. Measures listed in that section are also effective for improving baseflow levels as they promote the recharge of groundwater reservoirs with precipitation. (All)

2. **Improve channel morphology**: a straightened (and widened) stream channel tends to have a uniform, generally slow flow regime that does not promote diversity in biological communities. To improve channel morphology, the restoration suggestion included in Discussion, Geomorphological survey, above (Fig. 22), should be implemented with the help of a qualified professional. Such restoration would help diversify the flow regime by re-establishing channel sinuosity and the associated variability in flow patterns and water depth. (City)

3. **Low gradient**: this is a natural situation and cannot be remedied.

4. **Reduce effects of stormwater outfalls**: the highly localized force of water coming out of a stormwater outfall creates high shear forces that can cause localized erosion problems, and even the removal of organisms. If the removal of outfalls is not practical, the installation of BMPs suggested above in “Goal: Improvement in Instream Habitat Quality”, item 4, is recommended to reduce the amount of stormwater discharged through outfalls. To reduce the effect of an outfall on a stream, it should be located in an area that can withstand high erosive forces (e.g., inside a culvert), and should be designed so as to minimize the shear force (e.g., not pointed straight at a stream bank but more or less parallel to stream flow). (City)

Goal: Reduction in Toxicants

During the SI process, toxicants were identified as a major stressor with runoff from impervious surfaces, winter road sand/road dirt, and sewage discharge from CSOs as likely sources, and dumping, natural sources, atmospheric deposition, documented spills, and septic leaks as possible sources. A reduction in toxicant load would likely aid the recovery of the macroinvertebrate community. The following list provides BMPs and remedial actions aimed at reducing toxicant load.

BMPs and remedial actions

1. **Eliminate sewage input from CSO**: the city is in the planning stages for CSO separation, and should continue to work on this issue. To ensure that separation work leads to a reduction in toxicant load, the City should continue to consult with MDEP concerning remedial actions. (City)

2. **Reduce input of winter road sand and road dirt**: many toxicants are adsorbed onto sediment particles, and enter a stream in storm runoff. A reduction in metal load by way of loose sediment could be achieved by sweeping winter road sand and road dirt. The City has a road sweeping program in place and should continue it, with special attention given to post-winter clean-up (to remove chloride). If possible, sweeper types that employ a vacuum or regenerative air system should be used for cleaning as these maximize pick-up of fines (which hold the greatest toxicant load). Businesses that do not already sweep their premises are strongly encouraged to initiate this practice. Similarly, private homes with paved driveways/parking areas also should sweep sand and dirt on a regular basis. To capture any loose sediment and attached metals that is not removed by sweeping, runoff should be guided to a treatment system. Most of the systems listed above in "Goal: Improvement in Instream Habitat Quality", item 4 b, can remove sediment by either filtration or detention (which allows suspended sediment to settle out). Additional options suitable for sediment removal are filter and separator BMPs (e.g., oil/grit and oil/water separators, flow splitters, Vortechnics^{TM}-type systems, water quality inlets, sand filters, leaf compost filters). (All)

3. **Reduce storm runoff from impervious surfaces**: during rain and storm events, the stream receives a large amount of runoff either directly or via the storm drain system. This runoff can carry metals that are toxic to aquatic life. Implementation of the BMPs/remedial actions listed above in "Goal: Improvement in Instream Habitat Quality", item 4, will help to reduce stormflow volume and hence metal input into the stream. Additionally, filter and separator BMPs (e.g., oil/grit and oil/water separators, flow splitters, Vortechnics^{TM}-type systems) should be considered as a further alternative for stormwater treatment systems. (All)

4. **Reduce the incidence of spills** (both accidental and deliberate, i.e., dumping): a number of documented spills of hazardous substances have occurred in the watershed (App. E), and incidences of dumping were observed during a watershed survey. A reduction in spill frequency would likely have a beneficial effect on water quality and biological communities. Outreach efforts are useful for educating the public and businesses about safe ways for handling hazardous substances (e.g., paint and paint thinner, motor oil, gasoline, chemicals, pesticides), and proper ways for disposal. Storm drain stenciling has been shown to be useful in informing the public that any substance reaching a drain will go into a nearby waterbody where it may cause harm. The city might also consider increasing the frequency of their hazardous waste collections. Information material listing non-hazardous alternatives to hazardous substances could also help reduce the number of spills. Finally, where it has not already been done, industry and businesses should seal up floor drains or connect them

to the sewer system, as appropriate. (All, MDEP)

