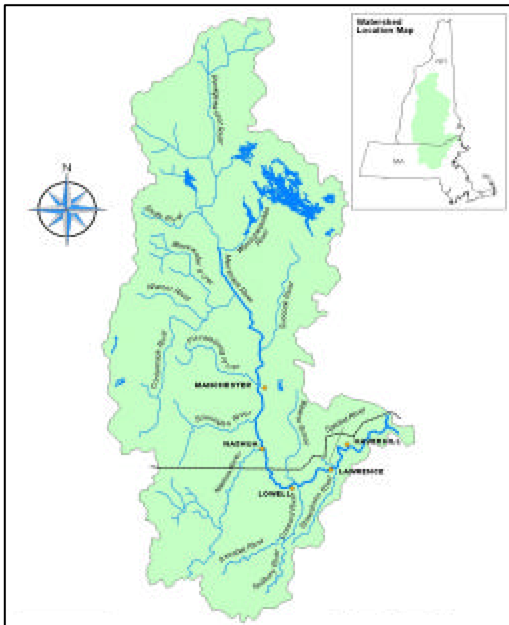

Merrimack River Watershed Assessment Study

Description of Existing Conditions

Prepared for:

New England District
U.S. Army Corps of Engineers

Sponsor Communities:
Manchester, NH
Nashua, NH
Lowell, MA
GLSD, MA
Haverhill, MA

January 2003

The River Basin Community Coalition concept was conceived in June 1998 in response to regulatory requirements to mitigate Combined Sewer Overflows (CSO) discharges. Because the coalition communities faced an aggregate financial commitment of 0.5 to 1.0 billion dollars, the five founding technical managers and administrators from each community believed that such an investment should be made wisely. They believed that this wise investment should be founded on good science that holistically embraces the needs of the watershed. Generally speaking the mission is to “spend smart” by making wise science based investments in activities related to water quality improvements that are not solely focused on CSO mitigation.

Executive Summary

This report is submitted to fulfill the requirements of Task Order 1A of Contract Number DACW33-02-D-0005: *"Evaluation of Existing Conditions"* for the Merrimack River Watershed Assessment Study. This is the first Task Order for Phase I of the comprehensive study, which has been jointly funded by the United States Army Corps of Engineers (USACE) through the New England District and the five sponsoring communities of Manchester and Nashua, New Hampshire; Haverhill and Lowell, Massachusetts; and the Greater Lawrence Sanitary District, Massachusetts. Phase I of this study is aimed at identifying relative planning level benefits (and costs) of generalized investment strategies such that beneficial uses of the water can be effectively improved through a shared-vision approach to watershed management.

Task Order 1A of the Study authorized the review of existing documentation on the Merrimack River watershed, and a summation of the findings in this report. Specifically, the Task Order requires "discussions of water quality, water quantity, dams and impoundments, sediment quality, and biological resources and habitat including phytoplankton, macroinvertebrates, fisheries (anadromous and resident fish population), shellfish, and wetlands (freshwater and tidal)." Additionally, the Task Order requires a review and discussion of designated water uses and attainment, and a limited discussion of pollution sources within the watershed. The discussions in this report focus on the mainstem of the Merrimack River, along with its significant tributaries. The report does not include new findings, but rather serves as a unifying summary of other documents that have been issued primarily within the past ten years.

This "Description of Existing Conditions" report is intended to serve two purposes. First, it is a medium to communicate the current state of the watershed to project participants, sponsors, and interested stakeholders. Second, portions of the report (especially the sections on designated use attainment and water quality) will serve as a reference during subsequent evaluations and comparisons during Phase I of the comprehensive study.

Watershed Overview

The Merrimack River is formed by the confluence of the Pemigewasset and Winnipesaukee Rivers in Franklin, New Hampshire. The River flows southward for approximately 78 miles in New Hampshire; it turns abruptly across the New Hampshire- Massachusetts border and flows in a northeasterly direction for approximately another 50 miles before discharging to the Atlantic Ocean at Newburyport, Massachusetts. The final 22 miles of the River are tidally influenced downstream of Haverhill, Massachusetts.

The Merrimack River watershed covers an area of approximately 5010 square miles in the south-central portion of New Hampshire (76-percent of the drainage area) and the northeastern portion of Massachusetts (24-percent of the drainage area), making it the fourth largest watershed in New England.

Physical Setting

The Merrimack River watershed encompasses a variety of terrain and climate conditions, from the mountainous White Mountain region in northern New Hampshire to the estuarine coastal basin of northeastern Massachusetts. Precipitation in the watershed is fairly evenly distributed throughout the year. There are, however, large inter-basin variations in the amount and type of precipitation (*i.e.* rain versus snow) primarily as a result of the effects of terrain, elevation, latitude, and proximity to the ocean (Flanagan *et al.* 1999). Temperatures in the basin generally vary widely on an annual basis. Based on a review of climate data, July is typically found to be the warmest month and January is generally the coldest.

A mix of deciduous and evergreen forest, covering approximately 77 percent of the watershed area, dominates the land use in the basin. Urban areas, including residential, industrial, commercial and commercial land uses, make up the second largest land use category, covering approximately 10 percent of the total watershed area.

The U.S. Geological Survey (USGS) currently operates two gaging stations on the mainstem Merrimack River at (1) Merrimack River near Goffs Falls, below Manchester, New Hampshire and (2) Merrimack River below Concord River at Lowell, Massachusetts. Numerous other gaging stations currently exist on major tributaries to the Merrimack River. A review of the monthly discharge statistics on the mainstem reveals that the highest average and most variable flows generally occur during the month of April; the lowest and least variable flows generally occur during the late summer (August and September).

Numerous hydropower dams currently exist on the mainstem Merrimack River and its major tributaries that significantly impact the daily, weekly, and monthly streamflow conditions. During high flow conditions, the hydropower facilities generally operate under “run of the river ” conditions, with substantial spillage. During periods of low flow, the dams are required to pass a minimum flow, while still operating to meet peak demands. This often results in short-term water level fluctuations during summer months.

Water Quality

Historically, the water quality of the Merrimack River was severely degraded by industrial and domestic wastes. In the 1960s, the River was listed as one of the nation’s ten most polluted waterways, primarily as a result of raw sewage, paper and textile mill wastes, and tannery sludge (USEPA 1987). However, the passage of the Federal Clean Water Act in 1972 ushered in a period of rebirth for the River. An infusion of large amounts of state and Federal funding for water resources infrastructure investments, such as wastewater treatment plant (WWTP’s), helped to revive the River into one that is currently a significant natural and economic resource in the New England region.

Despite the significant improvements, further work to improve water quality is required. For example, a 1997 study conducted as part of the Merrimack River Initiative (MRI) indicated that the four largest causes of non-support of designated uses in the basin are pollution from (1) urban runoff, (2) natural sources, (3) municipal point sources, and (4) combined sewer overflow (CSO) discharges. This study also identified elevated bacteria levels as the primary cause of non-supporting use in the basin, followed distantly by low dissolved oxygen concentrations and high nutrient levels (Donovan and Diers 1997). Other issues of concern include low-flow conditions, water supply, flooding, contamination of shellfishing beds, and fish and wildlife habitat and contamination issues.

The primary water quality data collection agencies in the watershed have been state and federal agencies, including the New Hampshire Department of Environmental Services (NHDES), the Massachusetts Department of Environmental Protection (MADEP), and the USGS. Recently, several volunteer monitoring programs have also started collecting data within the watershed with the help of these state agencies and the Merrimack River Watershed Council. The majority of the water quality data that exists in the basin from MADEP was collected prior to 1990. NHDES also collected water quality and biomonitoring data in the watershed throughout the 1990s. The most recent comprehensive analysis of the River's quality was performed under the Merrimack River Initiative (MRI) during the 1990's. This project was a collaborative effort between the USEPA, NHDES, MADEP, and the New England Interstate Water Pollution Control Commission. The MRI collected water quality samples throughout the basin during one wet-weather and one dry-weather event; benthic macroinvertebrate sampling was also performed.

Both Massachusetts and New Hampshire categorize waters according to their use class. Each class is associated with a series of designated uses; the ability of a waterbody to support these uses is assessed based on its ability to meet the applicable water quality standards. In New Hampshire, designated use categories include swimming (primary contact recreation), fish and shellfish consumption, drinking water, and aquatic life support. In Massachusetts, these uses include fish consumption, aquatic life support, drinking water, shellfishing, primary contact recreation (swimming), and secondary contact recreation (boating).

In general, the most recent statewide surface water assessments published by Massachusetts and New Hampshire in 2002 show that bacteria (*E. Coli* and fecal coliform) is the largest cause of water quality violations in the Merrimack River mainstem. This translates into a non-supporting use of primary and secondary contact recreation in the majority of the River downstream of Manchester, New Hampshire, as well as a closure of the shellfishing beds in the tidally influence portion of the River. The New Hampshire assessment report lists CSO's as the primary cause of these violations; Massachusetts does not provide a similar listing. The Massachusetts assessment report also lists metals, nutrients, and priority organics as significant problems along the mainstem, resulting in a non-attainment of the aquatic life use. Additionally, the recent MRI study also discovered exceedances of water quality standards for lead and zinc in the lower portion of the River during wet and dry-weather conditions, affecting aquatic life in the river. The following table provides a summary of the major causes of non-supporting use in the Merrimack River mainstem based on the states' 2002 assessment reports.

Causes of non-support in the Merrimack River mainstem

Pollutant	Listed Miles/ Area[1]			Non-supporting Use
	NH	*MA*	*Total*	
Pathogens	19.82 mi	27.9 mi, 7.14 mi^2	47.72 mi, 7.14 mi^2	Primary and secondary contact recreation (MA and NH), shellfishing (MA only)
Metals	---	20.8 mi	20.8 mi	Not listed
Nutrients[2]	---	18.7 mi	18.7 mi	Not listed
Priority Organics	---	15.9 mi, 6.97 mi^2	15.9 mi, 6.97 mi^2	Not Listed
pH	4.88 mi	---	4.88 mi	Aquatic Life
Unionized Ammonia	---	4.37mi^2	4.37mi^2	Not Listed
Flow Alteration	0.59 mi	---	0.59 mi	Aquatic Life

[1]Area (in mi^2) is provided for the tidally influenced portion of the basin in Massachusetts
[2]Massachusetts does not specify which nutrients are a problem; however, phosphorus is generally the limiting nutrient in freshwater and nitrogen is the limiting nutrient in marine waters.
Source: MADEP 2002, NHDES 2002

Elevated bacteria levels were also identified as a major problem on many of the tributaries to the Merrimack River, particularly in the Massachusetts portion of the basin, translating into a non-supporting use for primary and secondary contract recreation in the listed areas. Additionally, violations of the pH criteria for aquatic life support were identified in a majority of the New Hampshire tributaries. The Massachusetts assessment report listed metals, nutrients, and organic enrichment/ low dissolved oxygen as the other top causes of designated use non-attainment. The MRI study also discovered elevated levels of lead during wet and dry-weather in the Sudbury/Assabet/Concord (SuAsCo) and Nashua River watersheds, as well as elevated copper concentrations in the SuAsCo watershed.

Resource Summary

The Merrimack River watershed is a high value resource area that supports a range of biological, recreation, and other resources, such as hydropower and public drinking water supplies. The watershed also supports a range of important habitats, as follows:

- Aquatic Habitat- These habitats include quickwaters in the northern portion of the watershed, cold and warm water fisheries throughout the watershed, and an estuarine environment in the River's final reaches.

- Riparian Habitat- The diversity of river riparian habitat provides a valuable resource for wildlife. One of the riparian habitats found along the mainstem River, the pitch/scrub oak barrens, are considered globally rare and support the only identified New England population of Karner blue butterfly, a federally-listed endangered species.

- Freshwater Wetland Habitat- Freshwater wetlands play an integral role in the ecology of the Merrimack River corridor. The combination of high nutrient levels and primary productivity found in these habitats is ideal for the development of organisms forming the base of the food chain.

- Tidal Wetland Habitat- The unique freshwater/saltwater habitat in the lower 22 miles of the mainstem River supports a wide range of aquatic species, including extensive shellfishing beds (which are currently closed due to elevated bacteria levels).

Biological resources in the watershed include shellfish populations in the tidally influenced portions of the mainstem Merrimack River, various resident and anadromous fish populations, and numerous threatened and endangered species. In the past 20 years an extensive anadromous fish restoration program has been implemented on the Merrimack River designed to bring back extirpated stocks of the endangered Atlantic salmon, American shad, alewife, and blueback herring. The largest threats to the fish populations currently include mercury and polychlorinated biphenyl (PCB) contamination, hydromodification, thermal pollution, and flow regulation resulting in insufficient in-stream flow requirements.

The Merrimack River watershed also supports a range of primary and secondary contact recreation activities, including a Class II and III rapids and slalom kayaking course in Manchester, New Hampshire, a public beach at the Lowell Heritage State Park, and numerous marinas and private boat docks. In addition, hiking, camping, cross-country skiing and picnicking are popular activities associated with the River and adjacent back areas. The portion of the mainstem River from its origin at Franklin, New Hampshire to the backwater impoundment at Hooksett Dam is under Congressional study for designation to the Wild and Scenic River System.

In additional to the biological and recreational resources, the watershed supports a variety of economic uses, including seven hydroelectric dams, which currently operate on the mainstem Merrimack River and the Pemigewasset River. The mainstem River also supports numerous public and industrial water users along its length.

Pollution Source Summary

Water quality in the Merrimack River mainstem is affected by both point and non-point source pollution. Municipal wastewater treatment plants, CSO's, stormdrain discharges, and industrial dischargers are considered to be the largest cause of point source pollution in the watershed. These sources contribute significantly to the non-attainment of designated uses throughout the basin. Both CSO and stormdrain pollution are generally a wet-weather problem, whereas municipal and industrial dischargers are a continuous source.

The primary sources of non-point source pollution in the watershed include: urban and non-urban stormwater runoff, atmospheric deposition, natural sources (such as wildlife and waterfowl populations), pet waste, *in situ* contaminants, agricultural runoff, septic systems, illicit connections, and groundwater plumes from sites regulated under the Resource Conservation and Recovery Act (RCRA) and from landfills. Unlike point source discharges, pollution from non-point sources is very difficult to quantify and remediate. However, these sources may contribute significantly to the non-attainment of designated uses in the Merrimack River watershed.

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Preface

The cities of Manchester and Nashua, New Hampshire, Lowell and Haverhill, Massachusetts, and the Greater Lawrence Sanitary District (GLSD), Massachusetts are currently working separately to develop and implement long-term Combined Sewer Overflow (CSO) control plans in compliance with the Federal Clean Water Act. The collective cost of these potential CSO improvements could reach upwards of $1 billion over the next 20 years. Given this sizable investment, the communities are concerned that decisions regarding potential CSO abatement measures are being made without adequate understanding of the existing conditions in the Merrimack River, the pollution sources to the River, and the potential benefits of the proposed CSO improvements.

In order to develop a comprehensive assessment of the current Merrimack River mainstem and watershed conditions, the five sponsors, in conjunction with the U.S. Army Corps of Engineers - New England Division (USACE) are jointly funding the Merrimack River Watershed Assessment Study. The community coalition has provided 50 percent of the cost share for the first $2,000,000 phase of the Study. The Federal government, through the USACE, is providing the remaining financial support, in addition to technical assistance for the Study. Involvement of the USACE is authorized under Section 729 of the Water Resources Development Act (WRDA) of 1986 entitled "Study of Water Resources Needs of River Basins and Regions," as amended by Section 202 of WRDA 2000.

Section 1 Introduction

The cities of Manchester and Nashua, New Hampshire the City of Lowell, Massachusetts, the Greater Lawrence Sanitary District (GLSD), Massachusetts, and the City of Haverhill, Massachusetts are currently working separately to develop and implement long-term Combined Sewer Overflow (CSO) control plans in compliance with the Federal Clean Water Act. The collective cost of these potential CSO improvements may reach upwards of one billion dollars over the next 20 years. Given this sizable investment, the communities are concerned that decisions regarding the potential mitigation measures are being made without adequate understanding of the existing conditions in the Merrimack River, the pollution sources to the River, and the potential benefits of the proposed CSO improvements. The cities are looking to conduct a comprehensive assessment of the current River and watershed conditions, the results of which can then be used to guide decisions regarding CSO mitigation measures.

1.1 Study Authority

The Federal government, through the United States Army Corps of Engineers (USACE), is providing 50 percent of the cost share for the Merrimack River Watershed Assessment Study (hereafter referred to as the "Study"), as well as technical assistance. Involvement of the USACE is authorized under Section 729 of the Water Resources Development Act (WRDA) of 1986 entitled "Study of Water Resources Needs of River Basins and Regions" as amended by Section 202 of WRDA 2000. This report was prepared in response to specific language contained in Section 437 of WRDA 2000 that directed the USACE to conduct a comprehensive study of the water resource needs of the Merrimack River basin in Massachusetts (MA) and New Hampshire (NH).

Directed funds for this effort were provided to the USACE by Congress in the fiscal year 2001 and 2002 Energy and Water Development Appropriation. The City of Lowell, Massachusetts, serving as the local sponsor of this project, entered into a Memorandum of Understanding with the four other communities in the watershed (Haverhill and GLSD, Massachusetts; Manchester and Nashua, New Hampshire) to provide the remaining financial support for the Study.

1.2 Study Purpose

The purpose of this Study is to develop a comprehensive Watershed Management Plan (WMP) for the Merrimack River watershed. The WMP will be used to guide investments in the environmental resources and infrastructure of the basin and will be aimed at achieving conditions that support beneficial uses and ecosystem health, with a particular emphasis on water quality. The WMP will encompass the diverse interests and goals of the various partners and stakeholders throughout the Merrimack River watershed, which include local, state, and Federal governments, industry, and concerned citizen groups. Stakeholders will be consulted throughout the planning process to help ensure that the final plan is balanced and comprehensive.

The assessment will include a water resources and ecosystem restoration investigation of the Merrimack River and will be used to answer the following questions:

- What are the existing and potential future feasible beneficial uses of the River?
- What are the pollutant sources that may impact these uses?
- What is the relative contribution of pollutants from various sources?
- What project(s) will provide the most significant return on investment?
- Which projects have the highest priority?

1.3 Report Scope

The purpose of this "*Description of Existing Conditions*" report is to provide a comprehensive description of the current conditions in the watershed based on available resources. The report is not intended to serve as an evaluation of these existing conditions with respect to accuracy and adequacy of existing data, but rather as unifying summary of the relevant documents that have been issued primarily in the past ten years. Topics addressed in this report include the Merrimack River's physical setting; biological, recreational, and other resources; water quality of the mainstem and its significant tributaries; and potential contributors to point and non-point source pollution in the watershed. This report will serve as a reference for comparison during subsequent tasks of this Study.

1.4 Watershed Overview

The Merrimack River is formed by the confluence of the Pemigewasset and Winnipesaukee Rivers in Franklin, New Hampshire. The River flows southward for approximately 78 miles in New Hampshire; it turns abruptly across the New Hampshire-Massachusetts border and flows in a northeasterly direction for approximately another 50 miles in Massachusetts before discharging to the Atlantic Ocean at Newburyport. The mainstem Merrimack River flows past the five major urban centers of Manchester and Nashua, New Hampshire and Lowell, Lawrence, and Haverhill, Massachusetts. The final 22 miles of the River are tidally influenced below Haverhill.

The Merrimack River watershed covers an area of approximately 5,010 square miles in the south-central portions of New Hampshire (76 percent of the drainage area) and the northeastern portions of Massachusetts (24 percent of the drainage area), making it the fourth largest watershed in New England. Geographically, the basin encompasses a variety of terrain, from the relatively steep conditions of the White

Mountain region in northern New Hampshire to the estuarine coastal basin of northeastern Massachusetts.

Historically, the water quality of the Merrimack River was severely degraded by industrial and domestic wastes. In the 1960s, the River was listed as one of the nation's ten most polluted waterways, primarily as a result of raw sewage, paper and textile mill wastes, and tannery sludge (U.S. Environmental Protection Agency (USEPA) 1987). However, the passage of the Federal Clean Water Act in 1972 ushered in a period of rebirth for the River. An infusion of large amounts of state and Federal funding for spending on water resources infrastructure investments, such as wastewater treatment plant (WWTP's), helped to revive the River into one that is currently a significant natural and economic resource in the New England region.

Despite the significant improvements, further work to improve water quality is required. A 1997 study by the Merrimack River Initiative (MRI) reported that in the entire Merrimack River watershed, 268.2 river miles fully support, 67.5 river miles partially support, and 193 river miles do not support their designated uses (Donovan and Diers 1997). The reported 530 river miles represent only the assessed portion of the basin, as per the 305(b) Reports issued by Massachusetts and New Hampshire. Although this is only a small percentage of the 4,000 total river miles in the entire watershed, it includes most portions of the River where there are concerns over the ability of the river segment to support designated uses. The term "fully-supports" is used to describe segments where water quality is sufficient to fully support the designated uses; "partially supporting" describes segments where one or more designated uses is partially supported and the other uses are fully supported; "non-supporting" describes segments where one or more uses are not supported.

The 1997 MRI study indicates that the four largest causes of non-support of designated uses in the basin are pollution from (1) urban runoff, (2) natural sources, (3) municipal point sources, and (4) CSO discharges. This study also identified elevated bacteria levels as the primary cause of non-supporting use in the basin, followed distantly by low dissolved oxygen concentrations and high nutrient levels (Donovan and Diers 1997). Other issues of concern include low-flow conditions, water supply, flooding, contamination of shellfishing beds, and fish and wildlife habitat and contamination issues.

1.5 Study Scope

Given the size of the Merrimack River watershed and the range of issues identified for potential analysis, a phased implementation plan has been developed for this Study. Phase I efforts will focus on the following topics:

- Assessment of existing conditions in the watershed
- Identification of potential and future uses of the River

- Identification and quantification of pollutant sources
- Development of screening level models
- Collection of water quality and streamflow data (wet- and dry-weather)
- Development of water quality models
- Evaluation of various CSO and non-CSO abatement projects and other water management options
- Inventory of potential ecosystem restoration projects in the watershed

The data collection aspect of the project will be aimed at determining the causes of water quality degradation in the Merrimack River, particularly the impacts of CSO's, point, and non-point sources.

The scope of the Phase II assessments will be determined based on the results of the Phase I findings and will be contingent upon the availability of funding from local and Federal sources. It is anticipated, however, that the Phase II efforts will focus on in-stream flow issues, additional water quality monitoring for non-standard parameters, and supplemental analysis of potential abatement alternatives and ecosystem restoration projects.

1.6 Study Area

For the purposes of this report, existing conditions in the entire Merrimack River watershed, as defined in Section 1.4, are discussed wherever possible. Future tasks to be performed under Phase I will be limited in geographic range to the portion of the mainstem River south of Hooksett Falls Dam in Hooksett, New Hampshire. Water quality sampling and flow monitoring efforts will be concentrated in this area, as well as at the mouth of 11 major tributaries that join the mainstem south of Hooksett, New Hampshire. Water quality and flow models will be developed for this lower portion of the mainstem.

Section 2
Physical Setting

This section of the report summarizes the physical setting of the Merrimack River watershed, including the basin delineation, the geology and land use, the climate and hydrology, and the social and economic composition of the basin.

2.1 Watershed Area

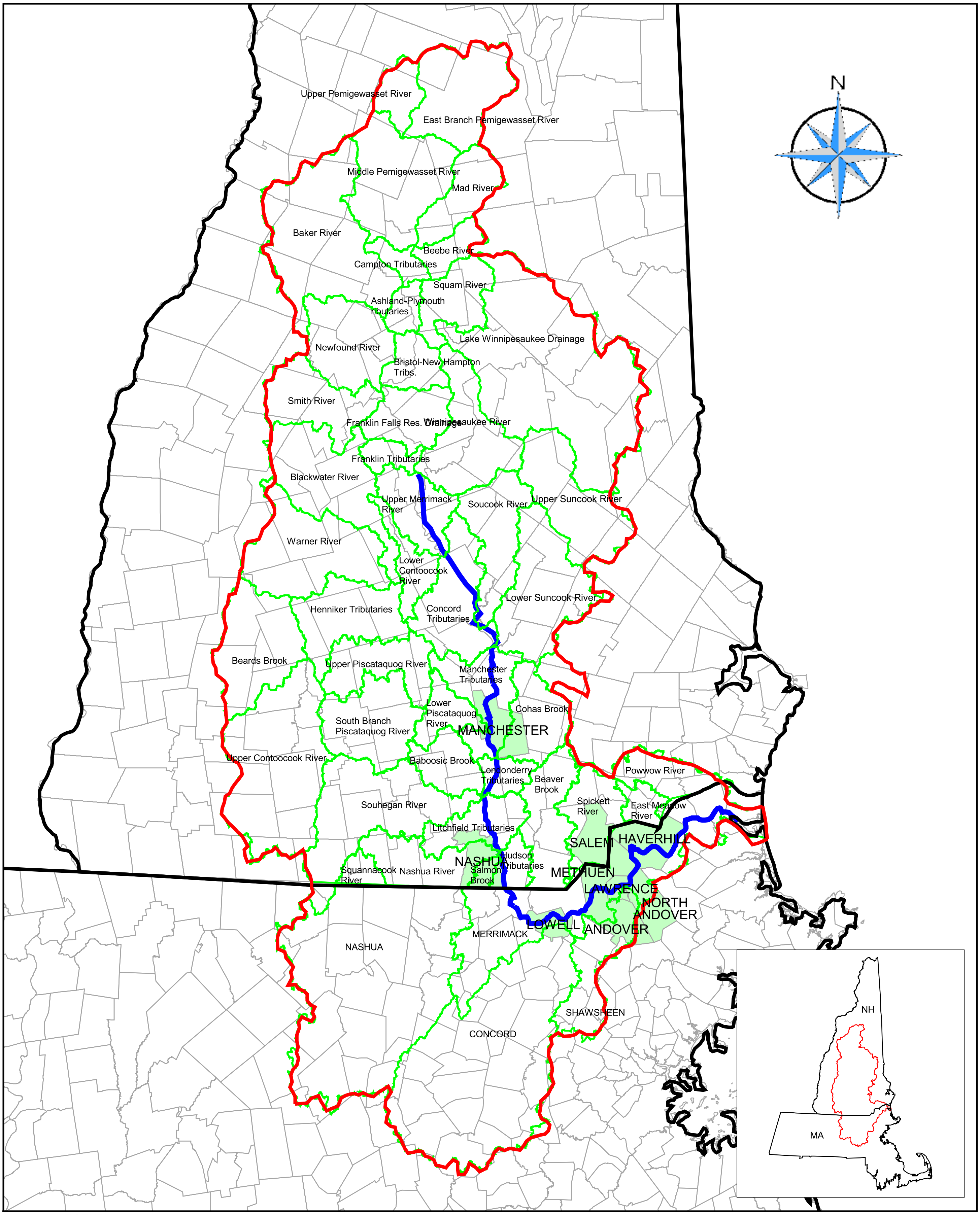
The Merrimack River watershed is comprised of numerous subwatersheds of varying size. Table 2.1 presents a summary of the watershed area, river length to the Merrimack River confluence, and distance upstream of the Newburyport Light for major tributaries to the Merrimack River mainstem. A map of the watershed and major subbasins is provided in Figure 2.1; the five sponsor communities of Manchester and Nashua, New Hampshire and Lowell, GLSD (Andover, North Andover, Lawrence, and Methuen, Massachusetts; and Salem, New Hampshire), and Haverhill, Massachusetts are also highlighted on the figure.

