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NEW HAMPSHIRE WATER RESOURCES PRIMER

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Prepared by

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Contents

List of Acronyms

BMP	Best management practices
CSO	Combined sewer overflow
CWA	Clean Water Act (federal)
CWS	Community water systems
DES	New Hampshire Department of Environmental Services
DPW	Department of Public Works
EPA	U.S. Environmental Protection Agency
FEMA	Federal Emergency Management Agency
HB	New Hampshire House Bill
LAC	Local advisory committee
LID	Low impact development
MCL	Maximum contaminant level
MTBE	Methyl tertiary-Butyl Ether
NFIP	National Flood Insurance Program
NHDES	New Hampshire Department of Environmental Services
NHF&G	New Hampshire Fish and Game Department
NHGS	New Hampshire Geological Survey
NHOEP	New Hampshire Office of Energy and Planning
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
OEP	New Hampshire Office of Energy and Planning
POTW	Publicly owned treatment works
RSA	Revised Statute Annotated
SB	New Hampshire Senate Bill
SDWA	Safe Drinking Water Act
SRF	State revolving fund
TMDL	Total maximum daily load
UNH	University of New Hampshire
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WWTF	Wastewater treatment facility

Executive Summary

The water running through, over and by New Hampshire has shaped the state's history and will influence its future. Over the last decade New Hampshire has been the fastest growing New England state, and there are another 260,000 new residents anticipated between 2005 and 2030. Hundreds of thousands of visitors come to New Hampshire each year to enjoy the state's beautiful lakes, rivers and coast in the summer and its ski areas, snowmobile trails and ice-fishing spots in the winter. Whether it is needed for drinking, manufacturing, recreating, waste assimilation or ecosystem health, water is a cornerstone of New Hampshire's beauty and prosperity, and wise management and protection of water resources is critical to New Hampshire's economy, public health and environment.

The Water Resources Primer was developed to inform policy makers and citizens about the state's water resources and the challenges faced in sustainably managing them. It was developed as part of an initiative to develop a statewide, comprehensive water plan, spearheaded by the Legislature's Statutory Water Resources Committee. The New Hampshire Department of Environmental Services is the lead author, although the document was significantly influenced and improved by the contributions of many volunteer stakeholders and experts.

This is the first document that contains all of the water related topics of importance to New Hampshire policy makers. It is meant to provide the reader with an understanding of the complex and interrelated nature of water resources and water resource issues. It is also formatted to provide topic specific chapters that can be used to understand particular subjects.

The first chapter of the primer describes four underlying challenges that are critical to understanding and effectively managing water resources. First, land development activities driven by economic and population growth can have profound impacts on water quality, water availability, and water-based recreational opportunities. Second, climate change, which is already bringing increasingly frequent extreme weather events to New Hampshire, is expected to exacerbate water quality, affect water availability, test our readiness to deal with droughts and flooding, and to overwhelm the existing stormwater infrastructure in many places. Third, as is the case nationwide, New Hampshire's infrastructure for water supply, wastewater treatment, stormwater, and water storage (dams) is sorely in need of maintenance, upgrade, or replacement, but no funding mechanism is in place to provide all of the needed money. Fourth, in order to inform the effective management of our water resources, we need to address critical data needs including expanding our efforts to gauge stream flows, monitor groundwater levels, gather water quality data, monitor the occurrence and spread of invasive species, and map flood-prone areas.

The first chapter also provides, in the section called "New Hampshire Water at a Glance," pertinent facts and statistics about the state's water resources, water use, water infrastructure and water law. The remaining chapters are topic specific and include: Rivers; Lakes and Ponds;

Groundwater; Wetlands; Coastal and Estuarine Waters; Water Use and Conservation; Drinking Water; Wastewater; Stormwater; Dams; and Floods and Droughts. Each of these chapters provides information about the topic, related issues and current management efforts. Each of these chapters also provides a few key stakeholder recommendations. Most, but not all, of those recommendations can be grouped into the following areas:

- Improve knowledge – data characterization and evaluation
- Increase water use efficiency
- Improve land use patterns – directing development
- Improve stormwater management
- Adapt to climate change
- Address infrastructure needs
- Improve integration of protection programs
- Shift towards watershed/regional vs. municipal planning and regulation
- Increase emergency preparedness

New Hampshire is fortunate to have an abundance of high quality water resources. With nearly 17,000 miles of rivers and streams, 1,000 lakes and large ponds, 238 miles of ocean and estuarine coastline, and potable groundwater throughout the state, New Hampshire is relatively water rich. The foldout graphic in Chapter 1 depicts the connectivity between New Hampshire's waters and how both water quality and quantity are influenced by what occurs on the landscape.

Making sound policy decisions regarding water resources and ensuring that there is enough good quality water for the many users that depend on this resource are not small tasks. They are, however, essential to sustaining New Hampshire's special quality of life. The Water Resources Primer has been developed and is intended to support this worthy goal.

Note Regarding Citation of Sources

The primer uses a format for citation of information sources that is commonly used in technical literature. Citations take the form of "(Author(s), year)." For the complete citation, please refer to the list of references at the end of the chapter. When a chapter cites more than one source published in the same year by a given author or team of authors, the year is followed by a letter, e.g., "(Author, 2008a)," to enable the reader to distinguish among sources. The editors of the primer have decided to err on the side of providing more citations rather than too few, in order to address potential questions about the authoritativeness of the information.