5. **Natural sources**: iron and aluminum are abundant in soils, and can easily leach out and enter a waterbody. This is a natural phenomenon and cannot be remedied. To minimize the negative impacts of natural toxicants, water quality and habitat parameters must favor healthy biological communities rather than provide additional stressors. Addressing the stressors identified in the SI process will help to provide such conditions.

6. **Atmospheric deposition**: the pollution potential from this source is difficult to assess and even more difficult to remove. Almost by definition, this type of pollution originates from very diffuse and potentially far-away and wide-spread sources and cannot be addressed by any action the City of Portland, local businesses, or residents can take. National action is required to deal with this issue. On a local scale, however, a reduction in sources of air pollution (e.g., motor vehicles, power plants, home heating systems, any type of fume) can improve local air quality and contribute to a decrease in atmospheric deposition. (All)

7. **Eliminate the potential for sewer/septic system leaks**: to ensure that all components of sewer system are in good working order, portions that have not recently been surveyed should be inspected, and repairs or required replacements made as allowed by budgetary constraints. For septic systems, regular maintenance and inspection are critical to ensure proper functioning. Only few homes in the watershed have septic systems, and the pollution potential from this source is deemed to be small. Home owners can ensure that they do not contribute to the toxicant load in the stream by keeping toxic substances out of the sewer/septic system. (City, public)

Goal: Reduction in Nutrient Levels

In the SI process, elevated nutrient levels were identified as a major stressor with sewage discharge from CSOs as the likely (primary) source, and runoff from local roads and parking lots, lawn/landscaping runoff, animal waste, sewer or septic leaks, and atmospheric deposition as possible sources. A reduction in nutrient load would likely aid the recovery of the macroinvertebrate community. The following list provides BMPs and remedial actions aimed at nutrient control.

BMPs and remedial actions

1. **Eliminate sewage input from CSO**: the city is in the planning stages for CSO separation and should continue to work on this issue. To ensure that separation work leads to a reduction in nutrient input, the City should continue to consult with MDEP concerning remedial actions. (City)

2. **Minimize impervious surface runoff**: runoff from roads and parking lots can contribute high levels of nutrients to a stream. BMPs listed above in “Goal: Improvement in Instream Habitat Quality”, item 4, will help to minimize the amount of nutrient-containing runoff that reaches the stream. (All)

3. **Minimize lawn/landscaping runoff**: fertilizers applied to landscaped areas, lawns or gardens can be washed into the stream during storms. Reduction or elimination of fertilizer use is an important step in reducing the nutrient load in a waterbody. Soil tests can be a useful way to determine actual nutrient requirements. (All)

4. **Maintain/replant riparian buffer**: a densely vegetated area separating a fertilized green space or an impervious surface from the water's edge will reduce runoff of nutrient-laden water into the stream. As a rule of thumb, a riparian buffer should have a minimum width of 15 m (50 feet; CRJC, 2000), though a width of ~23 m (75 feet) or greater provides better treatment. Shading of the stream will also minimize the risk that elevated nutrient loads can lead to excess algal growth and a depletion in DO. (All)

5. **Implement items listed under "Goal: Reduction in bacteria levels"**, below: discharges from a CSO, faulty sewer or septic systems, and pet waste as well as illicit discharges increase the nutrient load in a stream. (All)

6. **Atmospheric deposition**: studies have found that background nitrate concentrations in streams are higher in the Northeast than in other parts of the country. Almost by definition, this type of pollution originates from very diffuse and potentially far-away and wide-spread sources and cannot be addressed by any action the City of Portland or local business or residents can take. National action is required to deal with this issue. On a local scale, however, a reduction in sources of air pollution (e.g., motor vehicles, power plants burning fossil fuels) can improve local air quality and contribute to a decrease in atmospheric deposition. (All)

Goal: Reduction in Water Temperature

During the SI process, elevated water temperature in the summer was identified as a stressor with a high percentage of impervious surfaces and locally reduced riparian shading as the likely sources. An improvement in this parameter would likely aid the recovery of the macroinvertebrate community. The following list provides BMPs and remedial actions aimed at lowering temperatures.