Table 2.1: Summary of Major Tributaries

Location of Headwaters	Tributary	Drainage Area (mi^2)	Length (mi)	Distance above Newburyport Light (River miles)
New Hampshire	Pemigewasset River	1021	64	116
	Winnipesaukee River	486	23	116
	Contoocook River	766	66	101
	Soucook River	91	28	86
	Suncook River	260	39	83
	Piscataquog River	220	24	71
	Cohas Brook	68	7	68
	Souhegan River	219	34	62
	Beaver Brook	91	12	40
	Spicket River	75	15	28
	Powwow River	49	NA[1]	6
	Merrimack River mainstem	577		--
Massachusetts	Nashua River	530	34	55
	Salmon River	32	NA	NA
	Stony Brook	46	NA	NA
	Shawsheen River	74	24	27
	Assabet/Sudbury/Concord Rivers	400	16[2]	39

Sources: Merrimack River Watershed Council (http://www.merrimack.org)

[1]NA= Not available, [2]Concord River only



LEGEND
- Merrimack Watershed
- Mainstem Merrimack River
- Sub-Watershed
- CSO Community Mainstem River
- Town Boundaries
- State Boundary

10 0 10 20 Miles

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Figure 2.1 - Basemap
Merrimack River Watershed
Assessment Study

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2.2 Geology and Land Use

The Merrimack River watershed is located in the New England Physiographic Province, and traverses each of the three major sections -- the White Mountains, the New England Uplands, and the Seaboard Lowlands (Flanagan, *et al.* 1999). The majority of the basin falls within the New England Uplands region, which is characterized by rolling hills and local relief ranges from a few hundred feet to 1,000 feet in more mountainous regions. The watershed elevation ranges from a high of 5,249 feet on Mount Lafayette in the White Mountain region to mean sea level along the northeastern Massachusetts coast (Seaboard Lowlands).

2.2.1 Bedrock and Surficial Geology

Bedrock in the Merrimack River watershed (Figure 2.2) is generally of similar age and genesis. Intrusive igneous rocks, primarily Granitoid Plutonic Rocks, dominate the northeastern portion of the basin. Large deposits of metamorphic mixed and sulfide-bearing granofels cover the north-central and northwestern portion of the basin. A strip of metamorphic grade rocks, including mixed schist and gneiss deposits, cuts across the Massachusetts-New Hampshire border in a northeasterly direction. The southeast corner of the basin is dominated by sulfide-bearing schistose granofels and granitoids, and volcanics.

The Merrimack River basin is generally covered by a sheet of glacial till, with areas of large fine- and large-grained glacial-lake deposits along the River mainstem and major tributaries (Flanagan, *et al.* 1999). The till cover is composed of variable, unstratified, silty, gravelly, sand and clays. The cover is generally thin on the hilltops and in the deep valleys, with exposed bedrock typically visible in the hilly upland regions (USACE 1977). The immediate coastal portion of the basin is characterized by areas of fine-grained marine deposits (Flanagan, *et al.* 1999). Large glacial melt-water lakes formed throughout the basin during glacial retreat. Figure 2.3 presents a summary of the soil surface texture in the watershed.

2.2.2 Soil Composition

The soil composition of the basin is largely a result of the physiography and varying glacial deposits. The Natural Resources Conservation Service (NRCS), formerly the Soil Conservation Service (SCS), developed a national soils classification system known as the Hydrologic Soils Group. A hydrologic group is defined as a group of soils having similar runoff potential under similar precipitation and land use cover conditions. The NRCS divided soils into four classes: A, B, C, and D, with the following definitions:

<u>Group A (Low runoff potential)</u>: The soils have a high infiltration rate even when they wetted. They chiefly consist of deep, well drained to excessively drained sand or gravels. They have a high rate of water transmission.

Group B: The soils have a moderate infiltration rate when thoroughly wetted. They are generally moderately-deep to deep, moderately well-drained to well-drained soils that have moderately fine to moderately coarse textures. They have a moderate rate of transmission.

Group C: The soils have a slow infiltration rate when thoroughly wetted. They generally have a layer that impedes downward movement of water or have moderately fine texture. They have a slow rate of water transmission.

Group D (High runoff potential): The soils have a very slow infiltration rate when thoroughly wetted. They chiefly consist of clay soils that have a high swelling potential, soils that have a permanent high water table, soils that have a claypan or clay layer near the surface, and shallow soils over nearly impervious material. They have a very slow rate of water transmission.

Following the soil hydrologic group classifications the majority of soils in the watershed may be broadly classified as soil group C, interspersed with large deposits of soil group B. Soil group C is typically found in upland areas where glacial till is most commonly found at the surface (Flanagan, *et al.* 1999). This group is used to describe soils with slow infiltration rates and moderate to high runoff potential. Soil group B is typically found in areas of stratified-drift deposits and is characterized by moderate infiltration rates. Along the immediate coast, soils are classified as soils hydrologic group D, which is used to describe clayey soils with very slow infiltration rates and minimal depth to groundwater. The generalized hydrologic soils mapping for the basin is provided in Figure 2.4.

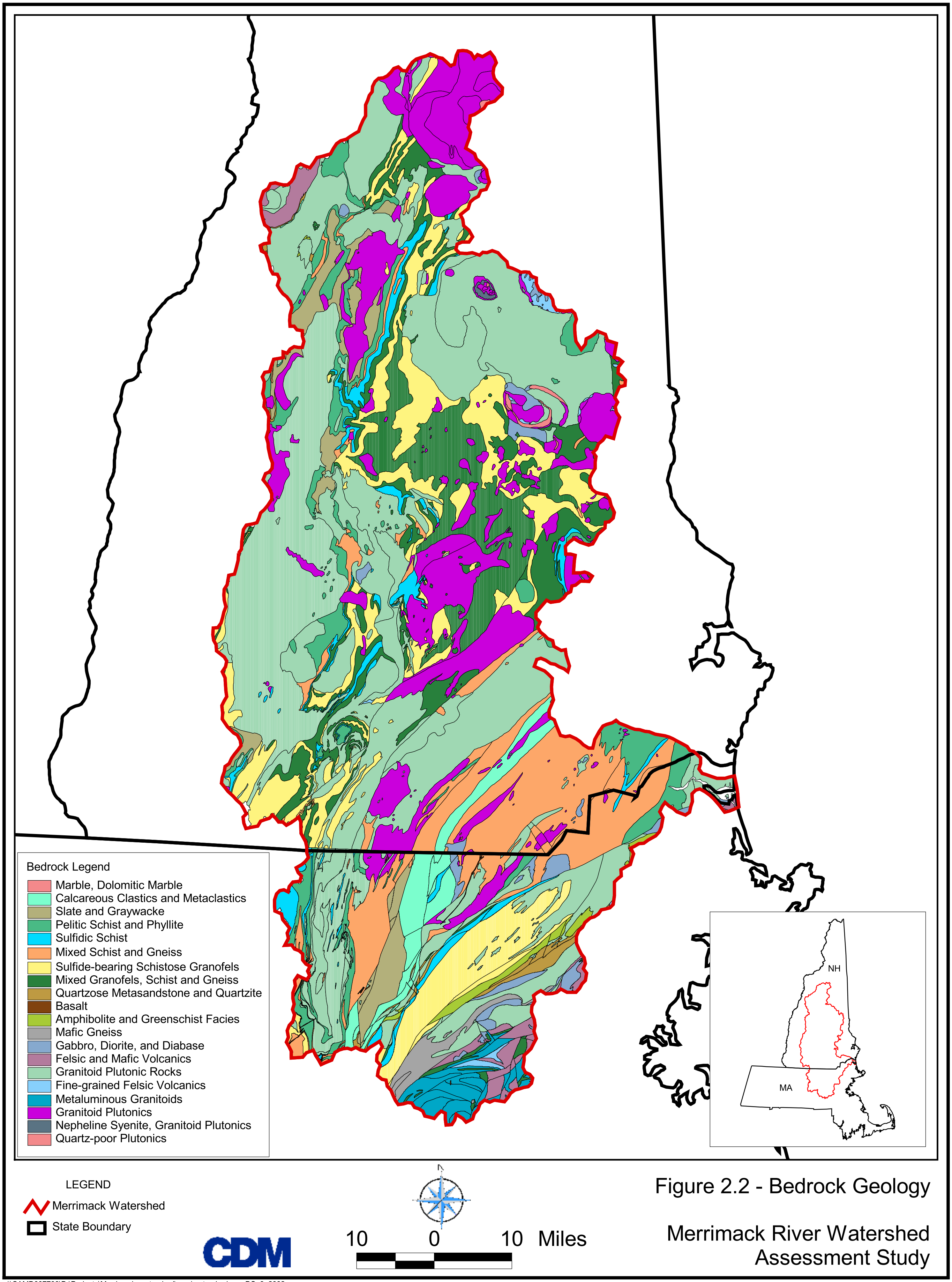

Figure 2.2 - Bedrock Geology

Merrimack River Watershed
Assessment Study

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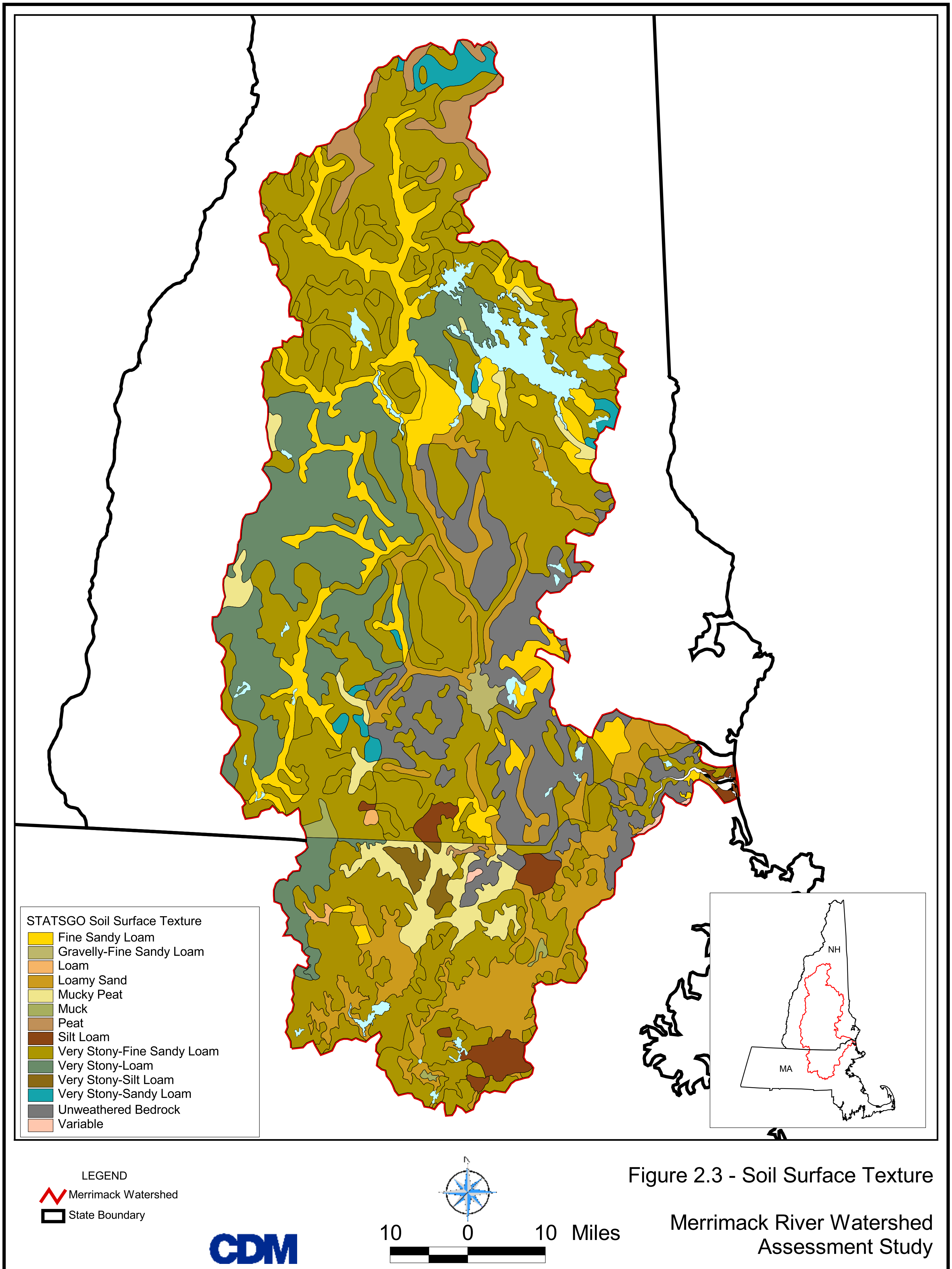

Figure 2.3 - Soil Surface Texture

Merrimack River Watershed Assessment Study

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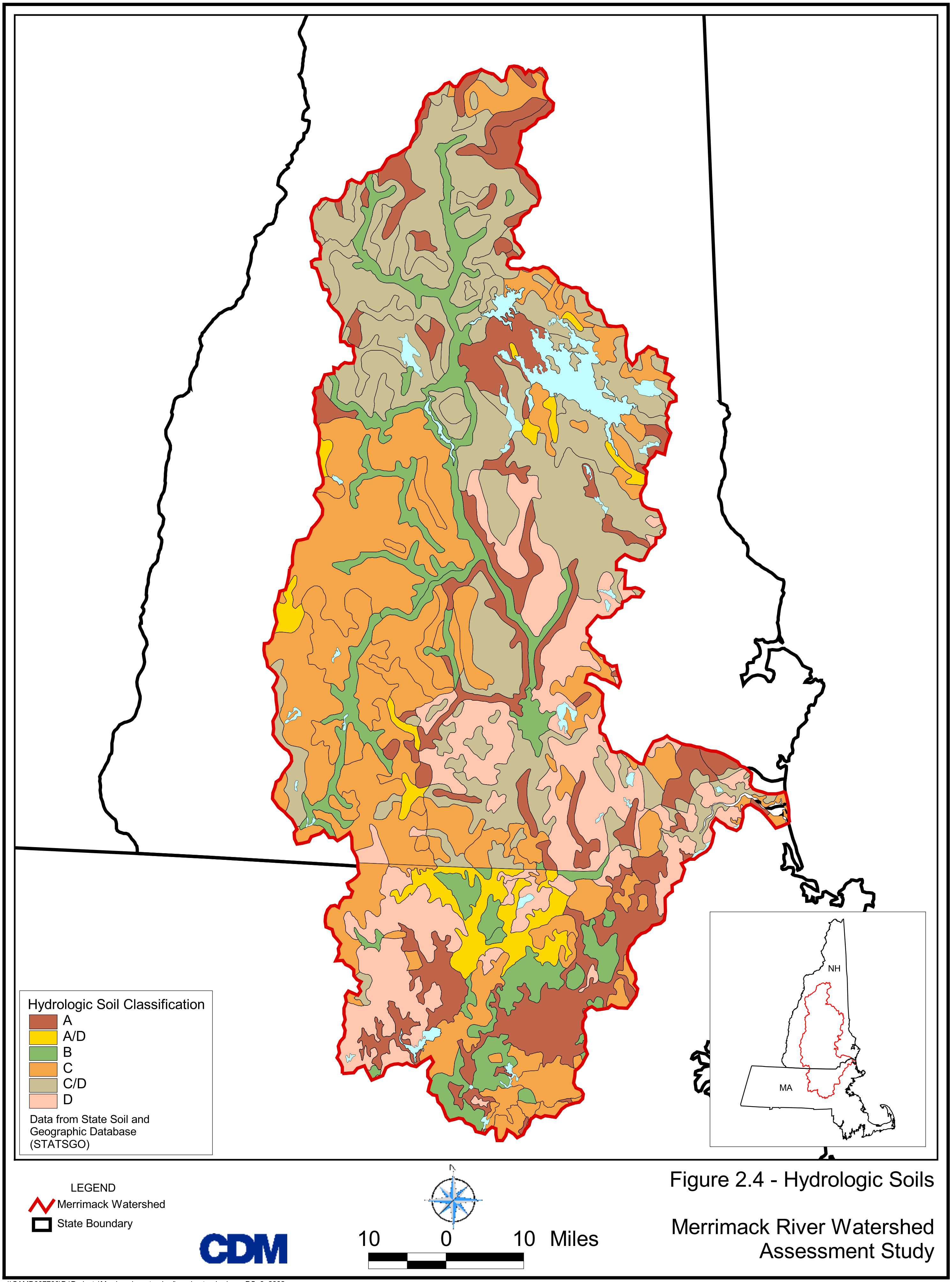

Figure 2.4 - Hydrologic Soils

Merrimack River Watershed Assessment Study

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2.2.3 Groundwater Aquifers

There are three primary types of aquifers in the Merrimack River watershed: stratified-drift, till, and bedrock. Highly productive stratified-drift aquifers dominate the Massachusetts portion of the basin. They are also found in the valleys of New Hampshire along the mainstem and significant tributaries. These aquifers consist mainly of layered sand and gravel deposits formed by the retreating glaciers. They serve as the main source of drinking water for many communities that rely on groundwater supplies and also supply the majority of streamflow during dry seasons (*i.e.*, late summer and early fall) and during droughts. Annual groundwater recharge to stratified-drift aquifers is approximately half of the annual precipitation. This translates to 20 to 24 inches per year in glaciated portions of eastern Massachusetts and in east-central and southeastern New Hampshire, and 14 inches per year in south-central New Hampshire (Flanagan, *et al.* 1999).

Glacial till aquifers are most commonly found in the New Hampshire portion of the basin. These aquifers are characterized by low-permeability and thus, are limited in their use for drinking water supplies. Recharge to till aquifers is approximately nine inches per year (Flanagan, *et al.* 1999). Fractured bedrock aquifers serve as the drinking water supply for numerous rural households, as well as for several communities and commercial and industrial users. Coarse-grain rocks, such as granite and basalt typically have higher yields than finer-grained rocks, such as schist and gneiss. Recharge to these aquifers is primarily controlled by land surface relief and the portion of bedrock above groundwater sinks, such as lakes. Recharge to crystalline bedrock aquifers is approximately three to five inches per year (Flanagan, *et al.* 1999).

2.2.4 Land Use

Historically, the Merrimack River played a large role in the development of the region's economy and land use patterns. The onset of the industrial revolution in the mid-1800s pulled many families from traditional subsistence farming towards more promising work in urban settings. Many of the larger towns adjacent to the Merrimack mainstem, including the five sponsor communities, began as factory or mill towns due to the need for hydropower to power the emerging industries. This economic shift resulted in the reclamation of previously predominantly agricultural lands by forest and woodland. Today, the basin is dominated by a mix of deciduous and evergreen forest cover (over 75 percent of the watershed area). Urban areas, including residential, industrial, and commercial land uses, make up the second largest land use category, covering approximately 10 percent of the watershed area. Table 2.2 and Figure 2.5 present a more detailed breakdown of land use in the Merrimack River watershed.

Table 2.2: Land Use Summary

Land Use Category	Area (mi^2)	Percent of Total Area (%)
Forest	3892	77
Wetland	56	1.1
Water	214	4.3
Residential	350	7.0
Commercial & Industrial	119	2.4
Transportation	36	0.7
Urban	47	0.9
Agricultural	294	5.9
Unknown	23	0.4
Beaches/Other Sandy Areas/Exposed Rock	1.2	0.02

Source: US EPA (http://www.epa.gov/ostwater/basins)

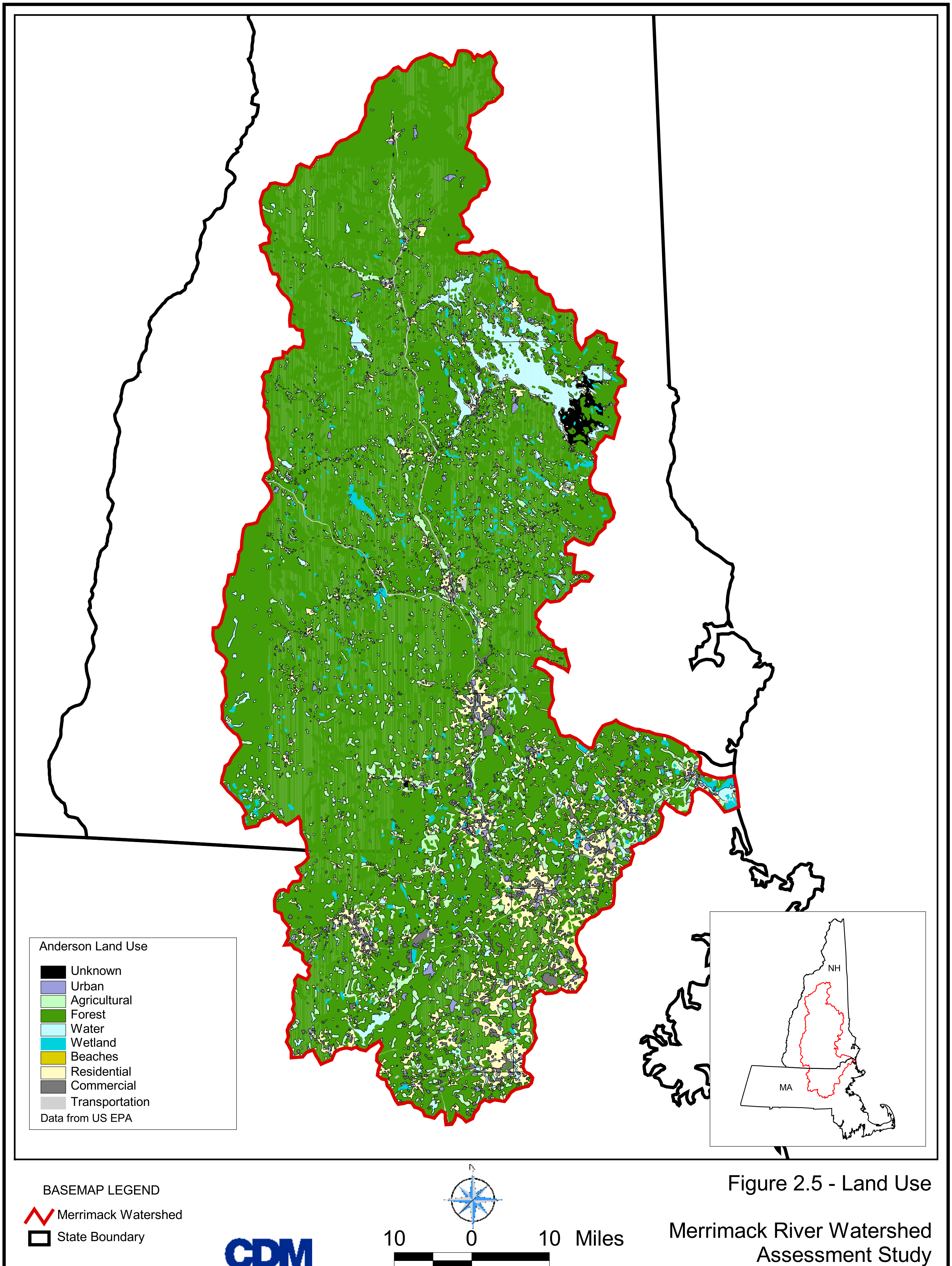

Figure 2.5 - Land Use

Merrimack River Watershed Assessment Study

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2.3 Climate and Hydrology

2.3.1 Climate

Climatic conditions within the Merrimack River watershed vary significantly from its headwaters in the White Mountain National Forest, to the mouth of the River along the Atlantic Ocean. The basin is located partially with the Northern and Coastal Climatic divisions along its far northern and southeastern boarders; the majority of the watershed falls within the Central Climatic division (Flanagan *et al.* 1999). Weather systems throughout the basin are primarily the result of prevailing westerly winds and the confluence of many continental weather patterns in North America. The climate of the Northern division is primarily influenced by high elevation and latitude. The Central division is generally more moderate than the Northern section due to its lower elevation and latitude; this division experiences some climate modification due to maritime influences. The climate of the Coastal division is influenced primarily by its low elevation and proximity to the Atlantic Ocean (Flanagan *et al.* 1999).

Table 2.3 and Figure 2.6 present a summary of the active climate stations in the basin; these stations are operated as part of the National Weather Service's Cooperative Station Network.