Chapter 1
Introduction and Overview

NEW HAMPSHIRE
DEPARTMENT OF
Environmental
Services

1.1 Purpose

This primer was developed for local and state policy makers and New Hampshire residents. It was written to bring together in one document an overview of the information necessary to understand and make informed policy decisions about New Hampshire's water resources.

1.2 Introduction

New Hampshire is a unique state with a quality of life that consistently rates among the highest in the nation (Public Service of New Hampshire, 2008). The water running through, over, and by New Hampshire has shaped the state's history and will influence its future. The wise management and protection of water resources is critical to New Hampshire's economic prosperity, public health and environment.

New Hampshire is a small state with plentiful, high quality water resources compared to other parts of the country. New Hampshire has almost 17,000 miles of rivers and streams, nearly 1,000 lakes and large ponds, and 238 miles of ocean and estuarine coastline. Groundwater in New Hampshire is found in fractured bedrock and in the sands, gravels and till left by past glaciers. There is great connectivity among New Hampshire's waters and both water quality and quantity are greatly influenced by what occurs on the landscape (see Figure 1-17, the fold-out graphic).

New Hampshire is also the fastest growing of all the New England states and our landscape will continue to change to accommodate the projected 260,000 new people that are expected to move to the state between 2005 and 2030 (New Hampshire Office of Energy and Planning [NHOEP], 2006). Hundreds of thousands of tourists come to New Hampshire each year to enjoy the state's beautiful lakes, rivers, mountains and coast in the summer and its ski areas, snowmobile trails and ice-fishing spots in the winter. Whether it is needed for drinking, manufacturing, recreating, waste assimilation, or ecosystem health, water is a cornerstone of New Hampshire's beauty and prosperity.

In 2003 a statutory Water Resources Committee was established in the Legislature to study water related issues. The New Hampshire Department of Environmental Services (DES), in conjunction with this committee, sought and acquired limited funding to begin development of a comprehensive water resource plan to ensure the sustainability of New Hampshire's water resources. Development of this primer to inform policy makers and citizens is an initial step toward development of a statewide water resource plan. Thanks to legislative actions and the hard work of many stakeholders, for the first time a description of New Hampshire specific issues and topics related to surface water, groundwater, water quantity, water quality, water use and conservation, and water related infrastructure will be contained in one document.

New Hampshire has long been a national leader in the protection of water resources. Foresighted leadership by policy makers at the state and local levels on many water related issues has been occurring for more than a century in New Hampshire, starting with the protection and treatment of drinking water and other early regulatory and non-regulatory approaches to address septic systems, wastewater disposal, wetlands, surface waters, groundwater and dams. The primer was developed to provide policy makers with the information they will need to continue to protect water resources given the current and future challenges of increasing water demand, a changing landscape as economic and population growth occurs, multiple water users with competing needs, climate change,and aging water infrastructure for water supply, stormwater, wastewater and dams.

1.3 Primer Organization

This document has been organized so that it can be read either in its entirety to give the reader an in-depth understanding of the complex and interconnected nature of New Hampshire's water resources and water resource issues, or by a particular chapter to understand specific water resource topics. An attempt has been made to strike a balance between providing a comprehensive overview and describing the state's more pressing water resource topics in greater depth.

The primer has 12 chapters.

Chapter 1 – Introduction and Overview provides a brief description of the four primary challenges to sustainable water resource management that underlie the remaining topic specific chapters. These include:

- Landscape Change and Increased Demand for Water Related to Population and Economic Growth.
- Climate Change: Increasing temperature, more frequent and intense storms, etc.
- Aging and Inadequate Water Infrastructure: Wastewater, drinking water, stormwater and dams.
- Information Needs: Water quantity and quality data collection, analysis and management.

This chapter also provides a section called "New Hampshire Water at a Glance" (Section 1.5) that contains summary information about New Hampshire's water resources, water use, water infrastructure and water law.

The remaining chapters are Rivers, Lakes and Ponds, Groundwater, Wetlands, Coastal and Estuarine Waters, Water Use and Conservation, Drinking Water, Wastewater, Stormwater, Dams, and Floods and Droughts. Each of these chapters provides information about the topic, issues related to it, and current management efforts, together with a few key stakeholder recommendations. Throughout the document, information sources cited within the text are fully referenced at the end of each chapter.

1.4 Underlying Challenges

In writing this document, four underlying challenges emerged that are of importance to most, if not all, of the specific topics covered in chapters 2 through 12. Accordingly, they are being introduced and described briefly in this overview chapter. In the chapters that follow, there is additional information about these challenges that pertains specifically to the chapter's topic.

Challenge 1: Landscape Change and Increased Demand for Water Related to Economic and Population Growth

Between 1990 and 2004 New Hampshire grew by 17.2 percent, twice the rate of the rest of New England. It is projected that between 2005 and 2030 there will be 260,000 new residents in New Hampshire and approximately 73 percent of them will live in the four southeastern counties (Figure 1-1) (NHOEP, 2006). Although New Hampshire's growth has slowed recently, the inevitable increasing population will result in more land development and, therefore, more demand for water. Significantly, recent trends suggest that this new growth comes with a greater need for water than historic development. It is also clear that as the landscape is developed, stormwater runoff must be addressed in a new way to avoid further degradation of surface water quality, replenish groundwater, and limit flooding and infrastructure damage. Water use efficiency practices and low impact development techniques are available to reduce the negative impacts of growth and support water sustainability. These are discussed in detail in Chapter 7 – Water Use and Conservation and Chapter 10 – Stormwater. Concerns regarding increased water use and stormwater, both related to growth and landscape change, are introduced briefly below because of their significance to protecting both water quantity and water quality.