BMPs and remedial actions

1. **Reduce percentage of impervious surfaces**: the heat absorbed by impervious surfaces exposed to direct sun increases the temperature of rainwater running off those surfaces and into a stream, leading to an increase in water temperature. A number of BMPs/remedial actions aimed at reducing the percentage of impervious surfaces or alleviating negative effects (such as an increase in water temperature) are listed above in "Goal: Improvement in Instream Habitat Quality", item 4. (All)

2. **Increase riparian shading**: the absence of trees in the riparian zone around the downstream station leaves the stream surface open to solar radiation, leading to a direct increase in water temperature. Furthermore, the open riparian zone also heats up and transfers this heat to rainwater running into the stream from this zone, indirectly causing an increase in water temperature. To minimize the heating effect,

the riparian zone in that section of the stream should be replanted with native vegetation, including trees. As a rule of thumb, a riparian buffer should have a minimum width of 15 m (50 feet; CRJC, 2000). (City, public)

Goal: Improvement in Dissolved Oxygen Levels

During the SI process, low DO concentrations during some times in the summer were identified as a stressor with sewage input from CSOs, elevated nutrient levels, and reduced riparian shading as likely sources, and a low gradient as a possible source. An improvement in this parameter would likely aid the recovery of the macroinvertebrate community. The following list provides BMPs and remedial actions aimed at improving the DO concentration .

BMPs and remedial actions

1. **Eliminate sewage input from CSO**: the city is in the planning stages for CSO separation and should continue to work on this issue. To ensure that separation work leads to an improvement in DO concentrations through a reduction in nutrient input, the City should continue to consult with MDEP concerning remedial actions. (City)
2. **Reduce nutrient input**: see BMPs and remedial actions listed above in “Goal: Reduction in nutrient levels”. (All)

3. **Increase riparian shading**: the absence of trees in the riparian zone around the downstream station leads to an increase in water temperature, and a reduction in the DO carrying capacity of the water. Furthermore, the absence of a canopy cover promotes algal growth and large diurnal swings with low nighttime DO levels. Finally, the absence of trees in the riparian zone leads to a reduction in LWD input and the turbulent areas associated with it. To minimize these effects, the riparian zone in that section of the stream should be replanted with native vegetation, including trees. As a rule of thumb, a riparian buffer should have a minimum width of 15 m (50 feet; CRJC, 2000). (City, public)

4. **Low gradient**: this is a natural situation and cannot be remedied.

5. **Improve channel morphology**: channel modifications reduce the number of riffles providing re-aeration potential. Channel morphology can be improved by implementing the restoration suggestion included in Discussion, Geomorphological survey, above (Fig. 23), with the help of a qualified professional such as a fluvial geomorphologist. (City)

Goal: Reduction in Bacteria Levels

At this point, Capisic Brook is not listed for bacterial violations although *E. coli* concentrations (of unknown origin) exceeded Maine’s criterion for mean counts of bacterial colonies (of human origin) (Table 5). Bacteria are not in themselves a stressor for macroinvertebrates, and thus were not included in the SI process. However, the presence of *E. coli* in the water is cause for concern because it can indicate the presence of raw sewage in the stream. Raw sewage, which can originate from the public sewer system, faulty septic systems, or illicit discharges, has the potential to also carry disease-causing organisms (as well as metals and nutrients). Therefore, elevated levels of *E. coli* in the stream suggest that a waterbody may be impaired in several ways. The following list provides BMPs and remedial actions aimed at a reduction in bacteria load.