Table 2.3: Active Climate Stations in the Merrimack River Watershed

State	Climate Station Location	COOP ID	Start of Record
NH	Alexandria	270045	September 1995
	Bow Garvins Falls	270834	June 1948
	Bradford	270913	April 1998
	Bristol	270998	June 1948
	Concord Municipal Airport	271683	October 1933
	Deering	271950	April 1976
	Franklin Falls Dam	273182	June 1948
	Franklin Junction	273172	June 1948
	Grafton	273530	June 1955
	Greenville	273658	June 1988
	Hopkinton Lake	274218	June 1963
	Laconia	54736	January 1965
	Lincoln	274732	June 1948
	Macdowell Dam, Peterborough	275013	June 1950
	Manchester	275072	June 1948
	Manchester Airport	14710	February 1937
	Massabesic Lake	275211	June 1948
	Meredith	275350	December 1993
	Milford	275412	June 1948
	Nashua	275712	June 1948

State	Climate Station Location	COOP ID	Start of Record
NH (cont'd)	Nashua Boire Field	54754	May 1953
	New Hampton	275813	April 1998
	Plymouth	276945	July 1984
	Salisbury	277833	September 1995
	South Lyndeboro	278081	June 1948
	Warren	278885	June 1948
	Weare	278972	July 1969
	Wentworth	279091	June 1948
MA	Ashburnham	190190	July 1985
	Bedford	190535	May 1957
	Bedford Hanscom Field	14702	September 1942
	Groveland	193276	June 1992
	Haverhill	193505	October 1899
	Lawrence	194105	June 1948
	Lawrence Municipal Airport	94723	May 1946
	Lowell	194313	June 1948
	Natick	195175	December 1968
	Newburyport	195285	June 1948

Source: http://www.ncdc.noaa.gov

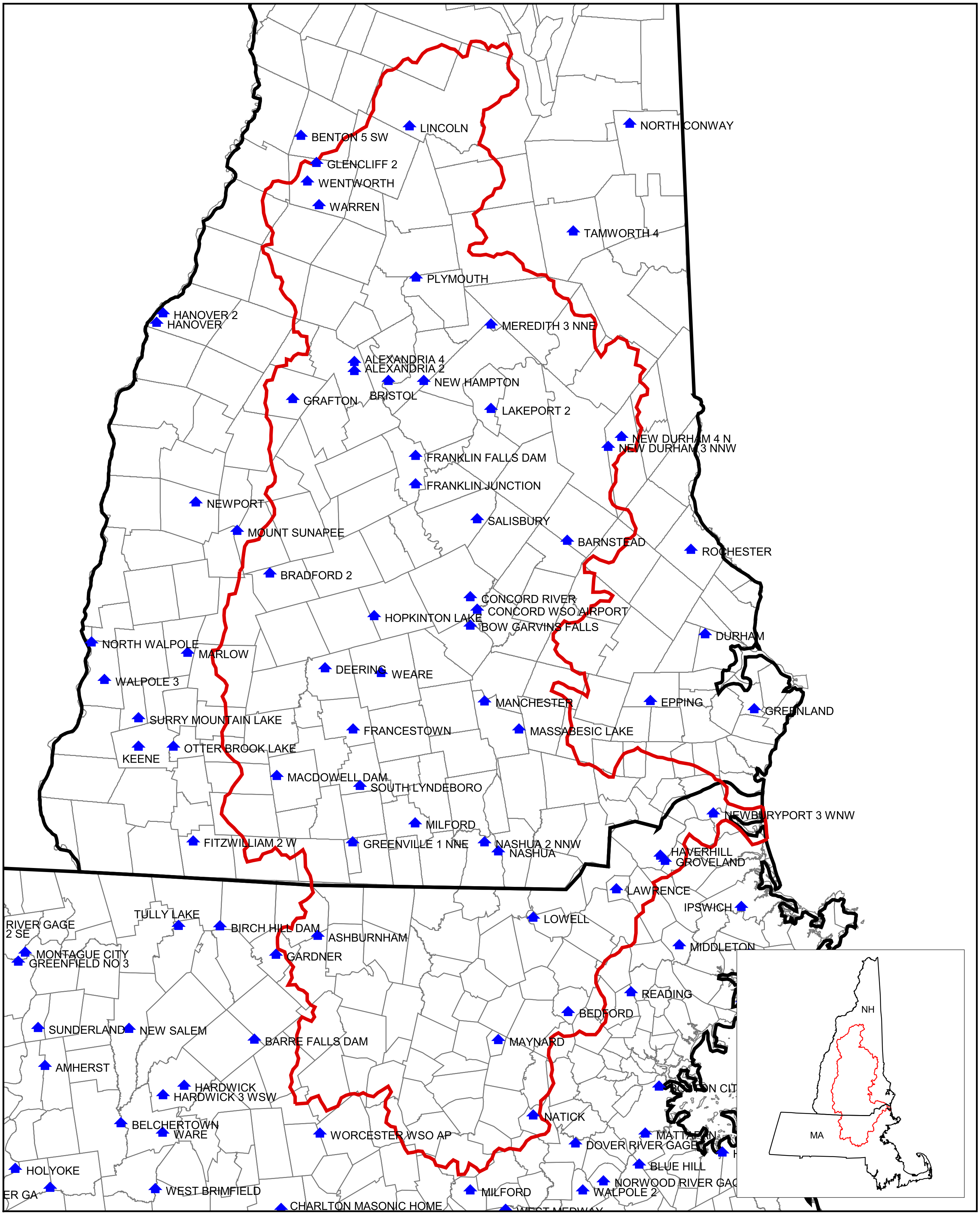
Precipitation in the watershed is fairly evenly distributed throughout the year. There are, however, large inter-basin variations in amount and type of precipitation (*i.e.*, rain versus snow) primarily as a result of the effects of terrain, elevation, latitude, and proximity to the ocean (Flanagan *et al.* 1999). Locations in the far northern portions of the basin may receive upwards of 60 inches per year of precipitation, while the majority of the low-lying portions receive approximately 42 inches per year. A summary of the normal monthly precipitation and snowfall is presented in Table 2.4 for select climate stations in the watershed.

Temperatures in the watershed generally vary widely on an annual basis. Temperature data taken from several weather observatories throughout the basin found that July was typically the warmest month and January was the coldest (Flanagan *et al.* 1999). Additionally, winter temperatures were found to vary more widely than did summer temperature across the basin. A summary of the normal minimum, maximum, and average daily temperatures for each month is presented in Table 2.4 for the COOP stations in Concord, New Hampshire and Bedford, Massachusetts.

Table 2.4: Summary of Average Monthly Precipitation and Temperature Statistics for Select Stations[1]

Month	Concord, NH[2]					Bedford, MA[3]				
	Max. Temp	*Min. Temp*	*Ave. Temp*	*Ave. Precip*	*Ave. Snow*	*Max. Temp*	*Min. Temp*	*Ave. Temp*	*Ave. Precip*	*Ave. Snow*
Jan	31.1	10.5	20.8	2.86	16.8	34.8	15.5	25.1	3.85	14.4
Feb	33.6	12.4	23.0	2.47	14.4	37.3	17.3	27.3	3.45	13.5
March	42.7	22.7	32.7	3.19	11.2	46.0	26.3	36.1	4.12	11.1
April	56.0	32.3	44.2	3.13	2.8	58.1	35.4	46.8	3.87	2.2
May	68.7	42.3	55.5	3.12	0.1	69.5	45.5	57.5	3.56	0.2
June	77.5	52.0	64.7	3.32	0.0	77.8	54.7	66.2	3.57	0.0
July	82.2	57.1	69.7	3.38	0.0	82.7	60.0	71.4	3.48	0.0
Aug	80.0	55.1	67.6	3.04	0.0	80.9	58.6	69.8	3.31	0.0
Sept	72.0	47.0	59.5	3.27	0.0	73.0	50.2	61.6	3.66	0.0
Oct	61.0	36.0	48.5	2.94	0.1	62.5	39.2	50.9	3.67	0.1
Nov	47.5	28.1	37.8	3.68	3.9	50.9	31.4	41.1	4.34	2.4
Dec	34.9	16.1	25.5	3.07	12.7	39.0	20.9	29.9	4.17	11.0

[1]Temperatures in degrees F; precipitation and snowfall in inches
[2]Based on period of record from 1921- 2001
[3]Based on period of record from 1957-2001



LEGEND

- Merrimack Watershed
- Weather Stations
- Town Boundary
- State Boundary

CDM

N

10 0 10 Miles

Figure 2.6 - Weather Stations

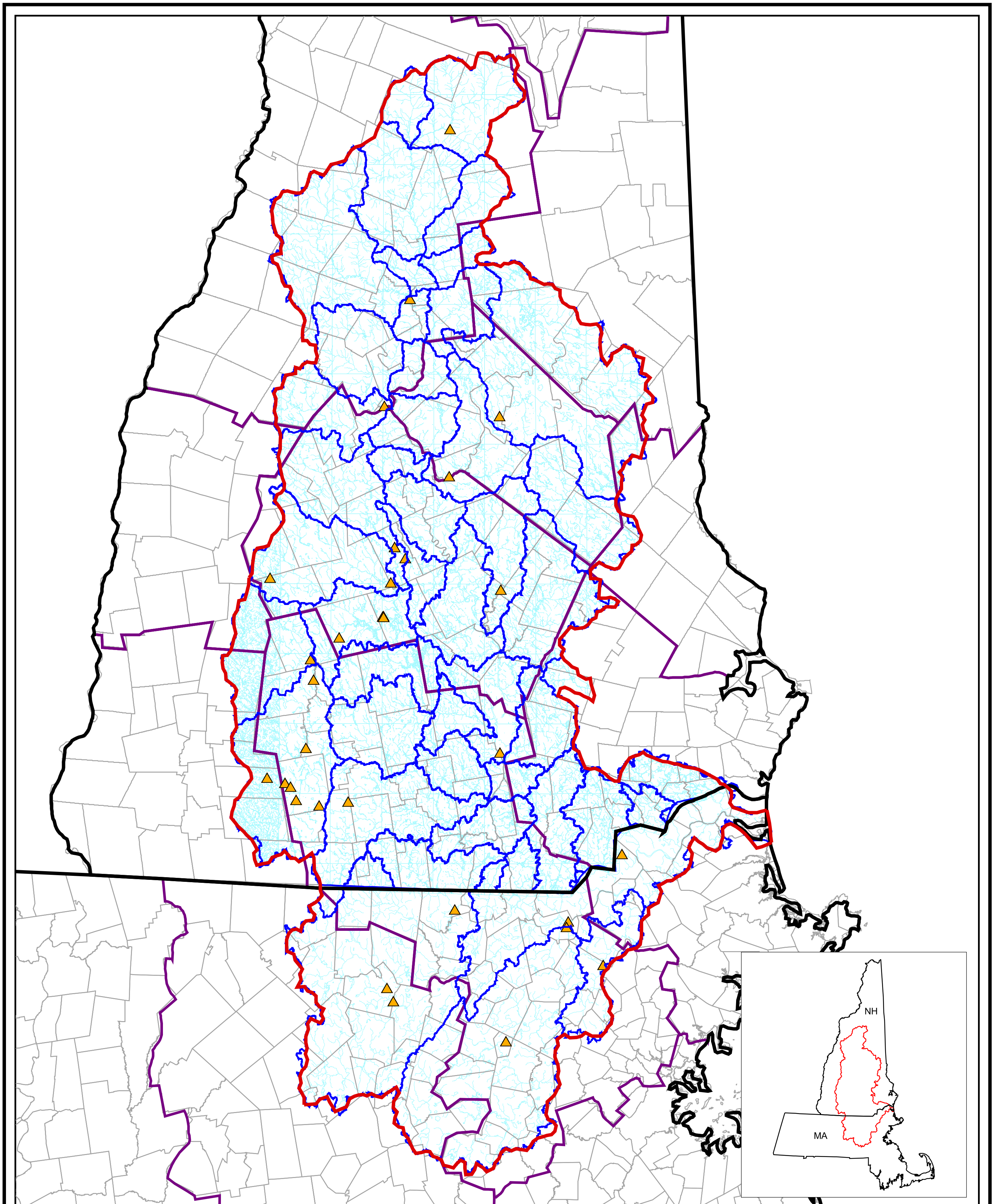
Merrimack River Watershed
Assessment Study

2.3.2 Hydrology

The U.S. Geological Survey (USGS) currently operates three flow gaging stations on the Merrimack River mainstem (including the Pemigewasset River) and 16 stations on its tributaries. Numerous additional historical records of varying length are available throughout the basin. Daily streamflow data and daily, monthly, and annual streamflow statistics are available for download from the USGS-NWIS website at http://water.usgs.gov/nwis. Table 2.5 and Figure 2.7 presents a summary of the active gaging stations in the watershed, the start year, and mean annual discharge.

Table 2.5: Summary of Active Streamflow Gaging Stations in the Merrimack River Watershed

	Station ID	Station Name	Start	Mean Annual Q (cfs)
Mainstem	01076500	Pemigewasset River at Plymouth, NH	1903	1370
	01092000	Merrimack River near Goff Falls, below Manchester, NH	1936	5339
	01100000	Merrimack River below Concord River at Lowell, MA	1923	7707
Tributaries	01074520	East Branch Pemigewasset River at Lincoln, NH	1993	337
	01081000	Winnipesaukee River at Tilton, NH	1937	710
	01080500	Lake Winnipesaukee Outlet at Lakeport, NH	1933	540
	01078000	Smith River near Bristol, NH	1918	145
	01089100	Soucook River at Pembrooke Road near Concord, NH	1988	125
	01093800	Stony Brook tributary near Temple, NH	1963	7.3
	010965852	Beaver Brook at North Pelham, NH	1986	75
	01100505	Spicket River at Island Pond Rd. at North Salem, NH	2000	
	01094400	North Nashua River at Fitchburg, MA	1972	122
	01094500	North Nashua River near Leominster, MA	1935	201
	01096500	Nashua River at East Pepperell, MA	1935	584
	01097000	Assabet River at Maynard, MA	1941	190
	01098530	Sudbury River at Saxonville, MA	1979	195
	01099500	Concord River below R. Meadow Brook at Lowell, MA	1936	649
	01100568	Shawsheen River at Hanscom Field near Bedford, MA	1995	5.1
	01100600	Shawsheen River near Wilmington, MA	1963	59



LEGEND
Merrimack Watershed
Hydrography
Sub-Watershed
CSO Community
County Boundary
State Boundary
Gaging Station, from US EPA

10 0 10 Miles

CDM

Figure 2.7 - Gaging Stations

Merrimack River Watershed
Assessment Study

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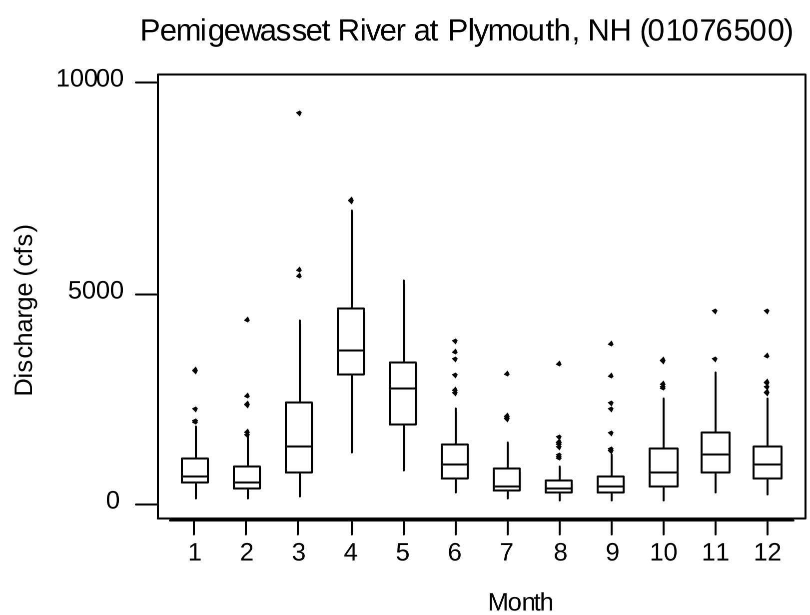
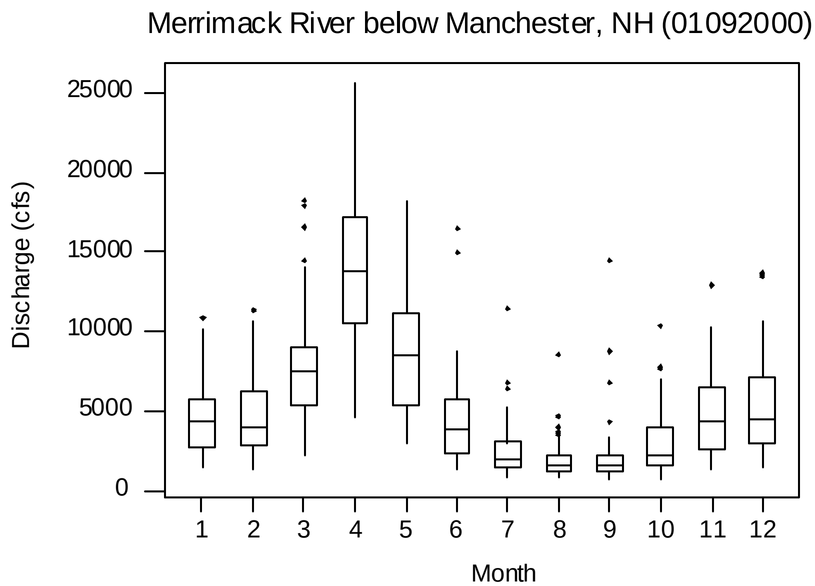
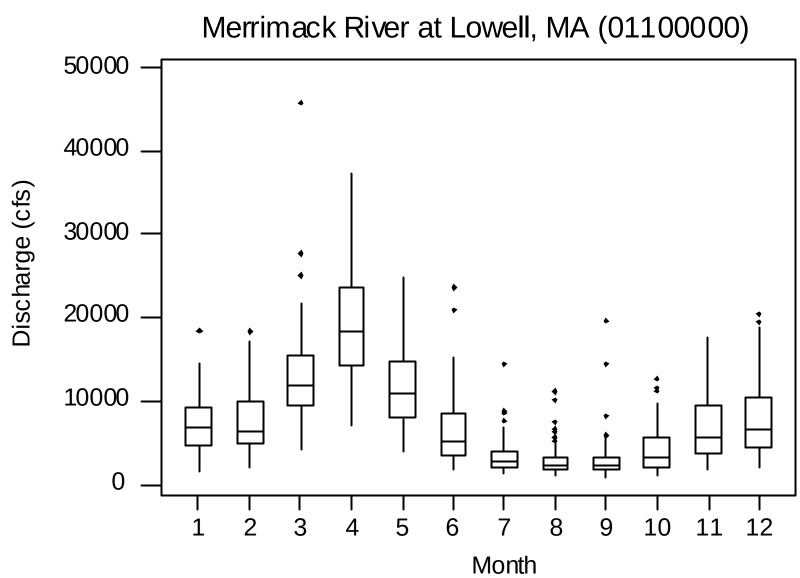
Boxplots of the monthly streamflow data for the period of record are provided in Figure 2.8 for the three stations on the Merrimack River mainstem (including the Pemigewasset River). Each box on the graph describes the range and location of the streamflow data for the respective month. At all three stations, the highest average flows occur during the month of April; this is also month with greatest variability in flow conditions. The lowest and least variable flows occur during late summer (August and September).

Figure 2.8: Boxplots of monthly streamflow data for select gaging stations



The bottom of the box coincides with the lower quartile of the data and the top with the upper quartile of the data; a line through the box marks the median of the data. The vertical lines on each side of the box run from the quartiles to the smallest and largest numbers that fall within 1.5 times the inter-quartile range (IQR). The IQR is the difference between the upper and lower quartiles of the distribution. The lower quartile is defined as that number such that at least 25-percent of the data fall at or below it and at least 75-percent of the data falls at or above it. Similarly, the upper quartile is the number such that at least 75-percent of the data fall at or below it and at least 25-percent falls at or above it. Outliers beyond the IQR are marked by a point on the graph.


Merrimack River below Manchester, NH (01092000)
Discharge (cfs)
25000
20000
15000
10000
5000
0
1
2
3
4
5
6
7
8
9
10
11
12
Month


Merrimack River at Lowell, MA (01100000)
Discharge (cfs)
50000
40000
30000
20000
10000
0
1
2
3
4
5
6
7
8
9
10
11
12
Month

Low-flow Conditions:

Low-flow conditions on the Merrimack River are a priority concern for the protection of wildlife habitat and water quality, as well as for the ability of the River to meet its water demands from municipal and industrial users. Typically, low-flows are expressed in terms of the magnitude, duration, and frequency of the condition. For regulatory purposes in Massachusetts, "*the lowest flow condition at and above which [water quality] criteria must be met is the lowest mean flow for seven consecutive days to be expected once every ten years*" (314 CMR 4.00). This is commonly referred to as the 7Q10 and is used as a guide for worst-case water quality assessments. The median or mean August flow is also a frequently used statistic in Massachusetts for water management and planning purposes.

In 1988, New Hampshire enacted the Rivers Management and Protection Act (RSA 483) in response to concerns over the balancing of water use priorities in the state. The Act gives the New Hampshire Department of Environmental Protection (NHDES) the authority and responsibility to maintain flow in support of "instream public uses" in river segments that have been designated by the state for special protection under the Act. Instream public uses include navigation, recreation, fishing, conservation, maintenance, and enhancement of aquatic life, fish, and wildlife habitat, protection of water quality and public health, pollution abatement, aesthetic beauty, and hydropower protection. In November 2001, NHDES completed draft Instream Flow Rules (ISFR); these rules were originally intended to apply to 14 designated rivers in the state. However, in August 2002 the ISFR were revised to apply only to two of the 14 rivers as a pilot program- the Lamprey River in the coastal watershed and the Souhegan River in the Merrimack River watershed. If the pilot rules are successfully implemented, they will be revised to be applied to the other 12 rivers. As part of this pilot program, an instream flow water management plan will be developed for each of the rivers. Additionally, NHDES will develop a report on the impacts on water users, wildlife, recreation, and other interests along the rivers, and recommendations for proposed legislation (www.des.state.nh.us/rivers/instream/legfacts.htm).

A 1994 study performed by the Cadmus Group, commissioned by the MRI, evaluated the low-flow hydrology of the Merrimack River watershed. The following table (Table 2.6) presents a summary of the 7Q10 statistics developed for those stations currently operating on the mainstem Merrimack and Pemigewasset Rivers. Statistics were calculated using the Log Pearson III extreme value distribution. This table also presents the mean August flow, based on monthly statistics published by the USGS (http://waterdata.usgs.gov/nwis).

Table 2.6: Summary of 7Q10 and Mean August Flow for Active Gaging Stations on the Merrimack and Pemigewasset Rivers

Station ID	Station Name	7Q10 (cfs)	Period of Record Used in Calculation	Mean August Flow (cfs)
01076500	Pemigewasset River at Plymouth, NH	117	1904-1992	504
01092000	Merrimack River near Goff Falls, below Manchester, MA	653	1937-1992	1958
01100000	Merrimack River below Concord River at Lowell, MA	950	1923-1992	2802

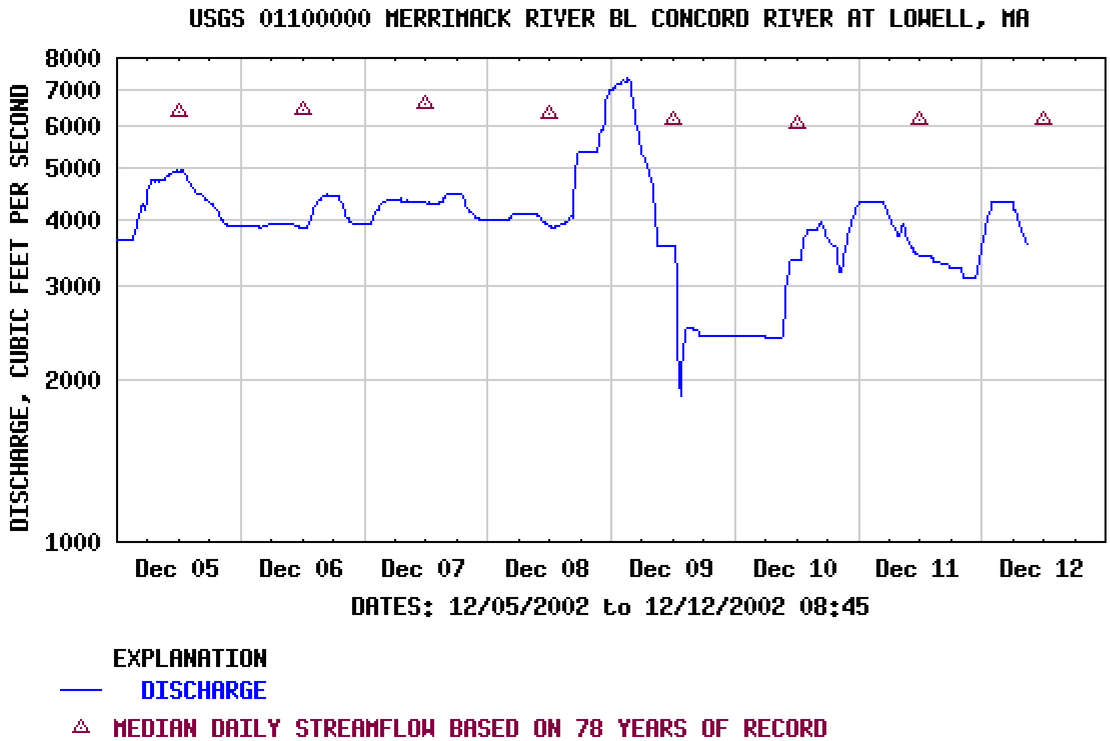
Hydropower Impacts:

Numerous hydropower dams currently existing on the mainstem Merrimack River and its tributaries have significant impacts on the daily, weekly, and monthly streamflow conditions in the River. Figure 2-9 shows the streamflow measured at the USGS gaging station on the Merrimack River downstream of Lowell, Massachusetts (01100000) during a one-week period from December 5 to December 12, 2002. This station is located downstream of the Pawtucket Dam in Lowell, Massachusetts. The effect of the hydropower operations is particularly evident on December 9, 2002 when a drop of over 5,000 cubic feet per second (cfs) is observed in the streamflow measured at this site, from a daily high of over 7,000 cfs to a daily low of less than 2,000 cfs.

During high flow conditions, the hydropower facilities generally operate as "run of the river" facilities, with substantial spillage. During periods of low flow, the dams are required to pass a minimum flow, while still operating to meet peak demands. This often results in short-term water level fluctuations during summer months.

Additional information on the dams located in the watershed and their hydropower operations is provided in Section 4.3.

Figure 2.9: Weekly Streamflow Record at USGS Gaging Station- Lowell, MA



2.4 Social and Economic

The 2000 U.S. Census survey indicates that the overall population of the Merrimack River watershed is approximately 2.04 million. This represents an increase of approximately 14 percent from the 1.76 million people living in the basin as of the 1990 U.S. Census survey (Flanagan *et al.* 1999).