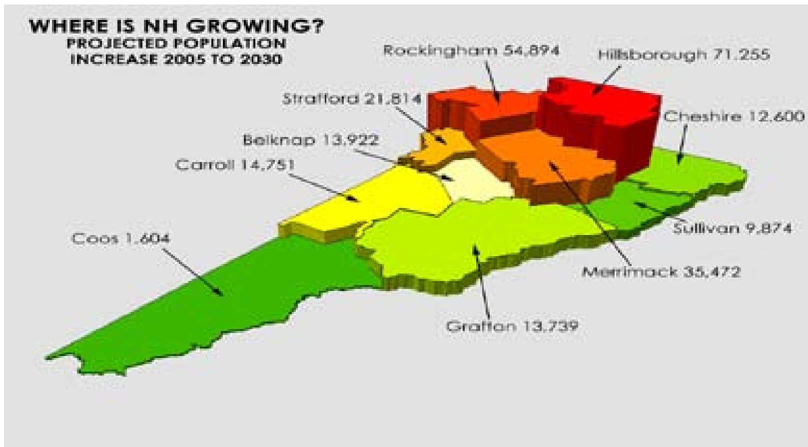


Figure 1-1. Projected population growth in New Hampshire. ***Source: SPNHF, 2008; data source: New Hampshire Office of Energy and Planning, 2006.***

Increasing Water Use

Water use in New Hampshire continues to increase over time with the state's growing population. From 1960 to 2000 New Hampshire's population doubled from 606,400 to nearly 1.2 million (SPNHF, 2005). Similarly, withdrawals from groundwater and surface water by public water systems increased from 54 million gallons to 97 million gallons per day (MacKichan & Kammerer, 1961; Hutson et al., 2004). The U.S. Geological Survey (USGS) estimates that the average overall water use in New Hampshire is 211 million gallons per day (Hutson et al., 2004).

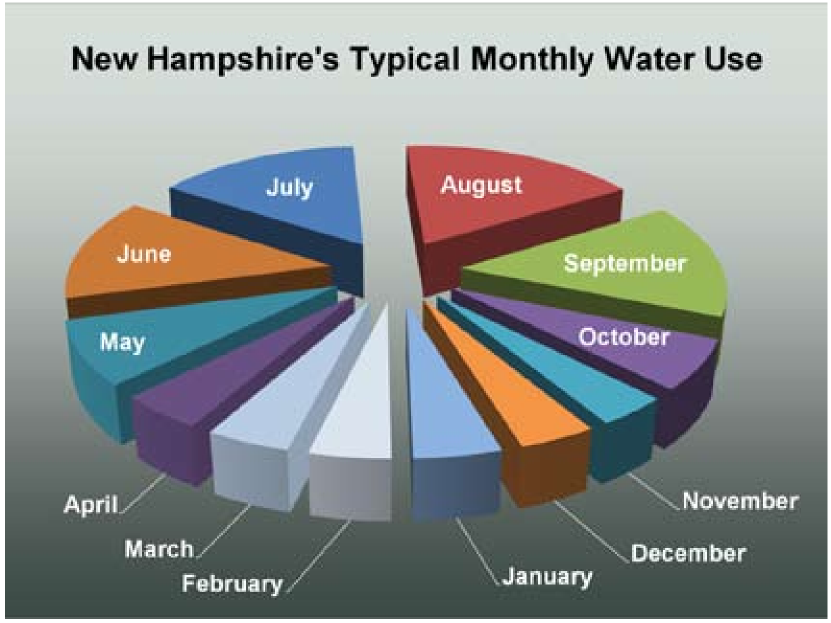


Figure 1-2. New Hampshire's typical monthly water use. *Source: NHDES Drinking Water and Groundwater Bureau.*

National estimates indicate that the average American uses approximately 100 gallons of water per day (Hutson et al. 2004; USEPA, 2008). A recent study specific to the Seacoast Region of New Hampshire derived an annual average use of 75 gallons per day (Horn et al., 2008). The current trend for residential development is toward large homes with more bathrooms, hot tubs, dishwashers and garbage disposals. Newer homes also tend to have large lawns and in-ground irrigation systems. These trends mean more water demand per residential unit and will likely increase the average daily water use over time.

The amount of water use varies significantly from one season to another. Typically, winter water use represents the domestic indoor water needs of a household. Water use increases substantially during the summer months due to discretionary outdoor uses of water. Many public water systems have reported a summer water demand that is twice the winter demand due primarily to lawn irrigation (Figure 1-2). In the summer, water demand increases at a time when there is naturally less water available in the environment due to plant uptake and evaporation. Temperature rise due to climate change will only exacerbate this situation. Chapter 8 – Drinking Water, discusses public water supply issues related to meeting summer water demand. Chapter 7 – Water Use and Conservation, provides information on current and projected water use and ways to use water more efficiently, which is increasingly important given climate change and aging, leaking infrastructure.