BMPs and remedial actions

1. **Eliminate sewage input from CSO**: raw sewage can be a major contributor of bacteria to a stream. The City must continue to work towards CSO separation to eliminate this source. (City - already initiated)

2. **Eliminate potential for sewer/septic system leaks**: to ensure that all components of sewer system are in good working order, portions that have not recently been surveyed should be inspected, and repairs or required replacements made as allowed by budgetary constraints. For septic systems, regular maintenance and inspection are critical to ensure proper functioning. (All)

3. **Eliminate illicit discharges**: entities/households with an illicit discharge must eliminate it through either stopping the discharge, or routing it into a septic system/the city sewer. The Center for Watershed Protection recently developed an extensive manual to help municipalities in the detection and elimination of illicit discharges (CWP 2004). (Industry/businesses, public)

4. **Minimize bacteria input from animals**: in many cases, *E. coli* do not originate from human sources but from warm-blooded animals, including pets, and eliminating this source would likely reduce bacteria levels. Keeping pets away from the stream and always picking up pet waste prevents waste from getting washed into the stream during a storm. Feeding of wildlife near the stream or on ponds connected to the stream is discouraged as animals (especially waterfowl) can contribute to the bacterial load in a waterbody. (Public)

5. **Be a steward of the stream**: alert city personnel if there is a sewage smell in the stream, or if signs of sewage discharge are obvious. Stream bank surveys by stream teams (see below) can reveal problems without requiring costly water analyses. (Public)

6. **Eliminate septic systems in watershed**: this could be achieved by connecting residences with septic systems to the city sewer. Because of the cost, this option should be used as a last resort. (City)

General Activities that Can Help Capisic Brook

1. **Invest in education and outreach efforts**: alert the public as well as industry and businesses to the role different stressors play in impairing biological communities and water quality in a stream. Encourage all concerned parties to implement BMPs and remedial actions listed here. (City, MDEP, Cumberland County Soil and Water Conservation District)

2. **Promote the formation of a Stream Team** for Capisic Brook. Owing to the impaired nature of the stream at this point in time, this initiative should be deferred to a later date. However, once stream quality has improved, citizens and/or businesses should be encouraged to become stewards of the stream. (MDEP)

3. **Encourage responsible development**: parts of the Capisic Brook watershed are not yet developed, and these wetland and forested areas have an important influence on the stream ecosystem. Future development should take into consideration the findings of this report, and be done so as to minimize the impact on the stream. Practices promoted under smart growth and low impact development (LID) guidelines should be implemented wherever possible. More information on such guidelines can be found at www.epa.gov/smartgrowth/ and www.epa.gov/owow/nps/lid/. The city should consider including such guidelines into the building code, or at least promoting their use when issuing construction permits (City, industry/businesses)

The list of BMPs and remedial actions given above provides guidance for the kinds of actions that could be taken to deal with the urban stressors the SI process identified for Capisic Brook. This list, or parts of it, will be incorporated into the TMDL plan to be developed by the Maine Department of Environmental Protection in 2005. More detailed recommendations that would be included in a restoration plan will require the input of experts from fields such as biology, geology, and engineering.

Restoring healthy aquatic communities in Capisic Brook will require collaboration among several parties (regulatory agencies, the City of Portland, industry and businesses, concerned citizens) as well as financial resources and time. The TMDL plan will likely estimate target loads for particular pollutants, and implementation of the plan should lead to an improvement in stream health over the next several years. Future biological and water quality monitoring is advisable to determine whether the TMDL plan achieved its goal of restoring aquatic communities to Class C standards, or whether additional actions are required.

REFERENCES

Beasley, G. & P. Kneale. 2002. Reviewing the Impact of Metals and PAHs on Macroinvertebrates in Urban Watercourses. Progr Phys Geogr 26: 236-270.

Beneski, B. 2000. Final Mini Site Inspection Report for Maine Central Railroad Rigby Yard, South Portland, Maine. Maine Department of Environmental Protection, Bureau of Remediation and Waste Management, Augusta, ME. 26 pp.

Bode, R.W. 1983. Larvae of North American *Eukiefferiella* and *Tvetenia* (Diptera: Chironomidae). New York State Museum, Bulletin No. 452. 40 pp.