Population density tends to increase from north to south in the Merrimack River watershed, ranging from fewer than 100 people per square mile in the northeastern and northwestern portions of New Hampshire to greater than 800 people per square mile in Manchester and Nashua, New Hampshire, and in northeastern Massachusetts. The expanding interstate highway system has precipitated the migration of people from more traditional Boston "metropolitan" areas to expanding suburban communities of northeastern Massachusetts and southern New Hampshire. Figure 2.10 presents a summary of the 2000 U.S. Census block data for the Merrimack River watershed.

Major urban centers along the mainstem Merrimack River include the cities of Concord, Manchester, and Nashua, New Hampshire, as well as Lowell, Lawrence, and Haverhill, Massachusetts. Concord, New Hampshire is the state capital. A summary of the 2000 U.S. Census population data for these communities is provided in Table 2.7.

Table 2.7: 2000 U.S. Census Population Data for Urban Centers in the Merrimack River Watershed

City	2000 Population
Concord, NH	40,687
Manchester, NH	107,006
Nashua, NH	86,605
Lowell, MA	105,167
Lawrence, MA	72,043
Haverhill, MA	58,969

Source: 2000 U.S. Census (http://www.census.gov/)

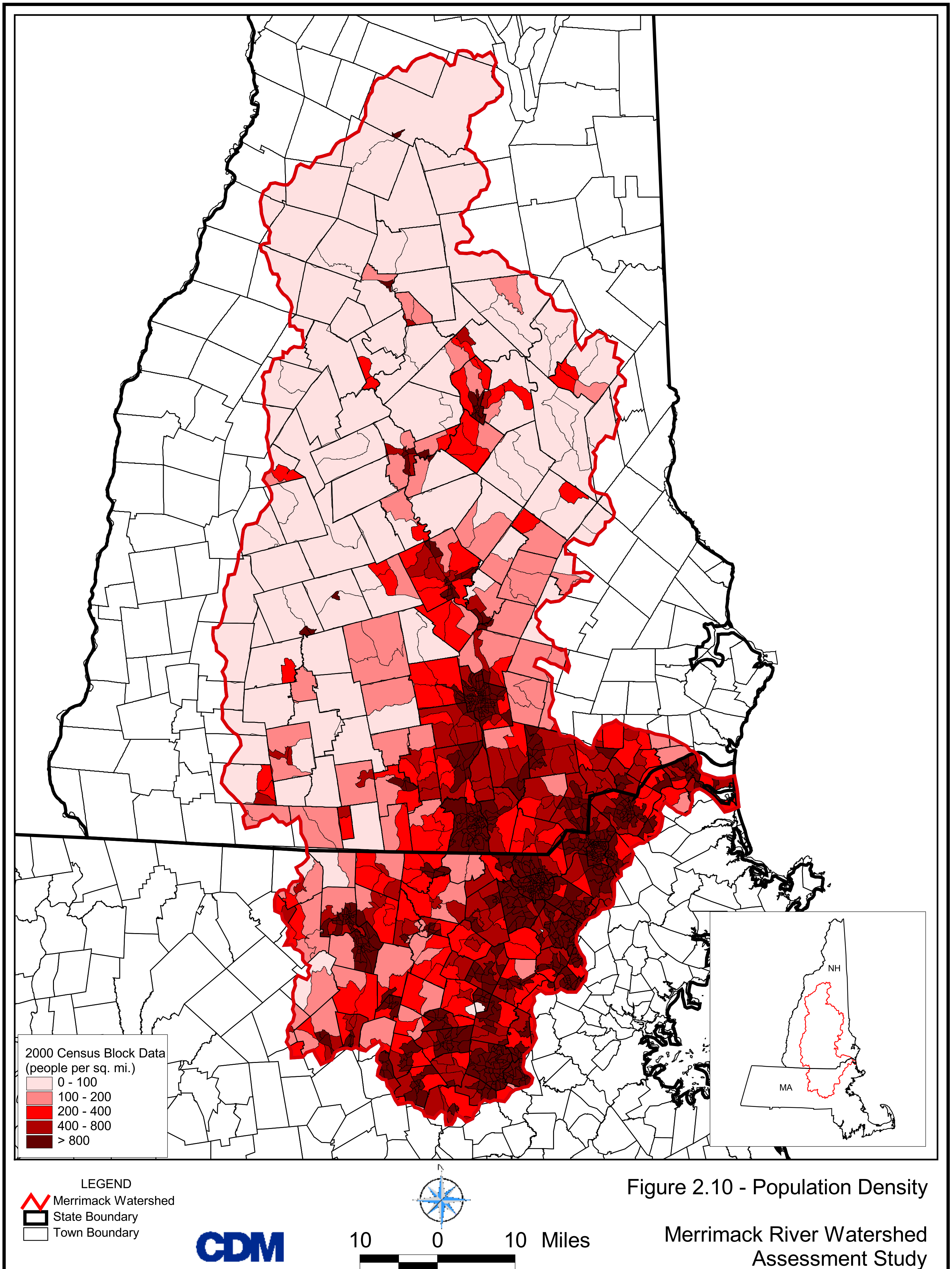


Figure 2.10 - Population Density

Merrimack River Watershed
Assessment Study

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Section 3
Water Quality

This section of the Existing Conditions report presents a summary of the current and historic water quality sampling programs conducted in the basin, as well as a summary of the current water and sediment quality. This description of existing conditions is based on a review of available resources for data collected in approximately the last ten years. Existing data discussed in this section will be used for reference and comparison purposes in subsequent tasks performed under Phase I of the Merrimack River Watershed Assessment Study. It will not be utilized at the same level as water quality data collected under Phase I of this Study.

The primary water quality data collection agencies in the watershed have been the New Hampshire Department of Environmental Services (NHDES), the Massachusetts Department of Environmental Protection (MADEP), and the U.S. Geological Survey (USGS). Recently, several volunteer monitoring programs have also started collecting data within the watershed with the help of these state agencies and the Merrimack River Watershed Council.

The majority of the water quality data that exists in the basin from MADEP was collected prior to 1990. In 1999, the MADEP initiated a Microbial Indicator Study of the Merrimack River, as well as aquatic benthic macroinvertebrate biomonitoring on major tributaries. NHDES also collected water quality and biomonitoring data in the watershed throughout the 1990s. The most recent comprehensive analysis of the River's quality was performed under the Merrimack River Initiative (MRI) during the 1990's. This project was a collaborative effort between the USEPA, NHDES, MADEP, and the New England Interstate Water Pollution Control Commission. The MRI collected water quality samples throughout the basin during one wet-weather and one dry-weather event; benthic macroinvertebrate sampling was also performed. A summary of water quality sampling program is provided in Table 3-1; additional detail on each program is provided in subsequent sections.

Table 3.1: Summary of Water Quality Sampling Programs

Agency	Program	Monitoring Period
New Hampshire Department of Environmental Services	Impaired waters monitoring program	1993- 1996
	Rotating watershed monitoring program	1989- 1993; 1997 to present
	National Water Quality Surveillance System (NWQSS)	1989 to present
	Primary Monitoring Network (PMN)	1989 to present
	Biomonitoring Program	1995 to present
Massachusetts Department of Environmental Protection	"Massachusetts Watershed Initiative" rotating watershed management program	1993 to present
	Microbial Indicator Study	1999

Massachusetts Division of Marine Fisheries	Shellfish bed sampling	On-going
USGS	National Water Quality Assessment Program (NAWQA)	On-going
Merrimack River Initiative (MRI)	Dry and wet-weather monitoring, biomonitoring	1994 and 1995
Water and Wastewater Treatment Facilities	Various locations in the watershed	On-going
Volunteer Monitoring Programs	Soucook River Watershed Project	1999 to present
	Upper Merrimack River Local Advisory Committee	1996 to present
	Piscataquog Watershed Association	1991 and 1992
	Nashua River Watershed Association	1993 to present
	Merrimack River Watershed Council	1999- 2001

Both Massachusetts and New Hampshire categorize waters according to their use class. Each class is associated with a series of designated uses; the ability of a waterbody to support these uses is assessed based on its ability to meet the applicable water quality standards. In New Hampshire, designated use categories include swimming (primary contact recreation), fish and shellfish consumption, drinking water, and aquatic life support. In Massachusetts, these uses include fish consumption, aquatic life support, drinking water, shellfishing, primary contact recreation (swimming), and secondary contact recreation (boating). In both states, the recreation and shellfish standards are based on human health concerns. E. coli and fecal coliform bacteria are used in New Hampshire and Massachusetts, respectively, as indicators of the possible presence of pathogens in surface waters and the risk of disease, based on epidemiological evidence of gastrointestinal disorders from the ingestion of contaminated waters. Contact with contaminated waters can also lead to ear or skin infections, and inhalation of contaminated water can cause respiratory diseases (http://www.epa.gov/OST/beaches/local/sum2.html#intro).

In general, the most recent statewide surface water assessments published by Massachusetts and New Hampshire in 2002 show that bacteria (*E. coli* and fecal coliform) is the largest cause of water quality violations in the Merrimack River mainstem. This translates into a non-supporting use of primary and secondary contact recreation in the majority of the River downstream of Manchester, New Hampshire. The New Hampshire assessment report lists combined sewer overflows as the primary cause of these violations; Massachusetts does not provide a similar listing. The Massachusetts assessment report also lists metals, nutrients, and priority organics as significant problems along the mainstem, resulting in a non-attainment of the aquatic life use. Additionally, the recent MRI study also discovered exceedances of water quality standards for lead and zinc in the lower portion of the River during wet and dry-weather conditions, affecting aquatic life in the river. Table 3-2 provides a summary of the major causes of non-supporting use in the Merrimack River mainstem based on the state's 2002 assessment reports. Further information is provided in Section 3.5.

Table 3.2: Causes of Non-support in the Merrimack River Mainstem

Pollutant	Listed Miles/ Area[1]			Non-supporting Use
	NH	*MA*	*Total*	
Pathogens	19.82 mi	27.9 mi, 7.14 mi^2	47.72 mi, 7.14 mi^2	Primary and secondary contact recreation, shellfishing (MA only)
Metals	---	20.8 mi	20.8 mi	Not listed
Nutrients[2]	---	18.7 mi	18.7 mi	Not listed
Priority Organics	---	15.9 mi, 6.97 mi^2	15.9 mi, 6.97 mi^2	Not Listed
pH	4.88 mi	---	4.88 mi	Aquatic Life
Unionized Ammonia	---	4.37mi^2	4.37mi^2	Not Listed
Flow Alteration	0.59 mi	---	0.59 mi	Aquatic Life

[1]Area (in mi^2) is provided for the tidally influenced portion of the basin in Massachusetts
[2]Massachusetts does not specify which nutrients are a problem; however, phosphorus is generally the limiting nutrient in freshwater and nitrogen is the limiting nutrient in marine waters.
Source: MADEP 2002, NHDES 2002

Elevated bacteria levels were also identified as a major problem on many of the tributaries to the Merrimack River, particularly in the Massachusetts portion of the basin, translating into a non-supporting use for primary and secondary contract recreation in the listed areas. Additionally, violations of the pH criteria for aquatic life support were identified in a majority of the New Hampshire tributaries. The Massachusetts assessment report listed metals, nutrients, and organic enrichment/ low dissolved oxygen as the other top causes of designated use non-attainment. The MRI study also discovered elevated levels of lead during wet and dry-weather in the Sudbury/Assabet/Concord (SuAsCo) and Nashua River watersheds, as well as elevated copper concentrations in the SuAsCo watershed.

3.1 Sampling Programs

The following section presents a summary of the historic and current sampling programs conducted in the Merrimack River watershed. The primary sources for this information included:

- New Hampshire Department of Environmental Protection (NHDES)
- Massachusetts Department of Environmental Protection (MADEP)
- Massachusetts Division of Marine Fisheries (DMF)
- United State Geological Survey (USGS)

- Merrimack River Initiative (MRI)

New Hampshire Department of Environmental Services:

In 1989, the New Hampshire Department of Environmental Services (NHDES) implemented a rotating watershed monitoring program based on the following division of state water resources: (1) the Connecticut River, (2) the Merrimack River, and (3) the combined Androscoggin, Saco, Piscaraqua, and coastal river basins. The intent was to monitor each basin at least once every three years; the Merrimack River basin was sampled in 1990. Between 1993 and 1996, NHDES altered its program to focus on waterbodies included on the list of potentially impaired waters from the 1994 and 1995 305(b) reports. The rotating sampling program was resumed in 1997 and the Merrimack River was again the focus for 1999. Sampling parameters typically included *E. coli*, dissolved oxygen, temperature, conductivity, pH, chlorophyll a, biological oxygen demand (BOD), alkalinity, hardness, metals (aluminum, copper, lead, zinc), turbidity, total solids, total suspended solids, nitrate, ammonia, total kjeldahl nitrogen (TKN), and total phosphorus. Recently, the NHDES has also conducted intensive water quality surveys on the Contoocook River as a part of separate study to determine the Total Maximum Daily Load (TMDL) for the river on dissolved oxygen.

In 1989, the state also developed five National Water Quality Surveillance System (NWQSS) and 12 Primary Monitoring Network (PMN) trend stations located throughout the state, nine of which are located in the Merrimack River basin (four on the mainstem, five on the tributaries). These 17 trend stations have been sampled three times a year since 1989 during the summer months of June, July, and August.

In 1995, the NHDES also implemented a biomonitoring program in order to assess the biological health and integrity of the state's aquatic ecosystems. Between 1997 and 2001, 55 sites throughout the Merrimack River watershed were monitored. Data collected includes information on aquatic macroinvertabrates and resident fish communities, an assessment of riparian habitat and land uses, and standard physical and chemical water quality parameters.

Massachusetts Department of Environmental Protection (MADEP):

The Technical Services Branch of the MADEP conducted surveys of the Merrimack River every two to five years between 1968 and 1989, with the results published in a comprehensive data report. These programs typically focused on monitoring during low-flow, dry-weather conditions that generally represented the "worst case" scenario with respect to the impact of point source discharges on receiving water quality.

In 1990, the Technical Services Branch undertook an extensive study of the water quality, wastewater discharges, and drinking water withdrawals in the Merrimack

River, with assistance from USEPA Region 1. Eleven stations were sampled on the Merrimack and Concord Rivers during dry-weather in June, July, and August. Three major NPDES discharges in the study area (the Lowell WWTP, the Greater Lawrence WWTP, and AT&T WWTP in North Andover) and the influent/effluent of two major drinking water treatment plants (Methuen and Tewksbury, Massachusetts) were also sampled. Wet-weather sampling was conducted at the same 11 stations and the two water treatment plants for three events. Sample parameters included standard chemical measurements, metals, and bacteria.

In 1993, the MADEP implemented a phased, rotating watershed management schedule for water quality assessments, permitting, and non-point source pollution control under the "Massachusetts Watershed Initiative." This program takes advantage of a five-year planning process, which includes outreach and reconnaissance, information/data development, water resources assessment, planning, implementation, and evaluation. In November 2001, the MADEP released the "*Merrimack River Basin - 1999 Water Quality Assessment Report*" (excluding the Nashua, Concord, and Shawsheen River basins). The report is based upon information gathered by the MADEP during the first two years of the watershed assessment cycle, including historic water quality data and limited sampling conducted by DEP's Division of Watershed Management (DWM) between April and September 1999 (excluding June). Sampling components included macroinvertebrate biomonitoring and habitat quality evaluations at five tributaries (Cobbler's Brook, Stony Brook, Spicket River, Beaver Brook, and Fish Brook), baseline lake monitoring, and fish toxic monitoring.

In 1999, the MADEP also initiated a Microbial Indicator Study of the Merrimack River, which consists of monitoring at 11 stations within the watershed, primarily around existing WWTP, water treatment plants, and CSO discharges. The project was scheduled to end in Fall 2001; final results are currently not available. Preliminary data tables were published in an appendix of the *1999 Water Quality Assessment Report*.

In February 2002, the MADEP published the draft "*Total Maximum Daily Load of Bacteria for the Shawsheen River Basin*." The study is based upon fecal coliform data collected by the MADEP at eight stations in 1989 and 16 stations in 1995-1996, and by the Merrimack River Watershed Council (MRWC) at three stations in 1996, 35 stations in 1997, and 24 stations in 1998. Both the MADEP and MRWC sampling programs ran between June and October.

Massachusetts Division of Marine Fisheries (DMF):

The DMF conducts fecal coliform monitoring as part of their Sanitary Surveys, which are used to assign classifications to shellfishing beds. These surveys are conducted at least every 12 years. Additionally, the Newburyport office of the DMF typically collects grab samples in the Merrimack River shellfishing beds between eight and 12 times a year, although no formal monitoring program exists. The samples are analyzed for fecal coliform, salinity, and temperature. Sample collection is usually triggered by rainfall events, which often cause spikes in the observed bacterial concentrations.

USGS - National Water Quality Assessment Program (NAWQA):

The goal of the NAWQA Program is to evaluate the status and trends in the quality of the nation's surface and groundwater water resources. The USGS operates one NAWQA station in the Merrimack River watershed in the mainstem below the confluence with the Concord River at Lowell, Massachusetts (01100000); this is located in the New England Coastal Basins (NECB) study unit. This station has approximately 243 samples taken between 1953 and 2000. Intensive monitoring (monthly plus extreme event sampling) began in October 1998 and continued through September 2001; low-intensity monitoring began in October 2001 and will continue through September 2007. Low-intensity monitoring is conducted at select locations in the NECB that were assessed during the high-intensity phase. Samples are analyzed for suspended solids, major ions, nutrients, organic carbon, and dissolved pesticides; no information was available on the frequency of the low-intensity monitoring.

Merrimack River Initiative (MRI):

The NHDES, MADEP, and USEPA, working under the MRI, conducted biomonitoring and ambient water quality surveys of the mainstem Merrimack and its significant tributaries during the summers of 1994 and 1995. The following tasks were performed:

- Ambient dry-weather testing was conducted on August 26, 1994 at 56 stations throughout the watershed (22 on mainstem, 34 on tributaries). The sampling consisted of water-column grab samples that were analyzed for nutrients, bacteria, dissolved oxygen, conductivity, pH, temperature, and hardness; total and dissolved metals were analyzed at 53 of the stations. Chronic toxicity testing was also performed at the same 53 stations; tests were conducted over a seven-day period using the test organism *Ceriodaphnia dubia*.

- Wet-weather monitoring was performed on October 28, 1995 during a rainstorm averaging 0.9 inches over the basin. Samples were collected at twenty stations (ten mainstem, ten tributary) throughout the watershed and analyzed for total and dissolved metals, nutrients, bacteria, solids, total organic carbon, dissolved oxygen, conductivity, pH, and temperature. Sampling stations were concentrated around more urbanized areas (Concord, New Hampshire south to Haverhill, Massachusetts).

- Benthic macroinvertebrate sampling was also conducted at 44 locations throughout the basin (ten mainstem, 34 tributary). Artificial substrates were deployed in August 1994 and collected seven weeks later after a colonization period.

The results of the MRI study were published in November 1996 as the "*Merrimack River Bi-State Water Quality Report, Part One*" and the "*Merrimack River Bi-State Biomonitoring Report, Part Two*."

Water and Wastewater Treatment Facilities:

Public water suppliers withdrawing from the Merrimack River are required by the Safe Drinking Water Act to perform intake water quality measurements at varying frequencies. Wastewater Treatment Facilities (WWTF's) are also required to conduct outfall sampling in accordance with their National Pollutant Discharge Elimination System (NDPES) permits. In both Massachusetts and New Hampshire the NPDES program is administered directly by the USEPA. Additional information on the number and location of water and wastewater treatment facilities in the watershed is provided in Sections 4.3 and 5.1, respectively. Limited water quality data is available online from the water and wastewater treatment facilities' monitoring programs through the USEPA's Permit Compliance System (PCS) database at (http://www.epa.gov/enviro/html/pcs/).

In 1999 and 2000, the Lowell Regional Wastewater Utility conducted monthly monitoring at five stations along the mainstem Merrimack River. Unfortunately, however, this data did not meet USEPA's and MADEP's minimum data acceptability requirements for use in the 305(b) reports.

Volunteer Monitoring Programs:

Soucook River Watershed Project. Members of the Soucook River Watershed Project worked with the NHDES Volunteer River Assessment Program (VRAP) to develop a volunteer monitoring program in 1999. The goal of the program is to establish baseline water quality data in the watershed.

Upper Merrimack River Local Advisory Committee (UMRLAC). The UMRLAC was established in 1995 through a joint effort of the NHDES and the Merrimack River Watershed Council (MRWC). The group began by monitoring seven sites the first year on the Pemigewasset, Winnipesaukee, Contoocook, and Merrimack Rivers north of Franklin, New Hampshire. In 1996, the team established an additional four sites on the Merrimack between Concord, New Hampshire and Garvin's Falls. These 11 sites are currently sampled every other week for eight to ten weeks during the summer and fall; data collected includes *E. coli*, field chemistry, habitat assessment, and benthic invertebrates.

Piscataquog Watershed Association (PWA). During the summers of 1991 and 1992, the PWA, in association with the NHDES, conducted surveys of macroinvertebrate communities at six stations in the Piscataquog River. Water quality samples were also collected at nine stations within the basin and analyzed for standard chemical and physical parameters, as well as for total phosphorus and *E. coli* bacteria.

Nashua River Watershed Association (NRWA). Since 1993, NRWA has collected up to 40 water samples along the Nashua River on a monthly basis from April through October with the intent of establishing baseline water quality data in the basin. Samples are typically analyzed for pH, temperature, alkalinity, dissolved oxygen, fecal and total coliform, and *E. coli* (in New Hampshire). In 2000, NRWA also sampled benthic macroinvertebrates.

Merrimack River Watershed Council (MRWC). The MRWC supports and directs numerous "Stream Teams" throughout the Merrimack River Watershed. Currently, efforts are focused on the Bare Meadow Brook, Cobbler's Brook, and Stony Brook. In 2000 and 2001, monthly water quality sampling was performed at three sites on the Bare Meadow Brook, three sites on the Cobbler's Brook, and 16 sites in the Stony Brook watershed from June through November. In July 2001, the Merrimack River Watershed Council published the "*Stony Brook Watershed Assessment*." In 1999, MRWC also published shoreline surveys and action plans for Cobbler's Brook, Bare Meadow Brook, Salmon Brook, and Lawrence Brook.

Other. The NHDES Volunteer River Assessment Program (VRAP) is also assisting the Lower Merrimack Monitoring Program (for the Souhegan, Nashua, and Lower Merrimack Rivers) and the Harris Center for Education in the Contoocook River watershed.

Other Studies:

Various other organizations and individuals have collected water quality data along the Merrimack River. In the early 1990s, the Massachusetts Bays Program studied organic loadings from the Merrimack River to the Massachusetts Bay. Five samples were collected at eight monitoring stations in the Merrimack River estuary and Massachusetts Bay between April 1992 and May 1993. Water and sediment samples were analyzed for polyaromatic hydrocarbons (PAH's), pesticides, and polychlorinated biphenyls (PCB's). A final report was published in 1995.

A two-year study of the Merrimack River was undertaken by Marie M. Studer, a Ph.D. candidate at the University of Massachusetts-Boston, between January 1989 and April 1991. Surface water samples were collected at twenty stations along the Merrimack River mainstem, Pemigewasset River, and Winnipesaukee River; the samples were analyzed for select total and dissolved metals, pH, and particulate organic carbon. Two sediment cores were also taken from Indian River Shoal, a tidal freshwater marsh on the Merrimack River in West Newbury; these will be further discussed in Section 3.5.

3.2 Designated Uses

This section provides a summary of the designated uses as well as the assessment criteria for the states of New Hampshire and Massachusetts.

New Hampshire:

The State of New Hampshire has designated the following two "Use Classes" that govern the baseline water quality required to protect a waterbody's intended uses:

- **Class A:** Highest quality waters considered acceptable for use as public water supply after adequate treatment. Discharge of sewage or waste is prohibited to Class A waters.

- **Class B:** Waters considered acceptable for fishing, swimming, and other recreational purposes; acceptable for use as public water supply after adequate treatment.

Massachusetts:

The Massachusetts Surface Water Quality Standards (SWQS) designate the most sensitive uses for which the surface waters of the state shall be enhanced, maintained, and protected; the state prescribes minimum water quality criteria required to sustain the designated uses (MADEP 2001). Massachusetts has developed separate use classifications for both inland and coastal waters, as follows:

Inland Waters:

- **Class A:** "These waters are designated as a source of public water supply. To the extent compatible with its use, they shall be an excellent habitat for fish, other aquatic life and wildlife, and suitable for primary and secondary contact recreation. These waters shall have excellent aesthetic value. These waters are designated for protection as Outstanding Resource Waters (ORW) under 314 CMR 4.04(3)."

- **Class B:** "These waters are designated as habitat for fish, other aquatic life and wildlife, and for primary and secondary contact recreation. Where designated, they shall be suitable as a source of water supply with appropriate treatment. They shall be suitable for irrigation and other agricultural uses and for compatible industrial cooling and process uses. These waters shall have consistently good aesthetic value."

- **Class C:** "These waters are designated as a habitat for fish, other aquatic life, and wildlife and for secondary contact recreation. These waters shall be suitable for the irrigation of crops used for consumption after cooking and for compatible industrial cooling and process uses. These waters shall have good aesthetic value" (MADEP 1996).

Inland waters may also be further classified as cold water or warm water fisheries; these distinctions will be further discussed in Section 4.1.2. The State also allows the reclassification of waters impacted by CSO discharge to Class B (CSO), since the development and implementation of Long-Term Control Plans (LTCPs) is not yet complete.

Coastal and Marine Waters:

- **Class SA:** "These waters are designated as an excellent habitat for fish, other aquatic life and wildlife and for primary and secondary contact recreation. In approved areas, they shall be suitable for shellfish harvesting without depuration (Open Shellfishing Areas). These waters shall have excellent aesthetic value."

- **Class SB:** "These waters are designated as a habitat for fish, other aquatic life and wildlife and for primary and secondary contact recreation. In approved areas they shall be suitable for shellfish harvesting with depuration (Restricted Shellfishing Areas). These waters shall have consistently good aesthetic value."

- **Class SC:** "These waters are designated as a habitat for fish, other aquatic life, and wildlife and for secondary contact recreation. They shall also be suitable for certain industrial cooling and process uses. These waters shall have good aesthetic value." (MADEP 1996).