Figure 1-3. Example of water not being used efficiently and runoff from impervious surfaces. *Source: Dukes, 2007.*

Landscape Change and Managing Stormwater

Long-term trends show that each year an average of 13,500 acres of New Hampshire's forest land is converted to other land uses (SPNHF, 2006). This change in the landscape means many more buildings, roads, driveways and parking lot areas. All of these create impervious surfaces – a surface that reduces or prevents the infiltration of water into the ground. Impervious surfaces affect the natural movement and treatment of precipitation that falls on the landscape, i.e., stormwater. Chapter 10 – Stormwater, explains the mechanics of this phenomenon. The most obvious

Figure 1-4. Stormwater draining to our surface water causes water quality impairment. ***Source: NHDES Watershed Management Bureau.***

effect of increased imperviousness is increased flooding because less water can soak into the ground. Historically, the increased volume of stormwater was managed by directing it to the nearest surface water as quickly as possible. Because of downstream flooding and erosion concerns, stormwater management evolved to include measures such as detention ponds, designed to store and slowly release stormwater while also allowing for the settling of some sediment. However, it is now evident that stormwater management must improve to halt the degradation of surface water quality, increase groundwater recharge, and limit flooding and infrastructure damage.

In 2008 23,778 acres of New Hampshire's lakes and rivers were classified as having threatened or impaired water quality. DES believes this to be largely attributed to stormwater, which picks up contaminants and nutrients as it moves through the developed landscape, discharging it into these water bodies. DES has also estimated that one acre of impervious surface where runoff is routed to surface water removes an estimated 250,000 to 500,000 gallons of water each year that would have otherwise replenished groundwater.

Chapter 10 – Stormwater, explains these issues in detail. It also describes a new approach to stormwater management known as Low Impact Development. Low Impact Development includes a number of techniques to limit flooding, erosion, and water quality degradation, while allowing groundwater to be replenished. Of all the techniques, clustering and concentrating development while leaving large open spaces offers the greatest challenge and biggest benefit. Not only will it result in improved water quantity and quality, it will protect the working and undeveloped landscape that is fundamental to New Hampshire's identity and prosperity.

Challenge 2: Climate Change

Evidence of climate change is unequivocal and includes observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level (Intergovernmental Panel on Climate Change, 2007). Most of the continental U.S. has already experienced a statistically significant trend toward increasingly frequent storms with extreme precipitation, a trend that is most pronounced in New Hampshire (Figure 1-5).

EPA's National Water Program Strategy Response to Climate Change, released in August 2008, summarizes climate change related impacts on water as follows.

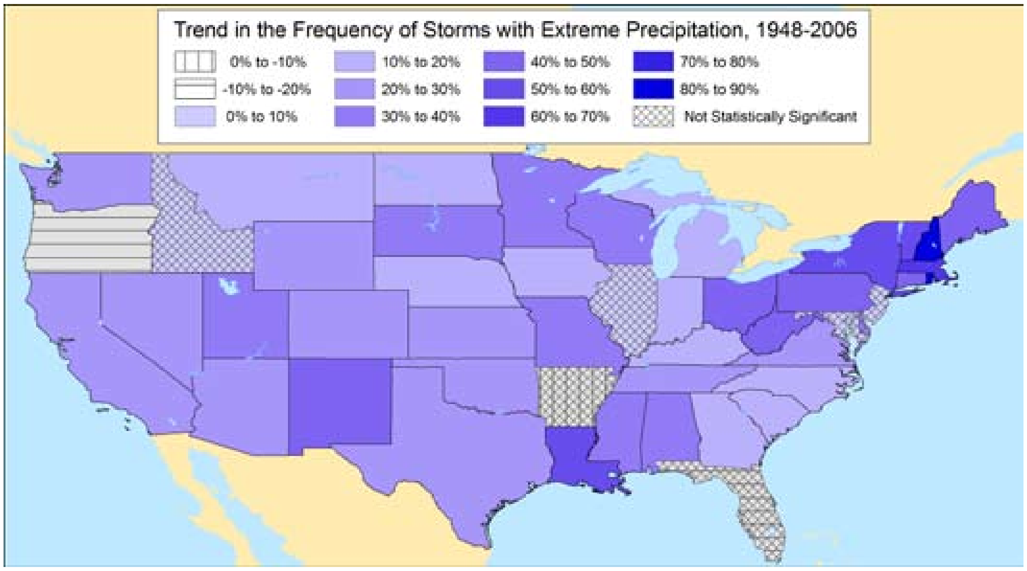


Figure 1-5. Trend in the frequency of extreme precipitation by state. New Hampshire and Rhode Island show the highest increase in the frequency of storms with extreme precipitation. *Source: Madsen & Figdor, 2007.*

1. **Increases in Water Pollution Problems:** Warmer air temperatures will result in warmer water. Warmer waters will:
   - Hold less dissolved oxygen making instances of low oxygen levels and "hypoxia," i.e., when dissolved oxygen declines to the point where aquatic species can no longer survive, more likely.
   - Foster harmful algal blooms and change the toxicity of some pollutants. The number of waters recognized as "impaired" is likely to increase, even if pollution levels are stable.
2. **More Extreme Water-Related Events:** Heavier precipitation will increase the risks of flooding, expand floodplains, increase the variability of streamflows, i.e., higher high flows and lower low flows, increase the velocity of water during high flow periods and increase erosion. These changes will have adverse effects on water quality and aquatic system health. For example, increases in intense rainfall result in more nutrients, pathogens, and toxins being washed into water bodies.
3. **Changes to the Availability of Drinking Water Supplies:** Changing patterns of precipitation and snowmelt, and increased water loss due to evaporation as a result of warmer air temperatures will result in changes to the availability of water for drinking and for use for agriculture and industry. In other areas, sea level rise and salt water intrusion will have the same effect. Warmer air temperatures may also result in increased demands on community water supplies and the water needs for agriculture, industry, and energy production are likely to increase.
4. **Water Body Boundary Movement and Displacement:** Rising sea levels will move ocean and estuarine shorelines by inundating lowlands, displacing wetlands, and altering the tidal range in rivers and bays. Changing water flow to lakes and streams, increased evaporation, and changed precipitation in some areas, will affect the size of wetlands and lakes.