Bode, R.W., M.A. Novak & L.E. Abele. 1996. Quality Assurance Work Plan for Biological Stream Monitoring in New York State. NYS Department of Environmental Conservation, Division of Water, Bureau of Monitoring and Assessment, Stream Biomonitoring Unit, Albany, NY. 89 pp.

Burian, S.K. & K.E. Gibbs. 1991. Mayflies of Maine: an Annotated Faunal List. Maine Agricultural Experiment Station, University of Maine, Technical Bulletin 142. 109 pp.

Burks, B.D. 1953. The Mayflies, or Ephemeroptera, of Illinois. Illinois Department of Registration and Education, Natural History Survey Division, Bulletin 26 (1): 1 - 216.

Cancilla, D.A., J.C. Baird, S.W. Geis & S.R. Corsi. 2003a. Studies of the Environmental Fate and Effect of Aircraft Deicing Fluids: Detection of 5-Methyl-1H-Benzotriazole in the Fathead Minnow (*Pimephales promelas*). Environ Toxicol Chem 22: 134 - 140.

Cancilla, D.A., J.C. Baird & R. Rosa. 2003b. Detection of Aircraft Deicing Additives in Groundwater and Soil Samples from Fairchild Air Force Base: A Small to Moderate User of Deicing Fluids. Bull Environ Contam Tox 70: 868 - 875.

Center for Watershed Protection (CWP). 2003. Impacts of Impervious Cover on Aquatic Systems. Watershed Protection Research Monograph No. 1. Center for Watershed Protection, Ellicott City, MD. 142 pp.

2004. Illicit Discharge Detection and Elimination: A Guidance Manual for Program Development and Technical Assessments. Center for Watershed Protection, Ellicott City, MD. 198 pp. www.cwp.org

City of Nashua, New Hampshire. 2003. Alternative Stormwater Management Methods. Part 2 – Designs and Specifications. City of Nashua, New Hampshire.

Coles, J.F., T.F. Cuffney, G. McMahon & K.M. Beaulieu. 2004. The Effects of Urbanization on the Biological, Physical, and Chemical Characteristics of Coastal New England Streams. USGS Professional Paper 1695. 47 pp.

Connecticut River Joint Commissions (CRJC). 2000. Introduction to Riparian Buffers for the Connecticut River Watershed. CRJC, Charlestown, NH. 4 pp. www.crjc.org/buffers/Introduction.pdf (2/9/2005)

Davies, S.P., L. Tsomides, J.L. DiFranco & D.L. Courtemanch. 1999. Biomonitoring Retrospective: Fifteen Year Summary for Maine Rivers and Streams. Maine Department of Environmental Protection, Augusta, ME; DEP LW1999-26. 190 pp.

Davies, S. P. and L. Tsomides. 2002. Methods for Biological Sampling and Analysis of Maine's Rivers and Streams. (3rd ed.). Maine Department of Environmental Protection, Augusta, ME; DEP LW0387-B2002. 31 pp.

DeLuca-Hoffman Associates, Inc. 1999. Capisic Brook Watershed Flood Control Study Re-evaluation. Final Draft.

Dolloff, C.A. 1994. Large Woody Debris – The Common Denominator for Integrated Environmental Management of Forest Streams. In: Implementing Integrated Environmental Management. Cairns, J. Jr., T.V. Crawford & H Salwasser (eds.). Virginia Polytechnic Institute and State University. University Center for Environmental and Hazardous Materials Studies, Blacksburg, VA. www.riparianbuffers.umd.edu/manuals/dolloff.html (2/9/2005)

Edmunds, G.F., S.L. Jensen & L. Berner. 1976. The Mayflies of North and Central America. University of Minnesota Press, Minneapolis, MI. 330 pp.

Field, J.J. 2003. Fluvial Geomorphic Assessment of Four Urban Streams in Portland and Bangor, Maine. Field Geology Services, Farmington, ME. 13 pp. plus figures, tables and appendices.

Hilsenhoff, W.L. 1987. An Improved Biotic Index of Organic Stream Pollution. Great Lakes Entomologist 20(1): 31 - 39.