Table 3.3 presents a summary of the water use classifications for mainstem and tributary segments in the Merrimack River Watershed in Massachusetts. Currently, all river segments in the basin are rated as Class A or B. Based on a personal communication with Ken Edwardson, Water Quality Specialist, at NHDES on September 19, 2002, New Hampshire currently has a draft Legislative classification as well, which is currently not approved for public distribution. However, all segments in the watershed are classified as either Class A or B.

Table 3.3: Designated Water Class in the Merrimack River Watershed for Massachusetts

Use Class	River Segment
Class A	• Powwow River, outlet of Tuxbury Pond to inlet Lake Gardner • Fish Brook, entire length and those tributaries thereto
Class B	• Beaver Brook, state line to confluence • Cobbler Brook, entire length • Merrimack River, state line to Pawtucket Dam (Treated Water Supply) • Merrimack River, Pawtucket Dam to Essex Dam, Lawrence (Treated Water Supply, CSO) • Merrimack River, Essex Dam, Lawrence to Creek Brook, Haverhill (CSO) • Stony Brook, entire length • Spicket River, state line to confluence with the Merrimack River • Little River, state line to confluence with the Merrimack River • Powwow River, outlet Lake Gardner to tidal portion
Class SA	• The Basin in Merrimack River Estuary, Newbury and Newburyport • Plum Island River, entire length (ORW) • Plum Island Sound (ORW) • Plumbush Creek, Little Pine Creek, Pine Island Creek and Jericho Creek (ORW)
Class SB	• Merrimack River, from Creek Brook, Haverhill to Atlantic Ocean (CSO) • Powwow River, tidal portion

Source: MADEP 2001

Assessment of Use:

Both Massachusetts and New Hampshire express the ability of a river segment to meet current water quality standards in terms of the segment's ability to support "designated uses." River segments are classified as "fully supporting" (all designated uses are fully supported), "partially supporting" (one or more uses partially supported, other uses fully supported), or "not supporting" (one or more uses not supported). Both states use the following three categories of water quality assessment status to determine river conditions:

- **Evaluated waters** - Waters where assessments are based on ambient water quality information that is greater than five years old or best professional judgment where there is limited or no ambient data

- **Monitored waters** - Waters where assessments have been based on reliable ambient water quality information collected within the past five years

- **Assessed waters** - Waters that were either monitored or evaluated

The majority of New Hampshire's waters fall into the "monitored" category, while most Massachusetts waters are "evaluated," since the bulk of the water quality data in the state was collected prior to 1990 (Donovan and Diers 1997).

The designated uses for New Hampshire waters include swimming (primary contact recreation), fish and shellfish consumption, drinking water, and aquatic life support. Designated uses in Massachusetts include aquatic life, fish consumption, drinking water, shellfish harvesting, primary contact recreation (*i.e.*, swimming), and secondary contact recreation (*i.e.*, boating) (Donovan and Diers 1997). Table 3.4a and 3.4b present summarizes the New Hampshire and Massachusetts guidelines for designated use classification as fully, partially, or not supporting. It is important to note that Massachusetts and New Hampshire currently use different indicator organisms to assess the primary and secondary contact recreation support-Massachusetts uses fecal coliform and New Hampshire uses E. coli. However, Massachusetts is planning on moving to an E. coli standard as well during 2003.

Table 3.4a: New Hampshire Guidelines for Use Classification

Use	Fully Supporting	Partially Supporting	Not Supporting
Primary Contact Recreation (swimming)	**Bacteria** - No confirmed exceedances of State standards **Bathing Area Closures**- No known beach closures or restrictions during the reporting period **Nuisance Plant Growth** - No algal blooms or macrophyte growth that interfere significantly with swimming	**Bacteria** - The source of bacteria is from CSO's or natural sources; fecal coliform measurements in freshwater (not from natural sources) exceed the state single sample standard for E. coli **Bathing Area Closures**- On the average, there is no more than one bathing area closure per year of less than one-week duration. Bathing closures are due to natural sources or heavy swimming.	**Bacteria** - There are known violations of the state's bacteria standard **Bathing Area Closures**- One or more bathing area closures per year of greater than one week duration, or more than one bathing area closure per year and not due to natural sources or heavy swimming
Primary Contact Recreation (swimming)-cont'd		**Nuisance Plant Growth**- Frequent and persistent algal blooms and / or excessive native macrophyte growth and / or exotic macrophyte growth occur that interfere with swimming	
Fish / Shellfishing Consumption	No fish or shellfishing "restricted consumption" or "no consumption" advisories or bans are in effect	"Restricted consumption" advisories in effect for subpopulation	"No consumption" advisories in effect for general population

Use	Fully Supporting	Partially Supporting	Not Supporting
Drinking Water	**Finished water** - no drinking water contaminants with exceedances of SDWA **Restrictions** - No source water closures or advisories lasting <30days, no more than conventional treatment required	**Finished water** - no exceedances other than occasional bacteria associated with operator/ equip failure **Restrictions** - One or more drinking water source advisories >30days, or more source waters requiring beyond traditional treatment	**Finished water** - one or more confirmed SDWA exceedances **Restrictions** - one or more contamination based closures
Aquatic Life Support	**DO & pH** - No known violations of state standards **Toxicants** - No known violations of state standards. No exceedance of WET tests **Bioassessments** - NYDEC bioassessment model >64% affinity, taxa richness of >15, EPT >10, habitat value of >150	**DO** - One or more violations of the state standards **pH** - One or more confirmed exceedances of pH with <6.5 and >6.0 or >8.5 and <9.0 **Toxicants** - One or more violations of any acute WQ criteria. WET tests show organisms may be adversely affected.	**DO** - Minimum conc. <5mg/l **pH** - One or more exceedances >6.0 or >9.0 **Bioassessment** - NYDEC model <35% affinity, EGT <2, taxa richness <5, habitat assessment <50 **Habitat** - Several habitat parameters in the "poor" category
Aquatic Life Support- cont'd	**Habitat** - within naturally occurring conditions	**Bioassessment** - NYDEC model 35-64% affinity, taxa richness 5-15, EPT values 2-10, habitat assessment 50-150 **Habitat** - "marginal" conditions in one or more category or significant erosion	

Source: NHDES 2000

Table 3.4b: Massachusetts Guidelines for Use Classification

Use	Fully Supporting	Partially Supporting	Not Supporting
Fish Consumption	No advisories/bans in effect.	A "restricted consumption" fish advisory is in effect for the general population or sub-population.	"No consumption" advisory or ban in effect for the general population or sub-population for one or more species; or there is a commercial fishing ban in effect.
Aquatic Life	Data available clearly indicates support. Minor excursions from chemical criteria may be tolerated if the biosurvey results demonstrate support.	Uncertainty about support in the chemical or toxicity testing data, or there is some minor modification of the biological community. Excursions are not frequent or prolonged.	There are frequent or severe violations of chemical criteria, presence of acute toxicity, or a moderate or severe modification of the biological community.
Drinking Water	No closures or advisories (no contaminants with confirmed exceedances of maximum contaminant levels, conventional treatment adequate to maintain supply).	One or more advisories or more than conventional treatment is required.	One or more contamination-based closures of the water supply.
Shellfishing	**SA Waters** - open for harvest without depuration **SB Waters** - open for harvest without depuration (Open, conditionally approved, restricted areas)	**SA Waters** - seasonally closed/ open, conditionally approved/restricted **SB Waters** - seasonally open/closed, conditionally restricted areas	**SA Waters** - prohibited areas **SB Waters** - prohibited areas
Primary Contact Recreation (swimming)	Criteria are met, no aesthetic conditions preclude the use.	Criteria are exceeded intermittently (neither frequent nor prolonged), marginal aesthetic violations.	Frequent or prolonged violations of criteria, formal bathing area closures, or severe aesthetic conditions that preclude the use.
Secondary Contact Recreation (boating)	Criteria are met, no aesthetic conditions preclude the use.	Criteria exceeded intermittently (neither prolonged nor frequent), marginal aesthetic violations.	Frequent or prolonged violations of criteria, or severe aesthetic conditions that preclude use.

Source: McVoy 2000, MADEP 2002a

3.3 Water Quality in the Merrimack River Mainstream

A 1997 report on water quality published by the Merrimack River Initiative found that of the assessed portion of the Merrimack River mainstem watershed, 126 miles did not support their designated uses, 33.75 miles partially supported their uses, and 67.2 miles fully supported their uses (Note: MRI's definition of the "Merrimack River mainstem watershed" includes the Merrimack River proper, Beaver Brook, Cohas Brook, Little River, Piscataquog River, Powwow River, Salmon River, Shawsheen River, Soucook River, Souhegan River, Spicket River, Stony Brook, Suncook River, and Winnipesaukee River). The MRI report was based on a compilation of data from the 1996 New Hampshire 305(b) report (based primarily on data from the 1994 and 1995 NHDES ambient water quality monitoring), the 1994 Massachusetts 305(b) report, the MRI Bi-State Water Quality Assessment, and various other water quality surveys and reports (see Donovan and Diers 1997).

3.3.1 2002 New Hampshire and Massachusetts 303(d) Lists

The Federal Water Pollution Control Act (commonly called the Clean Water Act [CWA]), as last reauthorized by the Water Quality Act of 1987, requires each state to submit two surface water quality documents to the USEPA every two years. Section 305(b) of the CWA requires the submittal of a report (known as the 305(b) report), that describes the quality of its surface waters and provides an analysis of the extent to which all such waters are able to support their designated uses as defined by the state's water quality standards. Section 303(d) of the CWA requires the submittal of a list (the "303(d) List") that provides an inventory of those waterbodies that are:

- Impaired or threatened by a pollutant or pollutants
- Not expected to meet water quality standards within a reasonable time even after application of best available technology standards for point sources or best management practices for non-point sources, and
- Require the development of a Total Maximum Daily Load (TMDL) (NHDES 2002)

In the past, both Massachusetts and New Hampshire submitted separate 305(b) Reports and 303(d) Lists to the USEPA. However, in an effort to simplify the reporting process, USEPA recently developed guidance to facilitate the integration of the 305(b) and 303(d) reports. In November 2001, USEPA released guidance on the preparation of an "Integrated List of Waters", which allows states to provide the status of all their assessed waters in a single multi-part list. States choosing this option must list each waterbody or segment thereof in one of the following five categories (MADEP 2002):

- **Category 1:** Unimpaired and not threatened for all designated uses;
- **Category 2:** Unimpaired for some uses and not for others;

- **Category 3:** Insufficient information to make assessments for any uses;
- **Category 4:** Impaired or threatened for one or more uses but not requiring the calculation of a TMDL, in accordance with the following three subcategories:
    - **Category 4a:** Impaired or threatened for one or more designated uses with a completed TMDL
    - **Category 4b:** Impaired or threatened for more designated uses but does not require the development of a TMDL because other pollution control requirements are reasonably expected to result in attainment of water quality standards in the near future
    - **Category 4c:** Impaired or threatened for one or more designated uses but does not require the development of a TMDL because the impairment is not caused by a pollutant
- **Category 5:** Impaired or threatened for one ore more uses and requiring a TMDL

Thus, the waters listed in Category 5 constitute the 303(d) List and, as such, are reviewed and approved by the USEPA. The remaining four categories are submitted in fulfillment of the requirements under Section 305(b), essentially replacing the 305(b) Report.

The new USEPA guidelines also specify that each state submit a comprehensive assessment and listing methodology and detailed monitoring strategy as part of the integrated list package. The Consolidated Assessment and Listing Methodology (CALM) was published by USEPA in its final form in September 2002; thus it was not implemented by all states in developing the 2002 integrated list.

New Hampshire

In December 2002, the NHDES published the "State of New Hampshire 2002 Section 305(b) and 303(d) Consolidated Assessment and Listing Methodology and Comprehensive Monitoring Strategy". They were one of the first states in the nation to use the new CALM approach, as published by USEPA in September 2002 (NHDES 2002). For the purposes of this assessment, NHDES divided each waterbody up into "Assessment Units" (AU). In general, the AU's are the basic unit of record for conducting and reporting the results of all water quality assessments (NHDES 2002). The CALM states that the AU's are intended to be representative of homogeneous segments; thus sampling stations in the AU's are assumed to be representative of the entire segment.

Data used in the 2002 assessment process were collected from a variety of sources, including non-profit environmental organizations (*i.e.* Appalachian Mountain Club), federal agencies (*i.e.* USGS and U.S. Fish and Wildlife Service), state universities, municipalities, state volunteer monitoring programs, NHDES monitoring programs, the 1998 303(d) list, and the 2000 303(b) Report. For rivers and streams, the maximum age of data eligible for making assessments was five years (1997 inclusive to present); any data collected prior to that time was not assessed. The data age requirement applied in all cases, except where waters were previously listed as threatened or impaired (*i.e.* on the 1998 303(d) List). In such cases, the data used to make the original assessment (regardless of age) was included in the reassessment provided that it was of good quality and met the minimum number of samples requirements specified in NHDES' CALM.

In addition to the CALM document, NHDES published the following two assessment lists:

- New Hampshire Draft 2002 List of Threatened or Impaired Waters that do not Require a TMDL

- New Hampshire Draft 2002 List of Threatened or Impaired Waters that Require a TMDL (*i.e.* the 303(d) List)

NHDES broke these list into following categories: (1) estuary, (2), freshwater lake, (3) impoundments, (4) ocean, and (5) river. A summary of the listed segments on the Merrimack River mainstem from the first table "Waters that do not require a TMDL" is provided in Table 3.5; no segment of the mainstem River are listed on the second table "Waters that require a TMDL". However, although not explicitly shown on this list, all waters in the state are listed on the second table as a result of the statewide ban on fish consumption due mercury contamination.

Approximately 20-miles of the mainstem Merrimack River downstream of Manchester, New Hampshire are listed as not supporting primary recreation due to exceedances of the E. coli standard as a result of CSO discharges. An additional 4.8-mile segment is listed as not supporting aquatic life based on pH requirements (source unknown), and three reaches downstream of the Amoskeag Dam, Hooksett Dam, and Garvins Fall By-passes are listed as not supporting aquatic life due to flow alteration. It is important to note that no segments of the Merrimack River mainstem in New Hampshire require a TMDL.

Table 3.5: 2002 CALM listed Merrimack River mainstem segments in New Hampshire for "Waters that do not require a TMDL"

Type	Description	Not Supporting Use	Cause	Suspected Sources	Size
Impound-ment	Amoskeag Dam	Primary Contact Recreation	E. coli	CSO's	443 ac
River	Garvins Falls By-pass	Aquatic Life	Flow Alt.	Hydrostructure	0.12 mi
	Hooksett Dam By-pass	Aquatic Life	Flow Alt.	Hydrostructure	0.11 mi
	Amoskeag Dam By-pass	Aquatic Life Primary Contact Recreation	Flow Alt. E. coli	Hydrostructure CSO's	0.36 mi
	Merrimack River (NHRIV700060803-14-01)	Primary Contact Recreation	E. coli	CSO's	5.01 mi
	Merrimack River (NHRIV700060804-11)	Primary Contact Recreation	E. coli	CSO's	5.74 mi
	Merrimack River (NHRIV700061002-13)	Primary Contact Recreation	E. coli	CSO's	3.83 mi
	Merrimack River (NHRIV700061401-04)	Aquatic Life Primary Contact Recreation	pH E. coli	Unknown CSO's	4.88 mi

Source: NHDES 2002

Massachusetts

In October 2002, MADEP published the following two documents in response to the new USEPA reporting requirements:

- Massachusetts Year 2002 Integrated List of Waters. Part 1- Context and Rationale for Assessing and Reporting the Quality of Massachusetts Surface Waters

- Massachusetts Year 2002 Integrated List of Waters. Part 2- Proposed Listing of Individual Categories of Waters

Unlike New Hampshire, MADEP did not publish a report in accordance with USEPA's September 2002 CALM guidelines; however, it did conform to the November 2001, "Integrated List of Waters" specifications.

Data used in the 2002 assessment was collected from variety of sources, including non-governmental organizations, state and federal programs, as well as reports resulting from Massachusetts Watershed Initiative (MWI) grants or funded through section 314, 319, 104, or 614(b) of the CWA (MADEP 2002). Data and supporting information older than five years was generally considered "historical" and was used primarily for descriptive purposes. However, the data was used for support determination if it was known to reflect current conditions (MADEP 2002).

Per the classifications described on page 3-15, no waters in Massachusetts were listed in Category 1 as a result of the statewide health advisory on fish consumption due to mercury contamination. Additionally, no waters were listed in Category 4b- "Waters expected to attain all designated uses in the new future", due to a lack of clarity in USEPA guidance documents on time frame for attainment of all designated uses. No segments from the Merrimack River mainstem were listed in Categories 2, 3, 4a, and 4c. Table 3.6 provides a summary of the segments listed in Category 5- "Waters requiring a TMDL" for the Merrimack River mainstem.

Table 3.6: 2002 Category 5[1] listed waters in the Massachusetts portion of the Merrimack River Mainstem

Mainstem Segment	Assessment Date	Size	Pollutant Requiring a TMDL
State line at Hudson, NH / Tyngsboro, MA to Pawtucket Dam, Lowell, MA	August 2001	9.2 mi	-Metals -Pathogens
Pawtucket Dam to Duck Island, Lowell, MA	August 2001	2.8 mi	-Metals -Nutrients -Flow Alteration[2] -Pathogens
Duck Island, Lowell to Essex Dam, Lawrence	August 2001	8.8 mi	-Priority Organics -Metals -Nutrients -Pathogens
Essex Dam, Lawrence to confluence with Creek Brook, Haverhill	August 2001	7.1 mi	-Priority organics -Nutrients -Pathogens
Confluence with Creek Brook, Haverhill to confluence Indian River, West Newbury	August 2001	2.6 mi^2	-Priority organics -Unionized ammonia -Pathogens
Confluence Indian River, West Newbury to mouth at Atlantic Ocean, Newburyport / Salisbury	August 2001	4.37 mi^2	-Priority organics -Pathogens
The Basin in the Merrimack River Estuary, Newbury / Newburyport	August 2001	0.17 mi^2	-Pathogens

[1]Category 5- Waters requiring a TMDL
Source: MADEP 2002

As noted in Table 3.6, the entire Merrimack River from the New Hampshire state line to the mouth at the Atlantic Ocean is listed in Category 5 (waters requiring a TMDL) for pathogens. Approximately 20 miles of the mainstem River are listed for metals (specific metals are not given), 11.6 miles are listed for nutrients, and 15.9 miles plus 6.97 square miles are listed for priority organics. It should be noted that the Massachusetts' Year 2002 Integrated List of Waters does not specify which metals or nutrients require TMDL. In general, however, phosphorus has generally been found to be the limiting nutrient in freshwaters and nitrogen is the limiting nutrient in marine waters. Unlike New Hampshire, the entire portion of the Merrimack River in Massachusetts requires a TMDL for at least one pollutant.

3.3.2 Other Studies

Massachusetts Department of Environmental Protection

The MADEP's "*Merrimack River Basin - 1999 Water Quality Assessment Report*" lists CSO's, urban runoff, septic systems, and waterfowl populations as the primary sources of bacterial contamination in these six listed segments. The report lists all of the segments as "not assessed" for the secondary contact recreation standard, except for the West Newbury-Atlantic Ocean segment, which is supporting. The Duck Island segment (in Haverhill, MA) does not supporting the primary contact recreation designated use; the West Newbury to Atlantic Ocean segment is supporting; all other segments are "not assessed."

New Hampshire 2000 305(b) Report

The New Hampshire 2000 305(b) Report lists 825.8 miles in the Merrimack River watershed as fully supporting its designated uses (531.8 assessed and 294.0 monitored); 42.5 miles are partially supporting (3.5 assessed and 39.0 monitored); and 8.5 mile are not supporting (100 percent monitored). The report lists four river segments along the mainstem Merrimack as partially supporting due to water quality violations. Three of these segments are listed for wet-weather *E. coli* violations caused by CSO discharges; one site just upstream of the Cohas Brook confluence is listed for chronic wet-weather lead violations (cause unknown). Merrimack River

Merrimack River Initiative

The MRI's Bi-State Water Quality Assessment Report points to a more widespread chronic wet-weather lead problem -- six sampling stations along the mainstem in the New Hampshire and upper Massachusetts portion of the basin exhibited lead violations on October 28, 1995. Five stations in the lower portion of the basin (Massachusetts) showed dry-weather lead (chronic) violations. One site in Manchester, New Hampshire showed wet-weather bacteria (E. coli) violations and one site in Haverhill, Massachusetts showed dry-weather acute zinc violations.

The MRI's 1994 dry-weather sampling for ammonia and nitrate/nitrite did not reveal the presence of any significant untreated sources. For total phosphorus, dry-weather concentrations generally increased with distance downstream and at stations located below impounded segments. Neither state currently has numeric criteria for this parameter; however, samples were well below the critical levels given in EPA's "Gold Book" of *Quality Criteria for Water - 1986*. During wet-weather conditions, concentrations of nitrate/nitrite and total phosphorus increased slightly, but still did not show significant water quality problems. Wet-weather ammonia values were again low, with most falling below the detection limit.

For dissolved oxygen, all wet and dry-weather samples from MRI's sampling program were well within the state's water quality standards, indicating that this is not a limiting factor. The same was true for temperature; however, the MRI notes that higher dry-weather temperatures may have been encountered if the samples were collected during lower flow-conditions. All dry-weather samples on the Merrimack mainstem met the water quality standards for pH; one station at Nashua, New Hampshire exceeded the criteria during the wet-weather survey.

Dry-weather chronic-toxicity tests collected in the watershed as part of the MRI's study indicated that the mortality of the indicator organism, *C. dubia*, was not statistically significantly different from zero; the reproduction rate of the species was statistically significant. The MRI's work shows that acute and chronic toxicity is not widespread in the basin during dry-weather conditions.

3.3.3 Summary

A review of the "Massachusetts Year 2002 Integrated List of Waters" and the "2002 Section 305(b) and 303(d) Consolidated Assessment and Listing Methodology and Comprehensive Monitoring Strategy" for the State of New Hampshire reveals that bacteria (E. coli and fecal coliform) is largest cause of water quality violations along the Merrimack River mainstem in both states. Additionally, in Massachusetts, metals, nutrients, and priority organics also appear to be a significant problem along portions the River. In New Hampshire, CSO's are listed as the primary source of E. coli; Massachusetts does not provide a similar listing. The listed portions of the River in New Hampshire are categorized as "waters not requiring a TMDL". However, in Massachusetts, the entire Merrimack River between the New Hampshire stateline and its mouth at the Atlantic Ocean requires a TMDL for at least one pollutant.

Results of the dry and wet-weather monitoring performed by the MRI indicate that there are exceedances of the chronic/total lead criteria in the lower portions of the basin (south of Manchester) under both conditions. The MRI's discovery of a dry-weather violation of the acute zinc criteria also points to a potential problem in the Haverhill area.

3.4 Water Quality in Significant Tributaries

The MRI's 1997 report on "*Water Quality in the Merrimack River Watershed*" divided the basin into the following five subwatersheds:

- **SuAsCo** - Includes the Concord, Assabet, and Sudbury Rivers
- **Contoocook** - Includes the Contoocook River, Blackwater River, Warner River, and North Branch Contoocook River
- **Merrimack Mainstem** - Includes the Merrimack River, Beaver Brook, Little River, Piscataquog River, Powwow River, Salmon River, Shawsheen River, Soucook River, Souhegan River, Spicket River, Stony Brook, Suncook River, and Winnipesaukee River
- **Nashua** - Includes the Nashua River, Nissitissit River, Squannacook River, North Nashua River, and Wachusett Reservoir
- **Pemigewasset** - Includes the Pemigewasset River, Baker River, Hubbard Brook, Mad River, and Smith River

Table 3.7 presents a summary of the river miles in each major tributary that is fully supporting, partially supporting, and not supporting its designated uses, as provided in MRI's 1997 report. Data for this analysis was taken primarily from the Massachusetts 1994 305(b) Report, the New Hampshire 1996 305(b) Report, and the MRI's Bi-State Water Quality Assessment (Donovan and Diers 1997):

Table 3.7: Status of Designated Use Support in Major Tributaries

Subwatershed	Fully Supporting (mi)	Partially Supporting (mi)	Not Supporting (mi)
SuAsCo	16.1	22.0	54.8
Contoocook	67.6	4.4	0
Nashua	46.3	7.3	11.9
Pemigewasset	71	0	0

Source: Donovan and Diers 1997

SuAsCo Watershed

The primary causes of non-support in the SuAsCo basin are, in order of importance, (1) nutrients, (2) bacteria, (3) dissolved oxygen, and (4) metals. In-place contaminants and municipal dischargers are listed as the main sources of nutrients and metals contamination in the watershed. Elevated bacteria concentrations are the result of urban runoff, industrial point discharges, on-site wastewater treatment, and municipal point sources. Impaired dissolved oxygen may be attributed to municipal point sources, in-situ contaminants, and natural causes. Supporting data for this analysis was collected by the MADEP in the mid-1980s and early 1990s (Donovan and Diers 1997). MRI's more recent *Bi-state Water Quality Monitoring Assessment* showed dry and wet-weather violations of copper and lead, as well as wet-weather violations of bacteria on the Concord River.

Contoocook River

The 1997 MRI report points to dissolved oxygen impairment as a result of municipal point sources as the primary source of partial support in the Contoocook River watershed. However, the Bi-State Water Quality Assessment showed chronic wet- and dry-weather lead violations at several locations along the River (Donovan and Diers 1997). The New Hampshire 2000 305(b) Report includes an additional seven miles of partially supporting use along the mainstem Contoocook as a result of elevated zinc concentrations from an unknown source. The NHDES is currently working on developing a TMDL for dissolved oxygen in the Contoocook River.

Nashua River

The principal causes of non-supporting use in the Nashua River watershed are (1) bacteria, (2) nutrients, (3) unknown, and (4) dissolved oxygen. Bacterial contamination is due primarily to urban runoff, CSO discharges, and municipal point sources (Donovan and Diers 1997). The MRI's bi-state water quality monitoring program showed additional wet- and dry-weather violations of lead (chronic / dissolved) and bacteria at two stations along the Nashua River in New Hampshire (these stations were added to the state's 2000 305(b) report). The New Hampshire 2000 305(b) report also included the addition of a river segment partially supporting use around Nashua, New Hampshire for dissolved oxygen, cause unknown.