5. **Changing Aquatic Biology:** As waters become warmer, the aquatic life they now support will be replaced by other species better adapted to the warmer water, i.e., cold water fish will be replaced by warm water fish. This process, however, will occur at an uneven pace disrupting aquatic system health and allowing non-indigenous and/or invasive species to become established. In 50 years or so, warmer water and changing flows may result in significant deterioration of aquatic ecosystem health in some areas.
6. **Collective Impacts on Coastal Areas:** Coastal areas are likely to see multiple impacts of climate change. These impacts include sea level rise, increased damage from floods and storms, changes in drinking water supplies, and increasing temperature and acidification of the oceans. These overlapping impacts of climate change make protecting water resources in coastal areas especially challenging.

Climate change will affect regions of the country differently. New Hampshire can expect impacts associated with more frequent extreme precipitation events, rising sea levels, less precipitation falling as snow, warmer temperatures, and peak recharge to groundwater occurring earlier in the year. For more information on predicted impacts for the Northeast under various emission scenarios, see Appendix A: Confronting Climate Change in the U.S. Northeast (Executive Summary).

In addition to the many other issues that New Hampshire faces in managing water resources, the impact of climate change and the need for adaptation strategies must be factored into future water protection efforts. Because of the anticipated growth in population and water demand in the seacoast as well as the anticipated impact from tidal flooding, an adaptation strategy for the coastal zone is essential.

New Hampshire is limited in its ability to significantly reduce greenhouse gas emissions that contribute to global warming. To the extent it can, the state has taken many steps towards being part of the solution, including the governor's formation of a Climate Change Task Force. Also, DES is a member of a Climate Change Workgroup at the New England Interstate Water Pollution Control Commission to work regionally in addressing water related impacts from climate change. Many communities have also taken on this challenge at the local level. Ultimately, the severity of impact from climate change will depend on societal and personal choices regarding the use of fossil fuels.

Challenge 3: Aging and Inadequate Water Infrastructure

New Hampshire residents are dependent on an array of infrastructure throughout the state that moves, stores, and treats water. Categories of water infrastructure include drinking water, wastewater, stormwater and dams. The story for each category is largely the same: the initial investment to construct the infrastructure was made long ago and there is a scarcity of funds to maintain and improve much of this infrastructure. Municipalities, in particular, face significant infrastructure related challenges. An overview of this issue is provided here. For each category, a great deal more information concerning the need to address aging infrastructure is provided in the associated chapter.

Drinking Water and Wastewater (Chapters 8 and 9)

Collecting and treating wastewater to protect water quality and treating and distributing water to provide safe drinking water require a great deal of infrastructure. For most municipalities, this infrastructure needs to be upgraded over the next 10 to 15 years to ensure capacity for economic growth, to meet more stringent environmental standards, and to replace aged system components. Over 30 municipal wastewater systems are at 80 percent or more of their design capacity. Projected wastewater infrastructure needs are $800 million to $1 billion over the next 10 years (Commission to Study the Publicly Owned Treatment Plants, 2007). Projected water supply system needs are about $600 million for the next 15 to 20 years (USEPA, 2005). User affordability, especially for low income households, is a major concern as water and sewer rates increase to pay for improvements. In the past there were significant federal grant programs to assist with wastewater infrastructure needs and limited state grant funds to help water systems comply with new drinking water treatment rules. Both water and wastewater have federally originated state revolving loan funds (SRFs). However the amount of funding available is much less than what is necessary. For instance the demand for drinking water SRF funds in 2008 was $39 million, while the funding available was $10 million.

Stormwater (Chapter 10)

An effort is underway to identify the statewide need for maintaining and upgrading municipal stormwater infrastructure. Given the more frequent, intense storms resulting from climate change, there is particular concern that undersized culverts will exacerbate flooding damage. Currently, there are no grant or loan funds designated specifically for stormwater infrastructure. Small source water protection and non-point source grants have been used for this purpose in some places and the SRF that has historically been used for wastewater infrastructure will be made eligible for this purpose. However, as noted above, this SRF is under-funded to meet current wastewater demands.

Dams (Chapter 11)

The 3,070 dams in New Hampshire must be maintained to keep them safe. Occasional upgrade or rehabilitation is necessary due to deterioration, changing technical standards, improved techniques, better understanding of the area's precipitation conditions, increases in downstream populations, and changing land use (Figure 1-6). There are 2,358 privately owned dams in New Hampshire. The state owns 273 dams, 12 are owned by utilities, 389 are owned by municipalities, and 38 are owned by the federal government. Many were constructed years ago for mills that no longer exist; in many cases the removal of

Figure 1-6. Installation of the automated spillway gates is an example of an upgrade at the Mascoma Lake Dam on the Mascoma River in Lebanon. ***Source: NHDES Dam Bureau.***

these dams would result in substantial environmental improvement, often at less cost than dam rehabilitation. Operation, maintenance and rehabilitation of dams can range in cost from the low thousands to millions of dollars, and owners are responsible for these expenses. Maintenance of privately owned dams is of greatest concern. However, the state Dam Maintenance Fund that supports maintenance and upgrades for state owned dams is significantly less than what is needed and what it has been historically. The reasons for this are explained in detail in Chapter 11 – Dams.