Kentucky Department of Environmental Protection (DEP). 1998. Impacts of Deicing Fluids on Elijahs and Gunpowder Creeks, Boone County, Kentucky. Kentucky Department of Environmental Protection, Frankfort, KY; 21 pp. plus appendices. www.epa.gov/owow/tmdl/examples/organics/ky_elijahgunpowder.pdf (2/9/2005)

Lane, C.R. (draft). 2004. Conceptual Models for Use with CADDIS: Causal Analysis/Diagnosis Decision Information System. US EPA Office of Research and Development, National Exposure Research Lab, Cincinnati, OH.

Lydersen, E., S. Øxnevad, K. Østbye, R.A. Andersen, F. Bjerkely, L.A. Vøllestad & A.B.S. Poléo. 2002. The Effects of Ionic Strength on the Toxicity of Aluminum to Atlantic salmon (*Salmo salar*) under Non-Steady State Chemical Conditions. J Limnol 61: 69 - 76.

Maine Department of Environmental Protection (MDEP). Statewide Water Quality Criteria (SWQC). Maine Department of Environmental Protection, BLWQ, Augusta, ME; www.state.me.us/dep/blwq/docmonitoring/wqc.pdf (2/9/2005)

1995. Stormwater Management for Maine: Best Management Practices. Maine Department of Environmental Protection, Augusta, ME. 222 pp.

2000. Surface Water Ambient Toxic Monitoring Program, 1997 technical report. Maine Department of Environmental Protection, BLWQ, Augusta, ME; DEPLW 2000-5.

2001a. Surface Water Ambient Toxic Monitoring Program, 1999 technical report. Maine Department of Environmental Protection, BLWQ, Augusta, ME; DEPLW 2001-8.

2001b. Summary of the Method Used to Develop an Algorithm to Predict the % Imperviousness of Watersheds. Dennis, J. & A. Piper, Maine Department of Environmental Protection, BLWQ, Augusta, ME; internal document. 2 pp.

2002a. Surface Water Ambient Toxic Monitoring (SWAT) Program, 2000 technical report. Maine Department of Environmental Protection, BLWQ, Augusta, ME; DEPLW0495.

2002b. Surface Water Ambient Toxic Monitoring (SWAT) Program, 2001 technical report. Maine Department of Environmental Protection, BLWQ, Augusta, ME; DEPLW0546.

2002c. River and Stream Biological Monitoring Program, Frequently Asked Questions. Maine Department of Environmental Protection, BLWQ, Augusta, ME; DEP LW0561. 8 pp. www.state.me.us/dep/blwq/docmonitoring/biomonitoring/faq.pdf (2/9/2005)

2002d. 2002 Integrated Water Quality Monitoring and Assessment Report ["305 (b) report"]. Maine Department of Environmental Protection, BLWQ, Augusta, ME; DEPLW 0633.

2003a. Maine Erosion and Sediment Control BMPs. Maine Department of Environmental Protection, BLWQ, Augusta, ME; DEPLW 0588.

2003b. June 4, 2003 Sediment and Surface Water Sampling Report, Birch Stream, Bangor, Me. Maine Department of Environmental Protection, BRWM, Augusta, ME.

2004a. Spill Report Master List. Maine Department of Environmental Protection, BRWM, Augusta, ME. 1183 pp.

2004b. DRAFT 2004 Integrated Water Quality Monitoring and Assessment Report ["305 (b) report"]. Maine Department of Environmental Protection, BLWQ, Augusta, ME; DEPLW 0665.

2004c. Surface Water Ambient Toxic Monitoring (SWAT) Program, 2002-2003 technical report. Maine Department of Environmental Protection, BLWQ, Augusta, ME; DEPLW 0693.

McCullough, D.A. 1999. A Review and Synthesis of Effects of Alterations to the Water Temperature Regime on Freshwater Life Stages of Salmonids, with Special Reference to Chinook Salmon. United States Environmental Protection Agency, Region 10, Seattle, OR. EPA 910-R-99-010. 279 pp.

Merrit, R.W. & K.W. Cummins. 1996 (3rd edition). Aquatic Insects of North America. Kendall/Hunt Publishing Company, Dubuque, IA. 862 pp.