Pemigewasset River

The New Hampshire 2000 305(b) report did not list any impaired river segments in the Pemigewasset River watershed. However, the MRI's bi-state monitoring did show an elevated dry-weather bacterial concentration in the Smith River (a tributary to the Pemigewasset) in 1994; elevated concentrations were not found during the wet-weather sampling in 1995 (Donovan and Diers 1997).

3.4.1 2002 New Hampshire and Massachusetts 303(d) Lists

Tables 3.8 and 3.9 present a summary of the listed tributary segments in the 2002 New Hampshire CALM and the Category 4c and 5 listed tributary segments in Massachusetts. A description of the listing and methodology is provided in Section 3.3. These tables provide a more detailed look at the particular water quality problems plaguing the Merrimack River tributaries than does the 1997 MRI report. Only major tributaries have been included in these tables.

Table 3.8: CALM listed tributary segments in New Hampshire for waters that do not require a TMDL and waters that do require a TMDL

List	Type	Description	Non Supporting Use	Cause	Suspected Source(s)	Size
Waters that do not require a TMDL	Impoundment	Pemigewasset River- Ayers Island Dam	Aquatic Life	DO sat.	Unknown	500 ac
		Winnipesaukee River- Franklin Falls Hydro Dam	Primary Contact Recreation	E. coli	Illicit Connections	1.5 ac
		Nashua River- Mine Falls Dam	Aquatic Life	Non-native aquatic plants	Unknown	60 ac
		Nashua River- Nashua Canal Dike	Aquatic Life	Non-native aquatic plants	Unknown	55 ac
		Nashua River- Nashua Canal	Aquatic Life	Non-native aquatic plants	Unknown	55 ac
		Nashua River- Jackson Plant Dam	Primary Contact Recreation	E. coli	CSO's	40 ac
		Souhegan River- Goldman Dam	Aquatic Life	DO sat.	Unknown	8 ac
		Powwow River- Powwow Pond	Aquatic Life	pH	Unknown	325 ac
	River	Pemigewasset River	Aquatic Life	pH	Unknown	5.72 mi
		Pemigewasset River	Aquatic Life	DO sat.	Unknown	10.2 mi
		Contoocook River	Aquatic Life	pH	Unknown	0.82 mi
		Contoocook River	Primary Contact Recreation	E. coli	Unknown	0.68 mi
		Contoocook River	Aquatic Life	pH	Unknown	2.73 mi
		Nashua River	Primary Contact Recreation	E. coli	CSO's	3.66 mi
		Nashua River	Primary Contact Recreation	E. coli	CSO's	1.3 mi
		Soucook River	Aquatic Life	pH	Unknown	3.86 mi
		Soucook River	Aquatic Life	pH	Unknown	8.79 mi

List	Type	Description	Non Supporting Use	Cause	Suspected Source(s)	Size
	River (cont'd)	Soucook River	Aquatic Life	pH	Unknown	1.88 mi
		Soucook River	Aquatic Life	pH	Unknown	4.83 mi
		Suncook River	Aquatic Life	pH	Unknown	3.48 mi
		South Branch Piscataquog River	Aquatic Life	pH	Unknown	0.05 mi
		Piscataquog River	Primary Contact Recreation	E. coli	CSO's	2.5 mi
		Cohas Brook and Long Pond Brook	Aquatic Life	pH	Unknown	6.17 mi
		Souhegan River	Primary Contact Recreation	E. coli	Unknown	3.34 mi
		Souhegan River	Aquatic Life	pH	Unknown	8.63 mi
		Souhegan River	Primary Contact Recreation	E. coli	Unknown	2.27 mi
		Souhegan River	Aquatic Life	Copper	Municipal Point Source	10.9 mi
		Salmon Brook	Primary Contact Recreation	E. coli	Illicit Connections	6.34 mi
		Powwow River	Aquatic Life	pH	Unknown	0.81 mi
Waters Requiring a TMDL	River	Contoocook River	Aquatic Life	DO	Industrial & Municipal Point Sources	1.35 mi

Source: NHDES 2002

Table 3.9: Listed tributary segments in the Massachusetts portion of the Merrimack River watershed in Category 4c and 5

Category	Description	Assessment Date	Size	Pollutant Requiring a TMDL
Category 4c	Shawsheen River- Headwater Lincoln to Bedford	April 1997	2 mi	-Pathogens
Category 5	Assabet River- Outlet flow augmentation pond to Westborough WWTP	October 1997	1.4 mi	-Nutrients -Organic enrichment/Low DO -Pathogens
	Assabet River- Westborough WWTP to Route 20 Dam, Northborough	October 1997	3.7 mi	-Metals -Nutrients -Organic enrichment/Low DO -Pathogens
	Assabet River- Route 20 Dam to Marlborough West WWTP	December 1999	2.4 mi	-Nutrients -Pathogens
	Assabet River- Marlborough West WWTP to Hudson WWTP	December 1999	7.9 mi	-Cause Unknown -Metals -Nutrients -Organic enrichment/Low DO -Pathogens
	Assabet River- Hudson WWTP to Route 27/62 at USGS gage, Maynard	October 1997	8.8 mi	-Nutrients -Organic enrichment/ Low DO -Pathogens
	Assabet River- Routes 27/62 at USGS gage to Powdermill Dam, Acton	November 1997	1.2 mi	-Priority Organics -Metals -Nutrients -Organic enrichment/Low DO -Thermal modifications -Taste, odor & color -Suspended solids -Noxious aquatic plants
	Assabet River- Powdermill Dam to confluence with Sudbury River, Concord	November 1997	6.4 mi	-Nutrients -Organic enrichment/Low DO -Pathogens
	Concord River- Confluence with Assabet and Sudbury Rivers, Concord, to Billerica Water Supply Filtration Plant	November 1997	9.5 mi	-Metals -Nutrients -Pathogens
	Concord River- Billerica Water Filtration Plant to Roger St. Bridge	November 1997	4.9 mi	-Metals -Nutrients

Category	Description	Assessment Date	Size	Pollutant Requiring a TMDL
	Concord River- Rodgers Street Bridge to confluence with Merrimack River, Lowell	November 1997	1.0 mi	-Metals -Nutrients -Pathogens
	Sudbury River- Fruit Street Bridge, Hopkinton to outlet Saxonville Pond, Framingham	November 1997	12.9 mi	-Metals
	Sudbury River- Outlet Saxonville Pond to confluence with Wash Brook, Sudbury	November 1997	5.6 mi	-Metals
	Sudbury River- Confluence Wash Brook to confluence Assabet River, Concord	November 1997	10.6 mi	-Metals
	Beaver Brook- NH state line, Dracut to confluence with Merrimack River, Lowell	August 2001	4.2 mi	-Cause Unknown -Pathogens -Oil and Grease -Turbidity
	Beaver Brook- Outlet Mill Pond, Littleton to inlet Forge Pond, Weston	September 1996	4.8 mi	-Nutrients -pH -Organic enrichment/Low DO -Pathogens -Suspended Solids
	Powwow River- Tidal portion to confluence with Merrimack River, Amesbury	July 2001	0.05 mi^2	-Pathogens
	Powwow River- Outlet of Lake Gardner to tidal portion, Amesbury	July 2001	0.59 mi	-Pathogens -Suspended Solids -Noxious aquatic plants -Turbidity
	Powwow River- Headwaters, Amesbury to inlet Lake Gardner, South Hampton, NH	July 2001	3.4 mi	-Pathogens -Suspended solids -Noxious aquatic plants -Turbidity
	Spicket River- NH state line to confluence with Merrimack River, Lawrence	July 2001	6.4 mi	-Cause Unknown -Metals -Nutrients -Pathogens
	Stony Brook- Outlet Forge Pond to Chamberlin Road, Westford	July 2001	7 mi	-Cause Unknown -pH -Organic enrichment/Low DO -Pathogens -Turbidity

Category	Description	Assessment Date	Size	Pollutant Requiring a TMDL
	Stony Brook- Chamberlin Road, Westford to confluence with Merrimack River, Chelmsford	July 2001	3.3 mi	-Cause Unknown -Nutrients -pH -Organic enrichment/Low DO Pathogens
	Nashua River- Confluence with North Nashua River, Lancaster to confluence with Squannacook River, Shirley/Groton/Ayer	August 2000	13.5 mi	-Cause Unknown -Unknown toxicity -Metals -Nutrients -Pathogens -Taste, odor, & color -Turbidity
	Nashua River- Confluence with Squannacook River to Pepperell Dam	August 2000	8.8 mi	-Cause Unknown -Metals -Nutrients -Organic enrichment/Low DO -Noxious aquatic plants -Turbidity
	Nashua River- Pepperell Dam to NH state line	August 2000	3.7 mi	-Cause Unknown -Nutrients -Pathogens -Turbidity
	Nashua River- Outlet Lancaster Millpond to Clinton WWTP	August 2000	3 mi	-Cause Unknown -Unknown toxicity -Pathogens
	Nashua River- Clinton WWTP to confluence with North Nashua River, Lancaster	August 2000	1.6 mi	-Cause Unknown -Pathogens
	North Nashua River- Outlet Snows Millpond to Fitchburg Paper Company Dam #1	August 2000	1.2 mi	-Cause Unknown -Pathogens
	North Nashua River- Fitchburg Paper Company to Fitchburg East WWTP	August 2000	6.3 mi	-Cause Unknown -Unknown toxicity -Pathogens -Taste, odor, & color
	North Nashua River- Fitchburg East WWTP to Leominster WWTP	August 2000	2.1 mi	-Cause Unknown -Unknown toxicity -Pathogens -Taste, odor, & color -Turbidity
	North Nashua River- Leominster WWTP Leominster to confluence with Nashua River, Lancaster	August 2000	9.9 mi	-Cause Unknown -Pathogens -Taste, odor, & color -Turbidity

Category	Description	Assessment Date	Size	Pollutant Requiring a TMDL
	Shawsheen River- Summer Street to confluence with Spring Brook, Bedford	April 1997	1.7 mi	-Unknown toxicity -Organic enrichment/Low DO -Pathogens
	Shawsheen River- Confluence with Spring Brook, Bedford to Central Street, Andover	April 1997	17.4 mi	-Unknown toxicity -Metals -Organic enrichment/Low DO -Pathogens
	Shawsheen River- Central Street to confluence with Merrimack River, Lawrence	April 1997	6.2 mi	-Unknown toxicity -Pathogens

Source: MADEP 2002

Although not explicitly discussed here, the MADEP recently (February 2002) published a Draft Total Maximum Daily Load (TMDL) for bacteria in the Shawsheen River (considered part of the mainstem Merrimack River subwatershed by the 1997 MRI report). NHDES is also working on developing a TMDL for dissolved oxygen in the Contoocook River between Peterborough and Antrim, New Hampshire.

3.4.2 Summary

A review of the "2002 Section 305(b) and 303(d) Consolidated Assessment and Listing Methodology and Comprehensive Monitoring Strategy" for the State of New Hampshire reveals pH (47.7 listed miles) and bacteria (20.04 listed miles) appear to be the major cause of non-supporting use for primary contact recreation and aquatic life throughout all the major tributaries. The primary cause for both violations is listed as unknown, except for E. coli exceedances on the Nashua River, which are listed as a result of CSO discharges. A 10.9-mile segment of the Souhegan River is listed as not supporting aquatic life due to an exceedance of the copper water quality criteria due to municipal point source. A 10.2-mile segment of the Pemigewasset River is also listed as not supporting the aquatic life use due to a violation of the dissolved oxygen requirements. Additionally, a TMDL is required for dissolved oxygen in the Contoocook River; all other waters as discussed above are listed as "waters not requiring a TMDL".

According to the "Massachusetts Year 2002 Integrated List of Waters", pathogens are the largest cause of non-attainment of designated uses in the major tributaries to the Merrimack River, with approximately 140 listed miles under Category 5. Metals (103 listed miles), nutrients (89 listed miles), and organic enrichment/low dissolved oxygen concentrations (70 listed miles) are the other top causes of non-supporting uses. The report does not provide any information regarding the source of these pollutants.

3.5 Sediment Quality

Review of available literature revealed a general lack of data on sediment quality in the mainstem Merrimack River and its major tributaries. The following section provides a summary of the limited number of monitoring programs, as well as the state reporting methods for sediment quality.

3.5.1 Monitoring Programs

Sediment sampling was intended to be included as part of the MRI studies conducted during the summer of 1994 and fall of 1995; however, due to Federal government budgetary cuts, the sediment sampling and analysis portions were cancelled.

Although the state of New Hampshire does not maintain a consistent sediment quality monitoring program, NHDES biologists conducted sediment testing at three marinas in the Lake Winnipesaukee watershed in 1993. Samples were analyzed for volatile organic compounds (VOCs) and bulk sediment toxicity tests were performed using a benthic worm as the test organism. Limited sediment testing in the Merrimack River was also performed by consultants in 1992 as part of the development of a CSO abatement plan for the City of Manchester. Results were not available for the NHDES 1993 sediment sampling program or the monitoring performed as part of the development of a CSO abatement plan for the City of Manchester.

Sediment sampling was performed by Marie M. Studer, a Ph.D. candidate at the University of Massachusetts-Boston, in completion of her dissertation entitled "The chemistry and geochemistry of selected metals in the Merrimack River of New England and regulatory considerations of water quality". Ms. Studer undertook a two-year study of the Merrimack River between January 1989 and April 1991. Two sediment cores were taken from Indian River Shoal, a tidal freshwater marsh on the Merrimack River in West Newbury. Sediment samples were sectioned at one-centimeter intervals and analyzed for select metals (Ag, Al, Cd, Cr, Cu, Fe, Mn, Ni, Pb, and Zn), organic carbon, and grain-size distribution. The results generally showed a decline in metals concentrations within the top two to three-centimeters of each core, which, on a temporal scale, corresponds to the time of inception of the Clean Water Act in the early 1970's (Studer 1995). However, Ms. Studer was unable to determine conclusively if the decline in concentrations was directly attributable to pollution controls implemented in response to the CWA or to other processes affecting metal accumulation. However, it is possible that this drop is a result of increased pollution control and sewage treatment plant upgrades from primary to secondary treatment (Studer 1995).

3.5.2 State Reporting

New Hampshire does not quantify sediment contamination in its bi-annual 305(b) Report. The *Commonwealth of Massachusetts Summary of Water Quality 2000* (Section 305(b) Report) provides a summary of those waterbodies in the state that are considered to have elevated levels of sediment contamination; however, no segments of the Merrimack River mainstem are included on the list (McVoy 2000). At the time of publication, sediment contamination criteria had not been established either nationally or by the State. A Sediment Quality Ranking system was developed by the State of Massachusetts for use in the assessment study based on accepted literature contamination values. The report listed the Assabet River for metals and priority organics contamination and the Sudbury River for metals (particularly mercury) contamination.

Section 4
Resource Summary

The Merrimack River has come a long way from its notorious past in the 1960's when it was listed as one of the top ten most polluted rivers in the county. Today, the watershed is a high value resource area that supports a range of biological, recreation, and other resources, such as hydropower and public drinking water supplies. Biological resources in the watershed include shellfish populations in the tidally influenced portions of the mainstem Merrimack River, various resident and anadromous fish populations, and numerous threatened an endangered species. Additionally, the watershed supports a range of recreational activities, including a Class II and III rapids and slalom kayaking course in Manchester, New Hampshire, a public beach at the Lowell Heritage State Park, and numerous natural trails and marinas throughout the basin. The watershed also supports various economic uses, including seven hydroelectric dams that currently operate on the mainstem Merrimack River and the Pemigewasset River. Finally, the mainstem River supports numerous public and industrial water users along its length.

The following section presents a summary of the biological, recreational, and other resources, such as hydropower and public drinking water supplies, of the Merrimack River watershed.

4.1 Biological Resources

This section addresses the existing biological resources of the Merrimack River watershed. Existing biological resources are first addressed by discussing the major habitats supporting biological resources that occur in the Merrimack River watershed. Second, major biological lifeforms are discussed by addressing the common and rare, threatened, or endangered species found along the Merrimack River and its major tributaries.

4.1.1 Habitat

Ecoregions are used to broadly define the general patterns of vegetation and aquatic habitat in an area (USEPA 1997). The Merrimack River watershed is located in both the Northeastern Highlands ecoregion and the Northeastern Coastal Zone. The north and westerly portions of the watershed, located in the Northeastern Highlands, are characterized by low mountains and mostly ungrazed forest and woodland; the primary vegetation is northern hardwood, such as northeastern spruce and fir. The southern portion of the watershed is located in the Northeastern Coastal Zone, which is characterized by irregular plains with low, open hills. Land cover in this ecoregion is primarily woodland and forest, composed mainly of oak, with some cropland and pasture (Flanagan *et al*. 1999).

The Merrimack River watershed's land use composition, from the relatively undeveloped White Mountain National Forest in northern New Hampshire to highly urbanized areas along the mainstem of the Merrimack River, is reflected in the basin's wildlife habitat. The River corridor's riparian areas and floodplain provide a valuable habitat resource in the form of undisturbed stretches of vegetation. However, increased development surrounding urban areas and sought after coastal sections threatens to impair further the quality of wildlife habitat. This section addresses aquatic, riparian, and wetland habitat resources.

Aquatic Habitat

Aquatic habitats found in the Merrimack River watershed include quickwaters in the northern portion of the basin, cold and warm water fisheries throughout the watershed, and estuarine environment in the River's final reaches. The River supports a range of species from macroinvertebrates to resident and anadromous fish populations. The integrity and health of the aquatic habitats is primarily dependant upon the River's water quality and in-stream flow conditions.

The MADEP and NHDES, working under the MRI, conducted biomonitoring at 14 sites on the Merrimack River mainstem and 31 sites on the River's tributaries. A broad range of aquatic environments were evaluated, including headwater tributaries in the northern sections of the basin and more riverine segments around Nashua, New Hampshire and Lawrence, Massachusetts. The study included an evaluation of habitat conditions at each biological monitoring station using the following 12 parameters: in-stream cover, epifaunal substrate, embeddedness, velocity/depth regimes, EPT richness (mayflies, stoneflies, and caddisflies), EPT abundance, ratio of EPT to Chironomidae, biotic index, ratio of collectors to scrapper feeders, ratio of shredder organisms to total number of organisms, Shannon diversity, and percent model affinity (PMA).

The 1999 biomonitoring conducted by MADEP on the Cobbler's Brook, Stony Brook, Spicket River, Beaver Brook, and Fish Brook indicates varying degrees of non-point source related pollution problems. Urban runoff, habitat degradation, and other sources of non-point source pollution were found to compromise the water quality and biological integrity of the tributaries. However, improvements in water quality were noted at a few of the stations with historical biomonitoring surveys (MADEP 2001).

Riparian Habitat

The development of riparian communities are influenced by their relative position to the river (distance from and height above) and river flooding interval. The diversity of river riparian habitat types provides valuable wildlife habitat. Significant riparian habitat found along the upper Merrimack include the following:

- Southern New England lake sediment/river terrace forest
- Sandy river bluff forest
- Mesic river bluff forest

- Acidic river side seep communities
- Floodplain forest communities, and
- Pitch pine/scrub oak barrens (NHDES 1997b; NHDES 1997d)

The pitch pine/scrub oak barrens on the Upper Merrimack River are considered globally rare and support the only identified New England population of the Karner blue butterfly (*Lycaeides melissa samuelis*); a Federally listed endangered species (NHDES 1997d). Riparian habitat of the Pemigewasset River supports nesting and foraging for the following endangered birds: golden eagle (*Aquila chrysaetos*), upland sandpiper (*Bartramia longicauda*), peregrine falcon (*Falco peregrinos*), and sedge wren (*Cistothorus platensis*) (NHDES 1997c).

Massachusetts floodplain communities are typically river birch associations. Developments (residential or camping) are contributing to the decline of these riparian communities (Carley 2001).

The Audubon Society of New Hampshire (2001) recently published a study on the uses of floodplain forest habitats by breeding and migrating birds. The study demonstrated that these habitats supported different bird communities than did upland forests. Additionally, the study reported that floodplain forest habitats along larger rivers (such as the Merrimack mainstem) support different populations than do smaller tributaries, as do larger parcels of floodplain habitat as compared to smaller fragments.

Freshwater Wetland Habitat

Freshwater wetland habitats play an integral role in the ecology of the Merrimack River corridor. The combination of high nutrient levels and primary productivity found in these habitats is ideal for the development of organisms that form the base of the food web. Many species of birds, fish, and mammals rely on wetlands for food and shelter, particularly during migration and breeding. Additionally, wetlands provide flood mitigation during periods of high flow and important filtering capabilities for the treatment of stormwater runoff, thus improving the quality of the River.

Carley (2001) notes that wetland coverage ranges from 10 to 25 percent of the land area in the Massachusetts portion of the watershed. Of this, approximately 50 percent is classified as deciduous forested wetlands. Additionally, 107 vernal pools have been certified and an additional 1,160 sites have been nominated for certification within the watershed (Carley 2001). No similar computation of wetland coverage in New Hampshire could be obtained from the available information; however, the University of New Hampshire maintains a GIS database (http://www.granit.sr.unh.edu/) that includes maps of the state's wetlands and major watersheds.

From the 1950s to the 1970s, the United States as a whole lost an average of 460,000 acres of wetlands annually, and continued into the 1980s at a reduced rate (Mitsch and Gosselink 1993). In the 1990s, the majority of wetland loss in the Merrimack River watershed is attributed to residential development and urban sprawl; this is particularly true in the southern New Hampshire and northeast Massachusetts portions of the watershed, which have been growing rapidly from the spread of the Boston metropolitan area.

The New Hampshire Natural Heritage Inventory has identified two exemplary natural communities in the portion of the River between Merrimack, New Hampshire and the Massachusetts-New Hampshire state line: the Southern New England lake sediment/river terrace forest and the Northern New England level bog (NHDES 1997b). Both communities support a wide range of plant and wildlife species.

Tidal Wetland Habitat

The lower Merrimack River is tidally influenced in its final 22 miles; the saltwater wedge extends upstream an additional 10 miles to Merrimackport during summer high tides and periods of low-flow conditions. This unique freshwater and saltwater habitat supports a wide range of aquatic species, including extensive shellfishing beds.

One of the largest freshwater tidal marshes in Massachusetts is found in the Merrimack River downstream of Haverhill, Massachusetts. One unique plant species found growing along the River is Wild rice (*Zizania aquatica*), considered rare in the region. It is typically found growing at river mouths in fresh to brackish waters (Carley 2001).

A 1998 study conducted by the DMF noted that eelgrass beds were declining throughout the lower Merrimack; however, only limited information exists on the historic and current status of these beds. DEP's Wetland Conservancy Program has mapped eelgrass sites in Massachusetts; the data is available through MassGIS (Carley, 2001). Eelgrass beds provide essential nursery and feeding habitat for shellfish and finfish, and thus, are important to the long-term success of these species.

4.1.2 Biological Lifeforms

This section presents a summary of the phytoplankton, macroinvertebrate, shellfish, terrestrial mammal, bird and waterfowl, and other significant wildlife populations found in the Merrimack River watershed. Discussion throughout this section will address those species that have been listed as "endangered", "threatened", or "special concern" by the state and/or federal government, as defined below:

- **Endangered (E):** Native species which are in danger of extinction throughout all or part of their range, or which are in danger of extirpation, as documented by biological research and inventory

- **Threatened (T):** Native species which are likely to become endangered in the foreseeable future, or which are declining or rare as determined by biological research and inventory

- **Special Concern (SC): N**ative species which have been documented by biological research or inventory to have suffered a decline that could threaten the species if allowed to continue unchecked, or which occur in such small numbers or with such restricted distribution or specialized habitat requirements that they could easily become threatened

Phytoplankton

Review of the available literature reveal no phytoplankton studies conducted in the Merrimack River watershed. This represents an important gap in the data due to the identified nutrient problems in the mainstem and major tributaries.

Macroinvertebrates

In recent years, the MADEP, NHDES, MRI, and numerous smaller watershed committees have begun conducting macroinvertebrate biomonitoring studies in the Merrimack River basin. Biomonitoring is a useful technique for detecting the anthroprogenic impacts to aquatic communities (MADEP 2001). Resident biota in a waterbody, such as benthic macroinvertebrates, are natural indicators of environmental quality. They can reveal the effects of episodic and cumulative pollution, and habitat alteration (Barbour *et al.* 1995; Barbour *et al.* 1999). Biological surveys and assessments are the primary approaches to biomonitoring.

Results from the MRI's monitoring were published as a data report in the "*Merrimack River Bi-State, Biomonitoring Report, Part Two*". The report summarized the following six general categories of information at each biomonitoring site:

- Physical Conditions or Geographic and Hydrologic Information

- Hydrolab Data (Temperature, pH, Total Dissolved Solids, Redox, Conductivity, Depth, and Dissolved Oxygen)

- Habitat Conditions

- Percent Composition by Major Groups

- Percent Composition by Functional Groups

The Upper Merrimack Monitoring Program, conducted by the Upper Merrimack River Local Advisory Committee, reported a decline in sensitive macroinvertebrate species and habitat assessment scores from 1995 to 1997. These declines mirrored the change in flow conditions of the River between Franklin and Bow, New Hampshire (Landry and Tremblay 1997). Results from the NHDES biomonitoring have not been independently published.

Shellfish Populations

The unique freshwater and saltwater habitat of the lower Merrimack River supports a wide range of aquatic species, including extensive shellfishing beds. However, all commercial and recreation shellfishing has been prohibited in the Merrimack River since 1986 due to contamination issues (particularly elevated bacteria levels). These sites are listed as "prohibited" under the Massachusetts Division of Marine Fisheries (DMFs) *Designated Shellfish Growing Area* program (Carley 2001). Table 4.1 presents a summary of shellfish populations found in the Merrimack River watershed.