Overall, New Hampshire is heavily reliant on water-related infrastructure to clean, move and store water. A significant investment to maintain and improve existing infrastructure must be a priority.

Challenge 4: Information Needs

Historically, New Hampshire has consistently invested in obtaining critical water-related data. The state is in an enviable position with respect to our water resource knowledge. Appendix C provides an overview of recent and ongoing projects, studies and initiatives focusing on water resource characterization, water quality assessment, and water planning, protection and eduction. There is, however, still some key information that must be obtained, analyzed and managed so that informed policy decisions about water resources can occur. Table 1-1 presents a brief description of key, current information needs and directs the reader to topic chapters that provide additional justification for this data. In addition to collecting the data identified in the table, resources are needed to analyze and manage the information so that it can be used by scientists, regulators and policy makers.

Table 1-1. Information needs for New Hampshire's water resources.

Information Needed / Related Chapter(s)	Importance
Stream Gages to Manage Protected Instream Flow Levels Chapter 2 – Rivers	As water use increases, a network of stream gages designed to monitor critical flow periods is needed so withdrawals and impoundments can be operated to preserve aquatic life. USGS now operates a network of gages in cooperation with DES, but more are needed.
Stream Morphology Chapter 2 – Rivers	New Hampshire has very limited data on the geomorphic characteristics of its rivers and streams. River morphology, or their form and shape, is a naturally dynamic process; rivers are not static systems. By knowing how a river system will achieve a stable morphology over time, significant human infrastructure and aquatic resource impacts could be prevented.

Information Needed / Related Chapter(s)	Importance
Groundwater Levels Chapter 4 – Groundwater Chapter 8 – Drinking Water	New Hampshire currently has a very limited network of wells where groundwater levels are routinely monitored. There is a great deal of concern regarding overuse of groundwater. A comprehensive groundwater monitoring network would provide the data to identify groundwater level changes and interpret their cause.
Water Quality Chapter 2 – Rivers Chapter 3 – Lakes and Ponds Chapter 4 – Groundwater Chapter 6 – Coastal and Estuarine Waters Chapter 8 – Drinking Water Chapter 9 – Wastewater Chapter 10 – Stormwater	Surface waters: The majority of the state's surface waters have not been assessed due to lack of data. More data, better utilization of existing data from multiple sources, and more efficient (statistical) analyses are needed. Groundwater: The primary data needed is information on the occurrence of naturally occurring contaminants such as arsenic, radionuclides, fluoride, beryllium, etc. This information would be used to promote increased private well testing in high risk areas.
Lake Carrying Capacity Chapter 3 – Lakes and Ponds	Lake carrying capacity is identified as important for lake management in RSA 483-A. Additional data on types and intensity of recreational lake use are needed to effectively assess carrying capacity.
Invasive Species Chapter 3 – Lakes and Ponds	Invasive aquatic species are a continuing threat. Volunteer "Weed Watchers" provide early detection. More comprehensive mapping of known infestations is needed for targeted exotics control efforts.
Updated Flood Elevations Chapter 12 – Floods and Droughts	Current flood maps are often inaccurate and do not reflect changes in hydrology from recent development or increased flood elevations associated with climate change. Updated maps are needed to keep development out of floodplains and for emergency preparedness.

1.5 New Hampshire Water at a Glance: Occurrence, Impairment, Uses, Infrastructure and Law

This section provides a summary of New Hampshire's water resources, including important facts and statistics to set the stage for the topic-specific chapters to follow.

1.5.1 Water Occurrence

The total area of New Hampshire is 9,304 square miles, comprising 9,027 square miles of land and 277 square miles of inland water, not including wetlands. There are approximately 23 square miles of estuarine tidal water and 238 miles of ocean and estuarine coastline. Although New Hampshire has only 18 miles of Atlantic Ocean coastline, its tidal waters, including Great Bay and Hampton Harbor estuaries and the Piscataqua River, are major ecological and recreational resources in a heavily populated portion of the state.

New Hampshire's approximately 1,000 larger lakes and ponds total nearly 165,000 acres and vary in size from small ponds to Lake Winnipesaukee, the largest lake, which is 22 miles long and eight miles wide. Lake Winnipesaukee is at the heart of the Lakes Region, a prime tourist location.

Figure 1-7. New Hampshire's major watersheds in a New England context. New Hampshire has five major watersheds that extend into other New England states. ***Source: NHDES Watershed Management Bureau.***

There are five major watersheds or drainage basins in New Hampshire. The largest is the Connecticut River watershed, followed by the Merrimack River, Saco River, Androscoggin River and Coastal watersheds (Figure 1-7). In total there are nearly 17,000 miles of rivers and streams in New Hampshire.