Morse, C.C. 2001. The response of first and second order streams to urban land-use in Maine, U.S.A. M.Sc. thesis, University of Maine at Orono, ME. 98 pp.

Ontario Ministry of the Environment. 1993. Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario. Ontario Ministry of the Environment, Toronto, ON (Canada); PIBS 1962 (ISBN 0-7778-9248-7).

PathFinder Science. 2004. Water Quality Index Protocol, Biochemical Oxygen Demand. http://pathfinderscience.net/stream/cp4bod.cfm

Paul, M.J. & J.L. Meyer. 2001. Streams in the Urban Landscape. Ann Rev Ecol Sys 32: 333 - 365.

Peckarsky, B.L., P.R. Fraissinet, M.A. Penton & D.J. Conklin. 1990. Freshwater Macroinvertebrates of Northeastern North America. Cornell University Press, Ithaca, NY. 442 pp.

Pennak, R.W. 1991 (3rd edition). Fresh-Water Invertebrates of the United States. Protozoa to Mollusca. John Wiley & Sons, Inc., New York, NY. 628 pp.

Platts, W.S., W.F. Megahan & G.W. Minshall. 1983. Methods for Evaluating Stream, Riparian, and Biotic Conditions. United States Department of Agriculture (USDA) Forest Service General Technical Report INT-138. 70 pp.

Rochfort, Q., L. Grapentine, J. Marsalek, B. Brownlee, T. Reynoldson, S. Thompson, D. Milani & C. Logan. 2000. Using Benthic Assessment Techniques to Determine Combined Sewer Overflow and Stormwater Impacts in the Aquatic Ecosystem. Water Qual Res J Canada 35 (3): 365 - 397.

Thorp, J.H., & A.P. Covich. 1991. Ecology and Classification of North American Freshwater Invertebrates. Academic Press, Inc., San Diego, California.

Schefter, P.W. & G.B. Wiggins. 1986. A Systematic Study of the Nearctic Larvae of the *Hydropsyche morosa* Group (Trichoptera: Hydropsychidae). Royal Ontario Museum, Life Sciences Miscellaneous Publications, Toronto , ON (Canada). 94 pp.

Schueler, T. 1994. The Importance of Imperviousness. Watershed Protection Techniques 1 (3): 100 – 111.

Simpson, K.W., R.W. Bode & P. Albu. 1983. Keys for the Genus *Cricotopus* Adapted from "Revision der Gattung *Cricotopus* van der Wulp und ihrer Verwandten (Diptera, Chironomidae)" by M. Hirvenoja. New York State Museum, Bulletin No. 450. 133 pp.

South Portland Land Trust (SPLT). In prep. Stream and Watershed Survey of Trout Brook, South Portland.

Sztruhar, D., M. Sokac, J. Marsalek, E. Frankova, L. Hyanek, D. Rusnak, S. Stanko, J. Ilavsky & J. Namer. 1997. A Case Study of Combined Sewer Overflow Pollution: Assessment of Sources and Receiving Water Effects. Water Qual Res J Canada 32: 563 - 578.

United States Department of Agriculture (USDA) Forest Service. 1997. Agroforestry Notes #5: A Riparian Buffer Design for Cropland. Dosskey, M.G., R.C. Schultz & T.M. Isenhart. USDA Forest Service, Lincoln, NE. www.unl.edu/nac/afnotes/rip-4/rip-4.pdf (2/9/2005)

United States Environmental Protection Agency (USEPA). 1997. Volunteer Stream Monitoring: A Methods Manual. Office of Water; Washington, D.C.; EPA 841-B-97-003.

1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers. Ch. 5, Habitat Assessment and Physiochemical Parameters. Office of Water; Washington, D.C.; EPA 841-B-99-002.

2000a. Stressor Identification Guidance Document. Cormier, S., S. Norton, and G. Suter. Office of Water, and Office of Research and Development, Washington, D.C.; EPA/822/B-00/025.

2000b. Ambient Water Quality Criteria Recommendations. Information Supporting the Development of State and Tribal Nutrient Criteria for Rivers and Streams in Nutrient Ecoregion XIV. Office of Water; Washington, D.C.; EPA 822-B-00-022.