Table 4.1 Summary of Shellfish Species

Species	Location	Abundance
Soft-shell clams (*Mya arenaria*)[1]	I-95 bridge to ocean	Believed to be abundant
Blue mussels (*Mytylus edulis*)[1]	Route 1 bridge to ocean	Believed to be abundant
Razor clams (*Siliqua patula*)[1]	Estuary	Minor quantities
Dwarf wedge mussel (*Alasmidonta heterodon*)[1]	Unknown	Extirpated (since 1983?)
Yellow lamp mussel (*Lampsilis cariosa*)[1]	Unknown	Extirpated since mid-1800s
Brook Floater (*Alismidona varicose*)[1]	Sewalls Falls	Listed as endangered
Eastern Pond Mussel (*Ligumia nasuta*)[2]	Amesbury, MA	Species of Concern
Triangle floater (*Alasmidonta undulata*)[2]	Harvard, MA	Species of Concern
Tidewater mucket (*Leptodea ochracea*)[2]	Haverhill, MA	Species of Concern

[1]Source: Interviews with staff of Plum Island

[2]Source: Carley 2001

Shellfish and finfish pollutions were found in abundance in the tidally-influenced lower Merrimack during the National Oceanic and Atmospheric Administration's (NOAA) Estuarine Living Marine Resources Program (ELMR). Several species of economic importance are found in the region, including northern quahogs (rare), American lobster (common), sevenspine bay shrimp (very abundant), and rock crabs (common).

Staff at the Plum Island Shellfish Purification Plant report relatively abundant populations of soft-shelled crabs (*Mya arenaria*) and blue mussels (*Mytylus edulis*) found between the mouth of the Merrimack and the I-93 bridge and the Route 1 bridge, respectively (Kennedy 2000). A small number of razor clams (*Siliqua patula*) were identified in the estuary as well (Kennedy 2000).

Data from the Massachusetts Heritage and Endangered Species Program (NHESP) indicate that two freshwater mussel species previously inhabited the Merrimack River, but no longer exist in the area. The dwarf wedge mussel (*Alasmidonta heterodon*) is listed as an endangered species at both the Federal and state level. The last siting of this mollusk was in 1983; it is believed that the species has been extirpated from Massachusetts (NHESP 1991a). The yellow lamp mussel (*Lampsillis cariosa*) also is listed on the endangered species list in Massachusetts. Although this mussel once inhabited the Merrimack, no living specimens have been collected from the River since the mid-1800s (NHESP 1991b). The Brook Floater (*Alismidona varicosa*) is a State-listed endangered mussel present at Sewalls Falls approximately nine miles upstream of Garvins Falls Dam.

Terrestrial Mammals

The Merrimack River provides habitat for a variety of large and small mammals. For example, the River's corridor serves as an important habitat for several water-dependant furbearers, including the beaver (*Castor canadensis*), the muskrat (*Ondatra zibethica*), and the mink (*Mustela vision*). Larger mammals, such as the white-tailed deer (*Odocoileus virginianus*) and the coyote (*Canis latrans*) also use the River corridor both as home range habitat and as a travel corridor to pass between other preferred habitats.

The Merrimack River also provides habitat for a number of state-listed mammals. Table 4.2 provides a summary of state-listed mammal populations in the Merrimack River watershed.

Table 4.2 State Listed Mammals

Scientific Name	Common Name	Listed Status	
		MA[1]	*NH*[2]
Lasionycteris noctivagans	Silver haired bat	---	SC
Pipistrellus subflavus	Eastern pipistrelle	---	SC
Lasiurus borealis	Red bat	---	SC
Lasiurus cinereus	Hoary bat	---	SC
Sylvilagus transitionalis	New England cottontail	---	SC
Synaptomys cooperi	Southern bog lemming	SC	---

Notes: E= Endangered, T= Threatened, SC= Special Concern
[1]Carley 2001
[2] http://www.wildlife.state.nh.us/nongameendlist.htm

Birds and Waterfowl

The watershed provides habitat for over of 117 species of birds and waterfowl, twenty of which have been designated as "endangered," "threatened," or "special concern." Table 4.3 presents a summary of the state and Federally registered avian populations in the Merrimack River watershed.

The common loon, listed as "special concern" in Massachusetts and "threatened" in New Hampshire, typically breeds in northern lakes and ponds; however, they commonly winter near the ocean, and thus are only likely to be found near the mouth of the Merrimack during the winter months. American bittern, listed only in

Massachusetts as "endangered," generally inhabit dense marshland, and as such, could be found anywhere that such habitat exists. The five designated raptors (*i.e.*, harrier, eagle, hawk, and falcon) use the River primarily as a food source. The Federally threatened and state-listed bald eagle is a particularly visible species within the watershed. Winter perching, roosting, and feeding activities have been documented along the Merrimack River mainstem from Franklin to Nashua, New Hampshire, and throughout the Massachusetts portion of the basin. The entire Massachusetts River corridor is designated as priority habitat for the bald eagle.

The Pemigewasset River corridor provides habitat for the "threatened" bald eagle, osprey, northern harrier, common loon, common nighthawk, Cooper's hawk, and purple martin (NHDES 1997c).

Table 4.3 Federally and State Listed Birds

Scientific Name	Species	Federal	MA	NH
Botaurus lentiginosus	American bittern	–	E	–
Sterna paradisaea	Arctic tern	–	SC	T
Haliaeetus leucocephalus	Bald eagle	T	E	T
Gavia immer	Common loon	–	SC	T
Gallinula chloropus	Common moorhen	–	SC	–
Chordeiles minor	Common nighthawk	–	–	T
Sterna hirundo	Common tern	–	SC	–
Accipiter cooperii	Cooper's hawk	–	SC	T
Sialia sialis	Eastern bluebird	–	–	T
Aquila chrysaetos	Golden eagle	–	–	E
Vermivora chrysoptera	Golden-winged warbler	–	E	–
Ammodramus savannarum	Grasshopper sparrow	–	T	–
Ardea herodias	Great blue heron	–	–	T
Rallus elegans	King rail	–	T	–
Ixobrychus exilis	Least bittern	–	E	–
Sterna antillarum	Least tern	–	SC	E
Circus cyaneus	Northern harrier	–	T	E
Pandion haliaetus	Osprey	–	–	T
Falco peregrinos	Peregrine falcon	E	E	E
Podilymbus podiceps	Pied-billed grebe	–	–	E
Charadrius melodus	Piping plover	T	T	E
Progne subis	Purple martin	–	–	T
Sterna dougallii	Roseate tern	E	E	E
Cistothorus platensis	Sedge wren	–	–	E
Accipiter striatus	Sharp-shinned hawk	–	SC	–
Bartramia longicauda	Upland sand piper	–	E	E

Notes: E= Endangered, T= Threatened, SC= Special Concern

The USEPA has designated the Merrimack River from Franklin, New Hampshire, to Lowell, Massachusetts, as a *Priority Waterbody/Wetland* due to its importance to waterfowl and fish populations (Carley 2001). Approximately 25 Atlantic Flyway Waterfowl Breeding sites are identified within the Merrimack River watershed in New Hampshire alone (Bramley 1996). Further, a 1987 study by the USEPA also designated the Merrimack River Tidal Flats as priority wetlands for the preservation of Black Duck wintering habitat, as recommended by the U.S. Fish and Wildlife Service (Carley 2001).

In 1997, the MRI in conjunction with MADEP published the "*Aquatic Species Mapping Project: Final Report.*" As part of this project, maps were developed from Massachusetts Audubon Society atlases showing the statewide potential breeding grounds for wood ducks and the statewide occurrence of the painted turtle, spring peppers, question mark butterflies, and bog copper butterflies. A map was also developed showing prime habitat, breeding plots, and wood duck box areas.

Other Significant Wildlife

The habitats associated with the Merrimack River support a variety of amphibians and reptiles. Table 4.4 lists those amphibians and reptiles found in the River's watershed that are listed by Massachusetts or New Hampshire as threatened, endangered or of special concern.

Table 4.4 State Listed Amphibians and Reptiles

Scientific Name	Common Name	Listed Status US	Listed Status MA	Listed Status NH
	Amphibians			
Ambystoma laterale	Blue-spotted salamander	---	E	---
Ambystoma opacum	Marbled salamander	---	E	---
Bufo fowleri	Fowler's toad	---	---	SC
	Reptiles			
Clemmys guttata	Spotted turtle	---	SC	---
Clemmys insculpta	Wood turtle	---	SC	SC
Emydoidea blandingii	Blanding's turtle	---	T	---
Terrapene carolina	Eastern box turtle	---	SC	---
Heterodon platyrhinos	Hognose snake	---	---	T
Opheodrys v. vernalis	Eastern smooth green snake	---	---	SC

Notes: E= Endangered, T= Threatened, SC= Special Concern
Source: DeGraaf and Yamasaki (2001)
[1]Carley 2001, [2]http://www.wildlife.state.nh.us/nongameendlist.htm

Two lepidopterans were documented at the Hooksett Riverbluff Barrens; a Noctuid moth (*Lithophane thaxteri*) and the Barrens Xylotype (*Xylotype capax*). The Nocuid moth is not a listed or ranked species due to lack of information and the Barrens Xylotype is also not listed, but has a State-imperiled conservation status.

4.1.3 Fisheries

Currently, the Merrimack River supports an excellent resident sport fishery, centered on smallmouth and largemouth bass, yellow perch, walleye, and bullhead (*Merrimack Station Fisheries Study* [NAI 1996]). Table 4.5 presents a list of fish that currently or historically inhabit the Merrimack River (NAI 2001; Carley 2001).

Table 4.5: List of Fish Identified in the Merrimack River, Sorted by Family

Family	Species
Petromyzontidae	Sea lamprey *Petromyzon marinus*
Acipenseridae	Atlantic sturgeon *Acipenser oxyrinchus oxyrhinchus* Shortnose sturgeon *A. brevirostrum*
Clupeidae	American shad *Alosa sapidissima* Alewife *A. pseusoharengus* Blueback herring *A. aestivalis* Gizzard shad *Dorosoma cepedianum*
Salmonidae	Atlantic salmon *Salmo salar* Rainbow trout *Oncorhynchus. Gairdneri* Brown trout *S. trutta* Brook trout *Salvelinus fontinalis*
Osmeridae	Rainbow smelt *Osmerus mordax*
Esocidae	Chain pickerel*Esox niger* Northern pike *E. lucius*
Cyprinidae	Fallfish *Semotilus corporalis* Creek chub *S. atromaculatus* Golden shiner *Notemigonus crysoleucas* Spottail shiner *Notropis hudsonius* Common/Redfin shiner *N. cornutus* Bridle shiner *N. bifrenatus* Blacknose dace *Rhinichthys atratulus* Longnose dace *R. cataractae* Carp *Cyprinus carpio* Goldfish *Carassius auratus*
Catostomidae	White sucker *Catostomus commersoni*
Ictaluridae	Brown bullhead *Ictalurus nebulosus* Yellow bullhead *I. Natalis* Channel catfish *I. Punctatus* White catfish *I. Catus* Marginated/Brindled madtom *Noturus insignis* Tadpole madtom *N. gyrinus*
Gadidae	Burbot *Lota lota*
Atherinopsidae	Atlantic silverside *Menidia menidia*

Family	Species
Cyprinodontidae	Banded killifish *Fundulus diaphanous* Mummichog *F. heteroclitus*
Gasterosteidae	Threespine stickleback *Gasterosteus aculeatus* Fourspine stickleback *Apeltes quadracus* Ninespine stickleback *Pungitius pungitius*
Syngnathidae	Northern pipefish *Sygnathus fuscus*
Anguillidae	American eel *Anguilla rostrata*
Percichthyidae	White perch *Morone Americana* Striped bass *M. saxatilis*
Ammodytidae	Sand lance *Ammodytes hexapterus*
Centrarchidae	Pumpkinseed sunfish *Lepomis gibbosus* Redbreasted sunfish *L. auritus* Bluegill *L. macrochirus* Largemouth bass *Micropterus salmoides* Smallmouth bass *M. dolomieui* Banded sunfish *Enneacanthus obesus* Black crappie *Pomoxis nigromaculatus*
Percidae	Yellow perch *Perca flavescens* Walleye *Stizostedion vitreum* Tessellated darter *Etheostoma olmstedi* Swamp darter *E. fusiforme*

Anadromous Fish Populations

An anadromous fish restoration program has been in effect on the Merrimack River for more than 20 years to bring back extirpated stocks of the endangered Atlantic salmon, American shad and alewife and blueback herring to the upper Merrimack River. As part of this restoration program and to provide quality fishing opportunities, the New Hampshire Fish and Game Department (NHFG) and U.S. Fish and Wildlife Service (USFWS) began a popular adult Atlantic salmon sport fishery in the Merrimack River in the mid-1990s by releasing excess Atlantic salmon brood stock each spring.

Anadromous fish populations in the Merrimack River watershed declined throughout the 1800 and early 1900s in response to the industrialization and impoundment of the River. Historically, Atlantic salmon swam up the Merrimack River to the Pemigewasset River where their spa wning grounds are located. Salmon fishery areas were damaged by the construction of a paper mill on the prime salmon-spawning stream. In conjunction, dams installed in the Merrimack River prevented fish from entering as early as 1847 (Schmitt 1976). Atlantic salmon, alewives and American shad were reduced to small populations using the lower parts of River. American shad were historically abundant in the Merrimack and Connecticut Rivers, typically entering Winnipesaukee River and the lake. Shad populations in Lake Winnipesaukee were reported to be as high as 830,000 in 1789 (Schmitt 1976). Anadromous fishways were constructed in 1866, 1867 and 1868, but were faulty and failed to help the problem. In 1867 Connecticut, Vermont and New Hampshire funded a juvenile shad-rearing program to stock the rivers; the program was unsuccessful, primarily due to dams and faulty fishways. Major remodeling of fishways in several areas in 1877 allowed alewives and lamprey to migrate successfully (Normandeau 1975).

Anadromous fish restoration was addressed in 1969 as a collaborative effort between the fishery agencies of Massachusetts and New Hampshire, the Bureau of Sport Fisheries and Wildlife, and the Bureau of Commercial Fisheries. Under provisions of the Anadromous Fish Conservation Act, P.L. 89-304 of 1965, U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), Massachusetts Division of Fish and Game and New Hampshire Fish and Game Department developed the Anadromous Fish Restoration Program. This cooperative program was an attempt to restore anadromous fish to the Merrimack River (Normandeau 1975).

The restoration program focused on the return of two species, Atlantic salmon and American shad. Goals were established via implementation of a four-phase expansion from 1975 to 1990:

- **Phase 1**: Establish a spawning run in the New Hampshire portion of the River south of the Amoskeag Dam by 1978 through the introduction of eggs, fry, or both
- **Phase 2**: Extend the spawning runs to Franklin Falls by 1980; this includes construction of fishways (areas designed to provide flow for fish ladders or stair-shaped areas that allow for inward and outward migration) at the Amoskeag, Hooksett, and Garvins Falls dams
- **Phase 3**: Expand Phase 2 to major tributaries and establishment of sport fishery
- **Phase 4**: Feasibility study performed and commercial fishing established

This program predicted a run of one million fish by 1990 (*Merrimack River Anadromous Fisheries Investigation* 1977). The Atlantic salmon restoration program is the third ranked program in New England, with regards to the number of fish, behind Penobscot Bay and Connecticut River.

The shad restoration program in the upper river began in 1969 with the introduction of fertilized eggs from the Connecticut River into the Massachusetts portion of the Merrimack River. Egg releases continued on an annual basis afterward. Hooksett Pond has been found to represent satisfactory habitat for shad spawning, as they prefer the alluvial depositions (gravel substrate) bathed by running water. Studies have shown the Pond to be suitable habitat for all other stages of shad freshwater life; however, reproductive success was not achieved in the early studies (*Merrimack River Anadromous Fisheries Investigation* 1977). Runs were sustained by continued release of Connecticut River eggs in the Essex Pool in Lawrence, Massachusetts in 1975 and in

Hooksett Pond in 1976. Extensive studies in 1976 revealed no eggs, larvae or juveniles after egg introduction (*Merrimack River Anadromous Fisheries Investigation* 1977).

More recently, in 1997, the Technical Committee for Anadromous Fishery Management of the Merrimack River Basin published its "*Strategic Plan and Status Review - Anadromous Fish Restoration Program;*" this report was the scheduled revision of the 1990 Atlantic Salmon Strategic Plan. The Plan set out the following three major goals for enhancing fish populations in the Merrimack through 2005:

- An adult Atlantic salmon population that will exceed the sea-run brood stock holding capacity of the Nashua National Fish Hatchery (300) and provide some level of reproduction in the wild

- An annual average of 35,000 adult American shad passing the Essex fish-lift in Lawrence

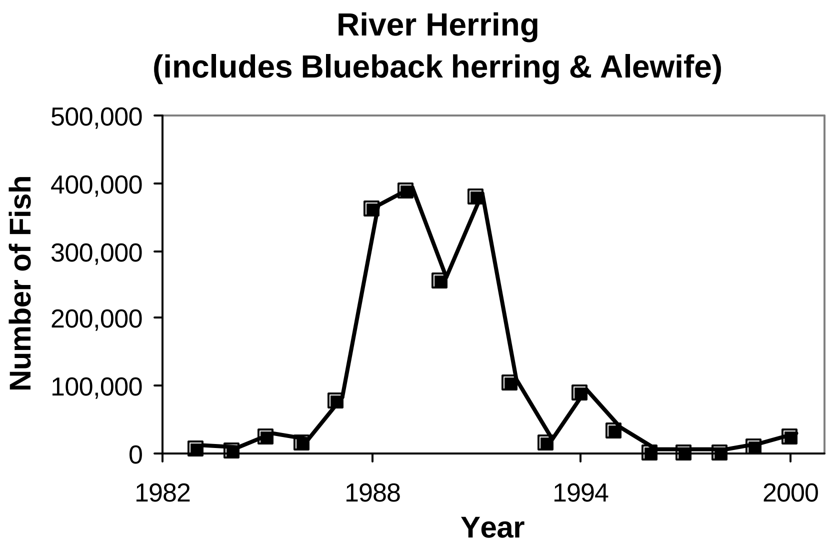
- An annual average of 300,000 adult river herring passing the Essex fish-lift in Lawrence

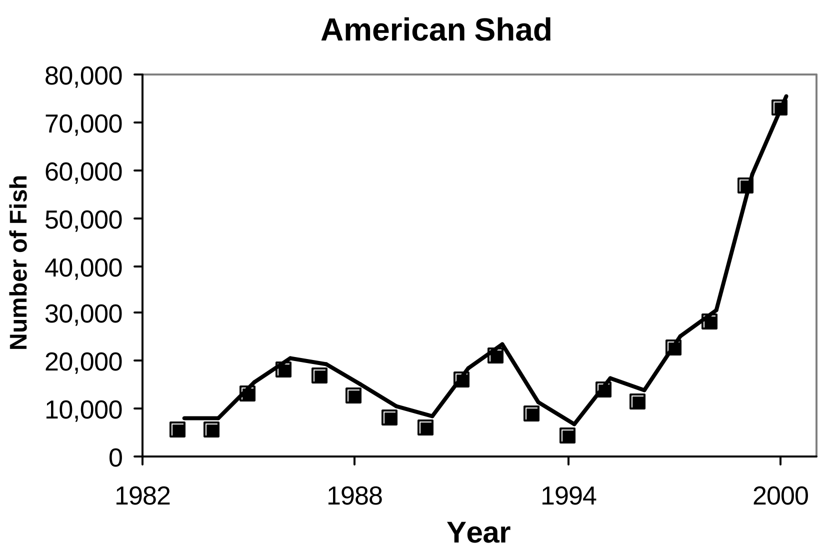
The program has had good success with shad; however, efforts to restore salmon and river herring are doing poorly at this time.

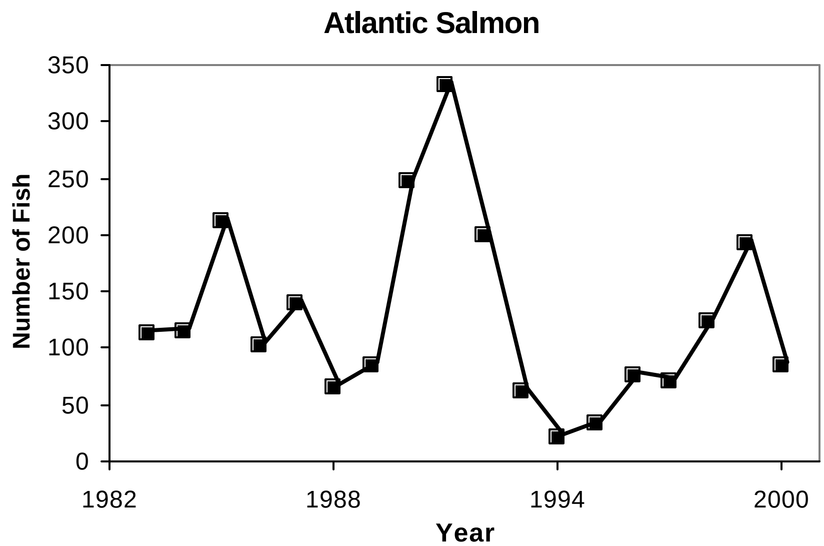
Currently, three dams along the Merrimack River mainstem slow the travel of the anadromous fish upstream: the Essex Dam in Lawrence, Massachusetts; the Pawtucket Dam in Lowell, Massachusetts; and the Amoskeag Dam in Manchester, New Hampshire. Each of the three dams impeding upstream fish passage contains a fish counting station and a "fish lift" or "fish ladder," which allows the fish to bypass the dams. Fish counts at these dams are available from the Central New England Fisheries Resource Office (http://www.fws.gov/r5cneafp/links.htm). Although the upper portions of the Merrimack have been well studied due to the existence of power plants, the adequacy and extent of fish passage in the lower portion or tributaries of the lower Merrimack River, particularly from Newburyport to the New Hampshire state line, is unknown (Carley 2001).

As an example of a recent summary of fish returns, Figure 4.1 presents fish population counts from 1982 to 2000 for river herring, American shad, and Atlantic salmon at the Essex Dam in Lawrence. Atlantic salmon returns have been much lower than predicted. Although the cause of the sharp decline in river herring returns after 1995 is causing concern, there is increasing evidence that predation is a key reason for their decline. American shad populations are increasing.

Figure 4.1: Anadromous Fish Returns - Essex Dam Fish Lift in Lawrence, Massachusetts







Resident Fish Populations

Surface waters in Massachusetts are classified as to whether or not they contain predominately cold-water or warm-water fish species. The state uses the following formal definition of cold-water fisheries: waters in which the maximum mean monthly temperature generally does not exceed 20°C and with temperature fluctuations less than 1.7°C due to a discharge (McVoy 2000). Massachusetts provides separate water quality standards for waters designated as cold water and warm water fisheries. The following table presents a summary of the Class B cold and warm water designated waters in the Commonwealth:

Table 4.6: Cold-Water and Warm-Water Designated Fisheries in Massachusetts

Fishery Designation	River Segment
Cold-water	• Beaver Brook, state line to confluence with Merrimack mainstem • Cobbler Brook, entire length
Warm-water	• Merrimack River, state line to Pawtucket Dam • Merrimack River, Pawtucket Dam to Essex Dam, Lawrence • Merrimack River, Essex Dam, Lawrence to Creek Brook, Haverhill • Stony Brook, entire length • Spicket Brook, state line to confluence with Merrimack mainstem • Little River, state line to confluence with Merrimack mainstem • Powwow River, Outlet Lake Gardner to tidal portion

New Hampshire currently does not have separate designations for cold and warm water fisheries that affect water quality standards. However, a 1999 USGS report showed that the remainder of Beaver Brook in New Hampshire and the northern tributaries to the Pemigewasset River (the East Branch Pemigewasset, the Mad River, and the Baker River) are suitable cold-water fisheries (Flanagan *et al.* 1999).

In 1996, the MRI, in coordination with NHDES, published the "*Resource Use and Value Inventory: Phase II Final Report - New Hampshire*" (Bramley 1996). This effort included the development of a GIS database and map series showing the extent of warm-water (sport) fisheries; cold-water (trout) fisheries (including stocked fisheries); mixed fisheries; confirmed wild trout streams; stocked, current, and historic runs and juvenile habitat for Atlantic Salmon; stocked, current, and historic migration routes and spawning and nursery routes for American shad and river herring. Similarly, the MADEP and MRI's *Aquatic Species Mapping Project* developed several maps showing the anadromous fish runs and spawning areas for nine species along the Merrimack River mainstem. Two additional maps were developed to show the fish runs and spawning areas for the American shad along the main tributaries in Massachusetts. All information is available electronically from MassGIS.

Warm-Water Fish. The upper Merrimack River contains a widely varied, healthy fish population. Numerous studies have been conducted investigating the relationship between the power generating plants along the River and the River's fish population. Most of the studies on the resident fish species in the upper Merrimack have centered around the impacts of the Merrimack Generating Station, which has been in operation since 1968. Public Service of New Hampshire (PSNH), the New Hampshire Fish and Game Department and Normandeau Associates, Inc. conducted numerous thermal and biological studies of the River from 1967 to 1974 to examine the effect of the Merrimack Generating Station's thermal plume of released heated effluent on the aquatic biota in the Hooksett Pond and Amoskeag Pond regions. Studies included chemical and physical parameters, as well as biota including chlorophyll a, plankton, periphyton, aquatic plants, aquatic insects, benthic macroinvertebrates and finfish (Saunders 1993).

Cold-Water Fish. According to the *Technical Committee for Anadromous Fishery Management of the Merrimack River Basin*, (1997) at least 15 to 20 of the fish species found in the watershed at that time were non-indigenous species that have been successfully introduced by humans; these include the largemouth and smallmouth bass, northern pike, walleye, carp, rainbow and brown trout, various catfish species, and goldfish.

In addition to the Federally endangered Atlantic salmon, the watershed is also home to two other endangered species: the Shortnose sturgeon (*Acipenser brevirostrum*) and Atlantic sturgeon (*A. oxyrhynchus oxyrhynchus)* below Lawrence, Massachusetts. Both are considered endangered by the Commonwealth of Massachusetts; the shortnose sturgeon is also on the Federally endangered species list. National Oceanic and Atmospheric Administration (NOAA) has implemented a shortnose sturgeon Recovery Plan but little is known about the habits or demographics of either sturgeon species (Carley 2001). A 1993 study found Atlantic sturgeon do not use the River for spawning but that it is probably an important nursery area. The same study discovered a Shortnose sturgeon population wintering near Merrimackport and spawning at Haverhill (Carley 2001). Sturgeon are hampered by dams similar to the salmon and river herring.