Groundwater in New Hampshire is found in fractured rock formations and in the surficial material deposited and shaped by receding glaciers. Sand and gravel materials of glacial origin are called stratified drift. Surficial aquifers are relatively shallow, generally less than 100 feet thick. The shallow nature of surficial aquifers and the limited space for water in fractured bedrock limits the storage of water in the ground. In general, surface waters and groundwater are highly interconnected with one another in New Hampshire.

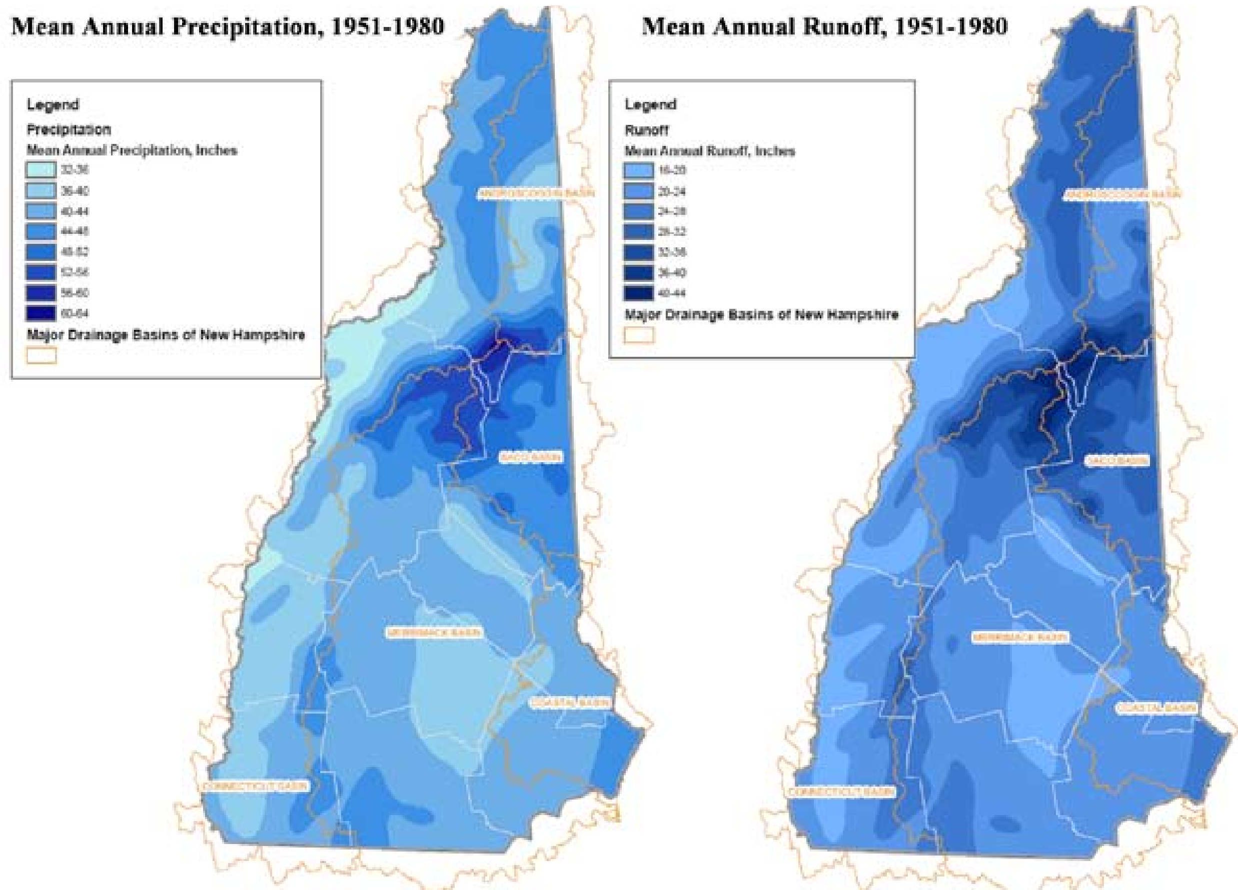


Figure 1-8. New Hampshire's mean annual precipitation and runoff from 1951 to 1980. ***Data Source: Randall, 1996.***

New Hampshire has a changeable temperate climate, with wide variations in daily and seasonal temperatures. The variations are affected by proximity to the ocean, mountains, lakes or rivers. The state experiences four seasons, with short, relatively cool summers and often long, cold winters. The average annual daily temperature for central New Hampshire is 45° F. Mean annual precipitation is typically between 35 and 45 inches, including a mean annual snowfall of between 65 and 75 inches. Mean annual precipitation and runoff across the state can be seen in Figure 1-8. When the ground is not frozen, on average 40 percent of precipitation recharges groundwater, with more recharge occurring prior to and after the growing season.

Hydrologic Cycle

The hydrologic cycle (see Figure 1-17, the fold-out graphic) governs the occurrence and movement of New Hampshire's water resources. Water falls on the land as rain or frozen precipitation and moves through various water bodies on its way to the ocean. It may move fast or slow; be evaporated; be stored for awhile in groundwater, wetlands, lakes or impoundments; and be used for drinking water supply, hydropower, or a variety of other uses. Water picks up chemicals and other substances along the way. Some of these are natural and some are manmade. New Hampshire has seven basic water body types: rivers and streams, lakes and ponds, wetlands, inland tidal waters (estuaries), impoundments (dammed rivers), ocean waters, and groundwater. Water that runs off the land or seeps from groundwater into surface waters moves through ever larger streams and rivers, residing along the way in lakes, wetlands and impoundments until it reaches tidal waters along the coast. Human uses of water may occur at any point along the way, as may the effects of too much water – floods, or too little water – droughts.