2001. Ambient Water Quality Criteria Recommendations. Information Supporting the Development of State and Tribal Nutrient Criteria for Rivers and Streams in Nutrient Ecoregion VIII. Office of Water; Washington, D.C.; EPA 822-B-01-015.

United States Geological Survey (USGS). 1996. Nutrients in the Nation's Waters – Too Much of a Good Thing? USGS (Mueller, D.K. & D.R. Helsel) Circular 1136.

Varricchione, J.T. 2002. A biological, physical, and chemical assessment of two urban streams in southern Maine: Long Creek & Red Brook. Volumes I and II, Maine Department of Environmental Protection, Portland, ME.

Weather Underground. 2003/2004. Current and historical weather data for Bangor (www.wunderground.com/US/ME/Bangor/KBGR.html, 2/9/2005) and Portland (`www.wunderground.com/US/ME/Portland.html, 2/9/2005`). Weather Underground, Ann Arbor, MI.

Wiederholm, T. (ed.). 1983. Chironomidae of the Holarctic region. Keys and Diagnoses. Part 1 – Larvae. Borgströms Tryckeri AB, Motala. 457 pp.

Wiggins, G.B. 1996 (2nd edition). Larvae of the North American Caddisfly Genera (Trichoptera). University of Toronto Press, Toronoto, ON (Canada). 457 pp.

Williams, D.D. & N.E. Williams. 1998. Aquatic Insects in an Estuarine Environment: Densities, Distribution and Salinity Tolerance. Freshwater Biol 39: 411-421.

Williams, D.D. & T. Hamm. 2002. Insect Community Organisation in Estuaries: the Role of the Physical Environment. Ecography 25: 372 – 384.

SOURCES OF PERSONAL COMMUNICATIONS

Cloutier, Patrick, Director, Water Resource Protection, City of South Portland, 25 Cottage Road, South Portland ME 04106; phone (207) 767-7675; e-mail pcloutier@southportland.org

Corsi, Steven, Research Hydrologist, U.S. Geological Survey, 8505 Research Way, Middleton WI 53562; phone(608) 821-3835; e-mail srcorsi@usgs.gov

Danielson, Tom, Biologist, MDEP, SHS # 17, Augusta ME 04333; phone (207) 287-7728; e-mail Thomas.J.Danielson@maine.gov

Davies, Susan, Biologist, MDEP, SHS # 17, Augusta ME 04333; phone (207) 287-7778; e-mail Susan.P.Davies@maine.gov

DiFranco, Jeanne, Biologist, MDEP, 312 Canco Road, Portland ME 04103; phone (207) 822-6359; e-mail Jeanne.DiFranco@maine.gov

Heath, Douglas, Hydrogeologist, EPA New England, 1 Congress Street, Suite 1100, Boston MA 02114; phone (617) 918-1585; e-mail heath.doug@epa.gov

Hopeck, John, Geologist, MDEP, SHS # 17, Augusta ME 04333; phone (207) 287-7733; e-mail John.T.Hopeck@maine.gov

Logue, Ed, Regional Director, MDEP, 106 Hogan Road, Bangor ME 04401; phone (207) 941-4190; e-mail Edward.Logue@maine.gov

Murphy, John, Engineer, City of Bangor, 73 Harlow Street, Bangor ME 04401; phone (207) 992-4247; e-mail john.murphy@bgr.org

Pineo, David, Engineer, Water Resource Protection, City of South Portland, 25 Cottage Road, South Portland ME 04106; phone (207) 767-7675; e-mail dpineo@southportland.org

Roland, Brad, Engineer, Public Works Department, City of Portland, 55 Portland Street, Portland ME 04101; phone (207) 874-8493; e-mail BRAD@portlandmaine.gov

True, John, Environmental Engineer, MDEP, SHS # 17, Augusta ME 04333; phone (207) 287-7808; e-mail John.N.True@maine.gov

Tsomides, Leon, Biologist, MDEP, SHS # 17, Augusta ME 04333; phone (207) 287-7844; e-mail Leon.Tsomides@maine.gov