Effect of Pollution on Fisheries

For several years during the mid-1980s a majority of the fishing on the Merrimack River was catch and release due to high levels of contamination, including domestic waste, in the waters. Due to the past industrialization of the Merrimack River watershed, fish populations are susceptible to contamination. The lower basin of the River, in particular, is significantly urbanized, with a significant amount of point sources of contamination including landfills, incinerators, failing septic systems, CSO's, UST's and industrial and municipal discharges (Carley 2001). The watershed is also affected by non-point sources of pollution in the form of paved area runoff and agricultural or suburban use of pesticides. The U.S. Fish and Wildlife Service (FWS) conducted a screening level survey for selected pollutants in 1982; this survey determined that wholebody fish tissue levels of heavy metals and Polychlorinated Biphenyls (PCB's) were above national levels (Major and Carr 1991). This survey was repeated in 1985 on an expanded level to determine finer resolution of contaminant hotspots, and again in 1998 (McDonald 1999). Per the 1998 data, PCB's and mercury continue to be at excessive levels at several stations, and levels increase markedly from upstream to downstream; PCB's exceed the FDA Action Level for whole fish body burden in 20 of 24 sampling sites.

According to the MADEP's *1999 Water Quality Assessment Report*, 5.9 miles fully support, 36.9 miles partially support, and 1.1 miles do not support the Aquatic Life Use designation in the Massachusetts portion of the watershed (60.59 river miles are not assessed). PCB contamination was listed as the cause of the partially supporting use for four of the seven river segments along the mainstem listed in this report (MADEP 2001). Furthermore, in 1999, the USGS initiated a New England Coastal Basin (NECB) Mercury Study in Maine, Massachusetts, New Hampshire, and Rhode Island when their National Mercury Pilot Study uncovered some of the highest mercury concentrations in the country from fish in the New England area. Both Massachusetts and New Hampshire have issued statewide advisories warning against the consumption of fish for pregnant women, women who may become pregnant, and children under 12 years old due to mercury contamination. Studies by the USGS, MADEP, and NHDES have pointed to atmospheric deposition as the primary cause of mercury pollution.

Additional factors threatening fish populations in the Merrimack River watershed include hydromodification and flow regulation, thermal pollution, and insufficient in-stream flow requirements. For example, three of the seven segments included in New Hampshire's 2000 305(b) report along the mainstem were listed as partially support use due to low-flow conditions caused by hydromodification and flow regulation.

Fish populations are also threatened by poor water quality conditions, such as impaired dissolved oxygen and pH levels.

4.2 Recreational Resources

The Merrimack River and its tributaries support a wide range of primary and secondary contact recreational activities. Boat launches are available at numerous parks and marinas along the mainstem; private boat docks are also prevalent. In addition, motorized boating, canoeing, kayaking, fishing, swimming, hiking, camping, cross-country skiing and picnicking are popular activities associated with the River and adjacent bank areas. Table 4.7 provides a list of recreational facilities located along the lower Merrimack River, south of Manchester, New Hampshire.

Table 4.7: Recreational Facilities Along the Lower Merrimack River

Community	Activities Offered	Facility
Manchester, NH	K, BL, CL	Kayaking (Class II/III rapids & slalom course)
	F, P, H	River Walk
	BL, CL, F	Singer Park Boat Ramp
Nashua, NH	P, SF	Greeley Park
Hudson, NH	P, SF	Merrill Park
Tyngsborough, MA	SF	Vesper Country Club
	SF	Tyngsborough Country Club
	BL, CL, F	Larson Ave. Boat Ramp
Chelmsford, MA	BL, CL, F, P, SF	Southwell Field
Lowell, MA	SF	St. Louis Field
	SF	Sheehy Park
	BL, CL	Greater Lowell Community Boating
	BL, S, P,	Lowell Heritage State Park
	SF	Firt St. Playgrounnd & Ferry Landing
Tewksbury, MA	SF	Trull Brook Golf Course
Andover, MA	H, XC, P	AVIS Deer Jump Reservation
	F, H, P	Conservation Land
Lawrence, MA	F, P	Pemberton Park
	BL, CL, P, SF	Merrimack Riverfront State Park
	CL, P	Cr. Lawrence Community Boating Program
North Andover, MA	BL, CL, F	Riverview St. Boat Ramp
Methuen, MA	CL, F, P	Pine Island
	F, P	Schruender Park
	P, SF	Raymond Riverside Park
	BL, CL, SF	Pirates Cove
Haverhill, MA	Bl	Abbots Marina Service
	CL, F, H, P	Hannah Dustin Recreation Area
	F, H, P	Consentino Adopted Nature Trail

Community	Activities Offered	Facility
Haverhill (cont'd)	BL	Riverrest Park
	CL, F, P, SF	Riverside Park
	P, F, SF	Riveredge Park
	BL	Lighthouse Landing Marina
	BL	Kazmiera Marina
	BL	Crescent Yacht Club
	CL, F	City Landing at Rock's Village
	CL, F	E. Meadow River Landing
Groveland, MA	P, SF	Elm Park
	SF	Shanahan Field
	BL, CL, P, SF	The Pines
	F, SF	Pentucket Middle School
Merrimac, MA	CL, F, P	Locust St. Landing
	CL, F, P	Duck landing
Merrimackport, MA	CL, F, P	Waterfront Park
	BL	Wallace Bros Boat Co.
West Newbury, MA	F, H, SF	Pentucket High School
	BL, CL, F, P	Rock's Village Landing
	F, H, P, SF	Page School
	F, H, P	Riverbend Recreation Area
Amesbury, MA	BL	Davy Jones Marina
	CL, F, H, P	Deer Island
	BL	Larry's Marina
	BL	Mackenzie's Marina
	BL, CL	Merrimac St. Boat Landing
	F, P	Alliance Park
	BL	Lowell's Boat Shop
Newburyport, MA	BL	American Yacht Club
	F, H, B, XC, P	Maudsley State Park
	F, H, P, SF	Moseley Pines
	BL, CL, F, P, SF	Cashman Park
	BL, P	Waterfront Boardwalk
	BL, CL, P	City Seawall and Ramp
	F, S, P	Plum Island Point
	F, H, S, P	Parker River NWR
	BL	Boatworks at Newburyport
	BL	Carr Island Marine
	BL	Ferry Landing Marine
	BL, F	Hilton's Fishing Dock
	BL	Merri-Mar Yacht Basin
	BL	Mackenzie's Channel Marker Marina
	BL	Windward Yacht Club
	BL	Preservation Shipyard
	BL	North End Boat Club

Community	Activities Offered	Facility
Newbury, MA	CL, CL, F	Plum Island boat access
Salisbury, MA	BL, CL, F, C, S, P	Salisbury Beach State Reserve
	F, H, P	Isaac Sprague WS Carr Island
	F, H, P	Ram Island WS
	F, H, P	Eagle Island
	F, H, P	Fish and Wildlife Land
	H, P	Greenbelt Mendelson Marsh
	BL, CL	Salisbury Town Wharf

Notes: BL= boat launch, CL= canoe launch, F= fishing, H= hiking, C= camping, XC= skiing, S= swimming, P= picnicking, SF= sports facilities, K= kayaking

In addition to the facilities listed in Table 4.7, there are numerous lakes, streams and ponds with access for fishing, boating and swimming within the watershed. One swimming beach exists on the Merrimack River in Lowell upstream of the Pawtucket Dam. The Salisbury Beach State Reservation and Plum Island Point also allow ocean swimming although both explicitly prohibit swimming in the River.

The Merrimack River Watershed Council (MRWC) is currently conducting a survey of recreation facilities in the mainstem Merrimack River in Massachusetts. The report is expected to be complete in spring 2002 and will include information on access points to the River and recreational uses at different locations. A review of the literature indicates that there is currently no numerical data available on the recreational uses at any of the facilities. Furthermore, there is currently no epidemiological data available that ties the use of these recreational facilities, particularly the swimming beach and boating reaches, to actual incidents of illness in humans. This is, however, an important link between the recreational usage of the River and the state water quality standards, which uses bacteria criteria as an indicator of human health risk.

The segment of the Merrimack River from its origin at Franklin, New Hampshire to the backwater impoundment at the Hooksett Dam is under Congressional study for designation to the Wild and Scenic River System. It is currently under protection of the Wild and Scenic Rivers Act pursuant to Section 7(b) of the Act (*National Park Service Rivers, Trails, and Conservation Assistance*, downloaded from http://www.ncrc.nps.gov/programs/rtca/nri/STATES/nh.html on June 25, 2002).

There is a considerable amount of open space within the watershed, both privately and publicly owned. There are several State parks within the watershed, including Lawrence Heritage State Park, Lowell Heritage State Park, Salisbury Beach State Reservation, as well as several Federally managed parks including the Lowell National Historic Park, Parker River National Wildlife Reserve and Plum Island National Wildlife Reserve.

4.3 Other Resources

The following section provides a summary of additional resources in the Merrimack River watershed, including hydropower facilities, exiting U.S. Army Corps of Engineers (USACE) projects, and water suppliers.

4.3.1 Hydropower

Five hydroelectric dams currently operate along the mainstem Merrimack River; two operate on the mainstem of the Pemigewasset River (Technical Committee for Anadromous Fishery Management of the Merrimack River Basin 1997). The name and location of the seven dams is listed below in order from upstream to downstream location:

- Ayers Island Dam in Bristol, New Hampshire
- Eastman Falls Dam in Franklin, New Hampshire
- Garvins Falls Dam in Bow, New Hampshire
- Hooksett Dam in Hooksett, New Hampshire
- Amoskeag Dam in Manchester, New Hampshire
- Pawtucket Dam in Lowell, Massachusetts
- Essex Dam in Lawrence, Massachusetts

The Garvins Falls, Hooksett, and Amoskeag Dams combined have a generating capacity of approximately 29.7 megawatts. The Pawtucket Dam in Lowell, Massachusetts has two identical Fujii Kaplan turbines with a total combined generation capacity of 17.3 megawatts at a normal head of 37 feet. Hydraulic capacity of the plant with both turbines running is approximately 7,200 cfs (3,600 per unit). The Essex Dam in Lawrence has two Kaplan bulb turbines with a combined generation capacity of 15 megawatts (7.5 for each turbine). Each turbine has a maximum hydraulic capacity of 3,750 cfs or a combined capacity of 7,500 cfs.

Numerous additional hydroelectric dams exist on tributaries to the Merrimack River. A 1998 study by the USGS NECB Study Team cited 93 dams in the watershed used to for hydroelectric purposes (USGS 1998). Some of these facilities have minimum flow requirements in bypass reaches and downstream reaches; however, neither New Hampshire nor Massachusetts has a specific in-stream flow policy applicable to the Merrimack River. As previously noted, New Hampshire is in the process of testing such a policy on two rivers in the state.

During high flow periods, these hydroelectric facilities operate under "run of the river flows," with substantial spillage. During low-flow periods, the dams are required to pass a minimum flow, while still operating to meet peak demands. This results in short-term (*i.e.* daily to weekly) water level fluctuations during the drier summer months.

4.3.2 Existing USACE Projects

The U.S. Army Corps of Engineers (USACE) currently owns and operates five flood control projects in the Merrimack River watershed and has constructed six total flood control projects in the basin. A list of the currently owned facilities is provided below:

- Franklin Falls Dam on the Pemigewasset River in Franklin, New Hampshire
- Blackwater Dam on the Blackwater River in Franklin, New Hampshire
- Everett Lake on the Piscataquog River in Contoocook, New Hampshire
- Hopkinton Lake on the Contoocook River in Hopkinton, New Hampshire
- Edward MacDowell Lake on the Nubanusit River in Peterborough, New Hampshire

Additionally, the USACE completed a navigation channel in 1907 in the mainstem Merrimack River that extended from Haverhill to Newburyport, Massachusetts. Jetty and channel work was also completed by the USACE at the mouth of the River in Newburyport in 1958.

4.3.3 Water Supply

Fifteen communities in Massachusetts and three communities in New Hampshire (through the Pennichuck Water Works) currently withdraw water from the Merrimack River watershed. Many of these municipalities have additional sources within the watershed as well. Manchester, New Hampshire is considering augmenting their current water supplies with water from the mainstem River. Additional communities along the River are expected to follow this trend as they struggle to meet future water demands. Many smaller communities also withdraw water from primary tributaries of the Merrimack River. For example, the town of Billerica, Massachusetts withdraws water from the Concord River. Still others obtain their drinking water from groundwater aquifers within the basin, which can affect baseflow conditions in the River and its tributaries.

Some industrial users are also allowed to withdraw water from the River. The Massachusetts Department of Environmental Protection, Water Management Program (MADEP-WMP) and the New Hampshire Department of Environmental Services, Water Management Bureau (NHDES-WMB) both maintain records of water withdrawals in the study area. In Massachusetts, major water uses, defined as withdrawals in excess of 100,000 gallons per day (GPD) averaged over a 90-day period, are regulated under the Water Management Act. In New Hampshire, any facility that uses 20,000 GPD averaged over any seven day period or 600,000 gallons in any 30-day period must register and report their monthly water use by each source and destination to the WMB (Saravanapavan 2001).

The 2001 Merrimack River Watershed Council report "*Water Demand Analysis on Merrimack River Watershed*" presents a summary of the municipal and industrial facilities that withdraw water from the Merrimack River mainstem between Manchester, New Hampshire and Newburyport, Massachusetts (Saravanapavan 2001); these results are replicated in Table 4.8. This list is based records between 1995 and 2000.

Table 4.8: Water Users Along the Merrimack River Mainstem downstream of Manchester, New Hampshire

Community	Water User
Manchester, NH	Public Service Co. NH Intervale Country Club Nylon Corp of America Manchester Water Works Saint Anselm College Coastal Material Corporation F&S Transit Mix Co.
Merrimack, NH	Pennichuck Water Works Merrimack Village District Anheuser-Busch Inc. Jones Chemicals Inc. Lockheed Sanders Texas Instruments Inc.
Litchfield, NH	Wilson Farm of NH Passaconaway Country Club Continental Paving Inc. Pennichuck Water Works Lockheed Martin Corp.
Bedford, NH	Manchester Country Club
Londonderry, NH	Pennichuck Water Works Century Village Community Association Moose Hill Orchards Inc. Londonderry Country Club Continental Paving, Inc.
Nashua, NH	Nashua Country Club Pennichuck Water Works Brox Industries Inc. Redimix Concrete Service Inc. Nashua National Fish Hatchery Unifirst Corporation Advanced Circuit Tech. Beebe Rubber Company

	Coca-Cola USA Compaq Computer Corp. GL&V Impco-Jones Inc. Hampshire Chemical Corp. Kollsman Lockheed Sanders Nashua Corporation Owens-Brockway Sanmina Corporation Teradyne Connect Systems Rivier College Saint Joseph Hospital Southern NH Medical Center Sky Meadow Country Club Mine Falls Ltd Partnership Nashua Hydro Associates
Hudson, NH	Green Meadow Golf Club Brox Industries, Inc. Coastal Concrete Company
Tyngsborough, MA	TJ Maxx
Westford, MA	Westford Water Department Laughton Garden Center, Inc. Vinebrook Estates
Chelmsford, MA	North Chelmsford Water District Laughton Garden Center, Inc.
Lowell, MA	Lowell Regional Water Utility Western Avenue Dyers, LP
Tewksbury, MA	Tewksbury Water Department Tewksbury Hospital
Dracut, MA	Dracut Water Supply District PJ Keating Company
Andover, MA	Andover Water Department
Lawrence, MA	Lawrence Water Works Malden Mills Industries, Inc. Merrimac Paper Company Newark Atlantic Paperboard Corp.
North Andover, MA	North Andover Water Department Lucent Technologies, Inc.
Methuen, MA	Methuen Water Department Hickory Hill Golf Course
Haverhill, MA	Haverhill Water Department Haverhill Paperboard Corporation Bradford Country Club Ogden Martin Systems of Haverhill Spring Hill Farm Dairy Inc.
Groveland, MA	Groveland Water Department

Merrimac, MA	Merrimac Water Department
West Newbury, MA	West Newbury Water Department
Amesbury, MA	Amesbury Utility Water District
Newburyport, MA	Newburyport Water Department
Salisbury, MA	Salisbury Water Supply

Source: Saravanapavan 2001

In 1996, the MRI, in conjunction with the MADEP and the NHDES, published the "*Verification of Water Use in the Merrimack River Watershed*." The group compiled information on known or presumed water users within the watershed. They were able to create a database summarizing withdrawals from all facilities whose self-supplied water use exceeded 20,000 gallons per day. The results were presented as a series of maps for each water use (*i.e.*, estimated withdrawals for public water supply, agriculture, industrial uses, etc.) grouped by subwatershed.

Additionally, in 2001 the Merrimack River Watershed Council published a DRAFT "*Water Demand Analysis on Merrimack River Watershed*." This report presents a summary of the self-supplied water users in the lower Merrimack River communities of Massachusetts and New Hampshire (from Manchester, New Hampshire to Newburyport, Massachusetts) (Saravanapavan 2001).

Section 5
Pollution Source Summary

This section provides a brief summary of the major point and non-point source pollution sources to the Merrimack River watershed. Future tasks performed under Phase I of the Merrimack River Watershed Assessment Study will help to further identify and quantify the major sources of pollution to the basin. The "Collection of Information on Pollutant Sources" task will assess the existing water quality impacts from combined sewer overflows (CSO's), stormdrain systems, municipal wastewater treatment plants, industrial dischargers, and other sources, such as air deposition, sediments, groundwater plumes from landfills, and illicit connections. The "Water Quality and Flow Monitoring" task will allow for the collection of water quality samples both in the river and at various CSO and stormdrain outfalls.

5.1 Point Source Pollution Summary

Municipal wastewater treatment plants (WWTP's), CSO's, stormdrain discharges, and industrial discharges are considered to be the largest causes of point source pollution in the Merrimack River watershed. These sources contribute significantly to the non-attainment of designated uses throughout the Merrimack River watershed. As noted Section 3.0, the non-attainment of the primary and secondary contact recreation standards in the Merrimack River mainstem south of Manchester, New Hampshire may be generally attributed to CSO discharges. Both CSO and stormdrain pollution is generally a wet weather problem, whereas municipal and industrial point source dischargers are a year-round source. These sources generally contribute to low dissolved oxygen levels and metals and nutrient contamination.

All point sources discharging to waters of the United States are required by law to obtain a permit under the National Pollutant Discharge Elimination System (NPDES). Permittees are categorized as either "major" or "minor" dischargers based on the toxic pollution potential, wastewater flow rate, type of wastewater, amounts of conventional pollutants, heat load, presence of downstream water supply, and water quality limitations of the stream (USEPA, 1987). Municipally owned treatment facilities operated by a city, town, or state are considered major if they (1) have a flow equal to or greater than one million gallons per day (1MGD), (2) impact downstream uses, or (3) discharge upstream of a public water supply. Stormdrain systems regulated under Phase I and II of the NPDES are required to have permitted outfalls; communities not meeting the "urbanized area" criteria for these regulations do not require NPDES permits for their stormdrain outfalls. Further discussion is provided in Section 5.1.3.

In 1999, the MADEP, in conjunction with the Executive Office of Environmental Affairs (EOEA) Merrimack River Watershed Team, published the "*Merrimack River Basin - NPDES Discharge Permit Inventory, CSO Discharge Review, GIS Mapping Effort*." The main objectives and deliverables of this study were:

- A review and inventory of all EPA/DEP NPDES Discharge Permits in the Merrimack River basin (in Massachusetts)
- An update of all WWTP CSO discharges in the Massachusetts portion of the basin in conjunction with the inventory and update process
- Verification of locations for facilities identified through the review and inventory process and development a GIS database containing this information

5.1.1 Municipal WWTP's and Industrial Point Source Discharges

Currently, seven communities in Massachusetts (Amesbury, Haverhill, Lowell, Merrimac, GLSD, Newburyport, and Salisbury) and four in New Hampshire (Derry, Manchester, Merrimack, and Nashua) operate wastewater treatment facilities that discharge to the mainstem Merrimack River south of Manchester, New Hampshire (Saravanapavan, 2001); numerous others discharge to primary tributaries of the Merrimack, as well as to upstream portions of the River north of Manchester, New Hampshire.

The 2001 Merrimack River Watershed Council report "*Water Demand Analysis on Merrimack River Watershed*" presents a summary of the facilities which discharge into the Merrimack River mainstem from Manchester, New Hampshire to Newburyport, Massachusetts (Saravanapavan 2001); these results are reproduced in Table 5.1. This list is based on information downloaded from USEPA's Permit Compliance System (PCS) database in Envirofacts regarding NDPES discharge permits (http://www.epa.gov/enviro/html/pcs/) for records between 1995 and 2000.

Table 5.1: Water Discharges to the Merrimack River Mainstem downstream of Manchester, NH

Community	Water Discharger
Manchester, NH	Nylon Corp. of America Manchester WWTF
Merrimack, NH	Anheuser-Busch Inc. Jones Chemicals Inc. Merrimack WWTP Nashua Corporation
Litchfield, NH	Derry WWTF
Nashua, NH	Brox Industries Inc. Nashua National Fish Hatchery Hampshire Chemical Corp. Lockheed Sanders Sanmina Corporation Nashua WWTF
Tyngsborough, MA	Browning Ferris
Westford, MA	Fletcher Granite
Lowell, MA	Lowell Regional WWTP Lowell Cogene PL
North Andover, MA	Lucent Technologies, Inc. Greater Lawrence Sanitary District AEP IND. Proponite
Haverhill, MA	Haverhill WPCF Vernon Plastics
Groveland, MA	Mill Pond GW INTER
Merrimac, MA	Merrimac WWTF
Amesbury, MA	Amesbury WWTP
Newburyport, MA	Gould Elect Inc. Newburyport WPC
Salisbury, MA	Salisbury WWTF

5.1.2 Combined Sewer Overflows

The cities of Manchester and Nashua, New Hampshire, Lowell and Haverhill, Massachusetts, and the Greater Lawrence Sanitary District each have combined sewer overflows that discharge to the Merrimack River or primary tributaries. A summary of the number of outfalls, receiving waterbody, and average annual discharge volume is provided in Table 5.2.

Table 5.2: CSO Discharges to the Merrimack River Mainstem

Community	Number of CSO's & Receiving Waterbody	Average Annual Discharge Vol. (MG)	Maximum No. of Discharges per Year
Manchester, NH	17 to Merrimack River 8 to Piscataquog River	220	49
Nashua, NH	4 to Merrimack River 4 to Nashua River	136	57
Lowell, MA	7 to Merrimack River 2 to Concord River	352	37
GLSD	4 to Merrimack River 1 to Spicket River	112	14
Haverhill, MA	16 to Merrimack River 7 to Little River	71	42

Source: CDM 1995, 1997, 2001, 2002a, and 2002b
MG= Million gallons
Note: CSO controls are currently being implemented in Manchester and Nashua, New Hampshire, which may be reduced the number of overflows from those listed above.

As noted in Section 3.0, most of the bacteria contamination in the Merrimack River mainstem south of Manchester, New Hampshire may be attributed to CSO discharges. As such, contamination from these sources is generally a wet-weather problem. Each of the communities is currently in the process of developing and implementing Long-Term CSO Control Plans in compliance with the Federal Clean Water Act to help mitigate the impact of the CSO discharges.

5.1.3 Stormdrain Discharges

As with CSO discharges, stormdrain pollution is generally a wet-weather problem, with the exception of illicit connections that may cause dry weather flows. In an effort to control the quality of stormdrain discharges, the USEPA is currently implementing Phase II of its NPDES Stormwater Regulations (Phase I focused on municipal storm sewer systems serving populations of 100,000 or more people). Under Phase II, small municipal separate stormwater systems (MS4s) in "urbanized" areas, as defined by the 1990 census data, are required to implement six minimum control measures aimed at minimizing the impacts of stormwater runoff on water quality and aquatic life. As part of this program, communities will be required to identify and eliminate illicit connections, develop public education and outreach programs, and implement construction and post-construction stormwater controls. The majority of communities in the Massachusetts portion of the basin and in southern New Hampshire (below Manchester, New Hampshire) will be required to comply with these new regulations; no communities in the watershed north of Hooksett fall under the Phase II jurisdiction. Additionally, in 1997 Massachusetts published statewide Stormwater Management Standards in a two-part series, "*Volume 1: Stormwater Policy Handbook*" and "*Volume 2: Stormwater Technical Handbook*". These standards are aimed at controlling the quality and quantity of stormwater runoff from new and redevelopment projects falling within the jurisdiction of Conservation Commissions.

5.2 Non-Point Source Pollution Summary

A review of the water quality problems in the Merrimack River and its tributaries suggests that non-point source pollution is a large contributor to the non-attainment of designated uses throughout the watershed. Table 5.3 provides a list of the potential contributors to non-point source pollution in the basin, as well as their impacts:

Table 5.3: Potential non-point source pollution sources and impacts

Source	Nutrients	Metals	Bacteria	Sediment
Urban and non-urban stormwater runoff	X	X	X	X
Atmospheric Deposition	X	X[1]		
Natural sources (*i.e.* wildlife and waterfowl populations)	X		X	
Pet Waste	X		X	
In-situ contaminants (*i.e.* sediments)	X	X		
Agricultural runoff	X		X	X
Septic systems	X	X	X	
Illicit connections			X	
Boating and marinas		X	X	
Groundwater plumes from RCRA[2] facilities and landfills		X		

[1]Mercury has been identified as a particular problem in the northeast

[2]RCRA- Resource Conservation Recovery Act

Unlike permitted point source discharges, pollution from non-point sources is much more difficult to quantify and remediate. End-of-pipe treatment options, such as those used to control industrial and municipal WWTP point sources, cannot be readily applied to non-point sources. However, as noted above, many of these potential non-point sources may play a large role in the non-attainment of water quality standards in the Merrimack River watershed and as such are an important component that must be considered when addressing water quality.

Section 6
Future Directions

The goal of this "*Description of Existing Conditions*" report was to provide a comprehensive description of the existing conditions in the Merrimack River watershed, with respect to its physical setting; biological, recreational, and other resources; water quality in the mainstem and significant tributaries; and the potential sources of point and non-point source pollution.

This report will serve as a reference document for use and comparison during subsequent tasks performed under Phase I of this project. These tasks include a detailed collection and analysis of information on pollutant sources; the development and implementation of an extensive wet and dry-weather monitoring program; detailed analysis of the Merrimack River using developed water quality and hydrologic models; development and preliminary alternatives analysis; and an inventory of potential ecosystem restoration opportunities.

Section 7
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