1.5.2 Water Quality Assessment

Surface Waters

New Hampshire's surface waters and wetlands are home to a myriad of aquatic life and provide essential habitat for many other wildlife, among other uses. DES maintains a statewide catalog of surface water bodies and a statewide database of water quality data. Every two years all available water quality data are used to assess the extent to which each water body is attaining the water quality to support each of five designated uses (aquatic life, recreation in and on the water, drinking water supply, wildlife, fish and shellfish consumption). These assessments and an interpretive report, sometimes called the "305(b) Surface Water Quality Report" after a section of the federal Clean Water Act, are posted on the DES website. The most recent report was released in 2008 (NHDES, 2008b). A water body that is attaining water quality to support a designated use is called supporting, and one that is not is called impaired.

Table 1-2 is a summary of 2008 assessments. The table really only reflects two of the five designated uses, aquatic life and recreation. As for the other uses, all waters are impaired for fish consumption due to mercury in fish tissue, caused by atmospheric deposition, so this use has been excluded from the table. Similarly, all waters are presumed to support drinking water supply after adequate treatment, although detailed criteria have not been developed. Finally all waters are unassessed for the wildlife use because criteria have not been developed, so the table does not reflect the status of this use.

Table 1-2. Summary of surface water quality standard (WQS) assessments. *Source: NHDES, 2008b.*

Water Body Type	Overall Use Support (excluding mercury fish advisory) based on Site Specific Assessments (Percent of Assessment Units and Designated Uses)			
	Fully Meets WQS	Insufficient Information or No Data	Impaired	Total Assessed
Rivers / Streams	67.3%	29.5%	3.2%	70.5%
Impoundments	55.1%	39.8%	5.1%	60.2%
Lakes	57.7%	30.6%	11.7%	69.4%
Estuaries	51.2%	18.5%	29.3%	81.5%
Ocean	54.7%	15.4%	29.8%	84.6%
All Waters	57.4%	26.8%	15.8%	73.2%

Figure 1-9 summarizes the causes of impairment for rivers. Summary charts for other water body types are similar. The largest cause is pH, which is attributable to acid rain. Next are Escherichia coli bacteria, which are indicators of contamination with human or animal wastes. Dissolved oxygen, which is essential for aquatic life, is also a significant cause of impairment.

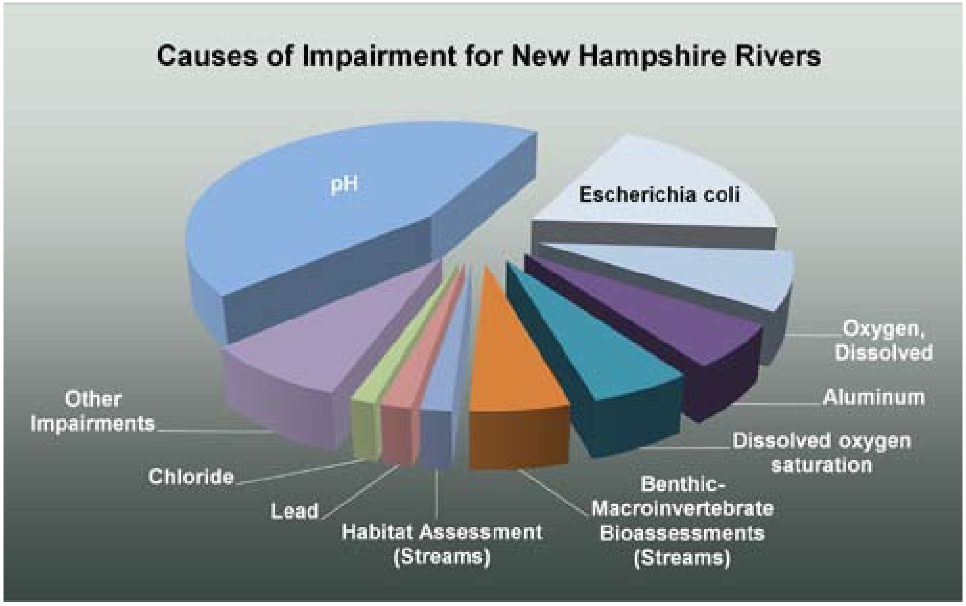


Figure 1-9. Causes of impairment for New Hampshire rivers.
Source: NHDES, 2008b.

Groundwater

Groundwater is present everywhere beneath the land surface. Underneath most of New Hampshire the bedrock is the main groundwater resource, but in river valleys and some associated glacial formations such as eskers and kame terraces, stratified drift deposits of sand and gravel can produce moderate to large sustained yields of groundwater. Natural groundwater quality is generally good. The predominant crystalline rock formations produce groundwater of low mineral content, hardness and alkalinity. Although the majority of groundwater can be used as a drinking water source with little or no treatment, most groundwater is of low pH and highly corrosive to water supply distribution systems. Ambient groundwater quality from both bedrock and stratified drift aquifers can be impacted by such aesthetic concerns as iron, manganese, taste and odor. Bedrock well water quality is sometimes impacted by naturally occurring contaminants including fluoride, arsenic (Figure 1-10), mineral radioactivity and radon gas. Elevated concentrations of radon gas occur frequently in bedrock wells, and elevated arsenic levels are found in some locations, correlated with specific bedrock

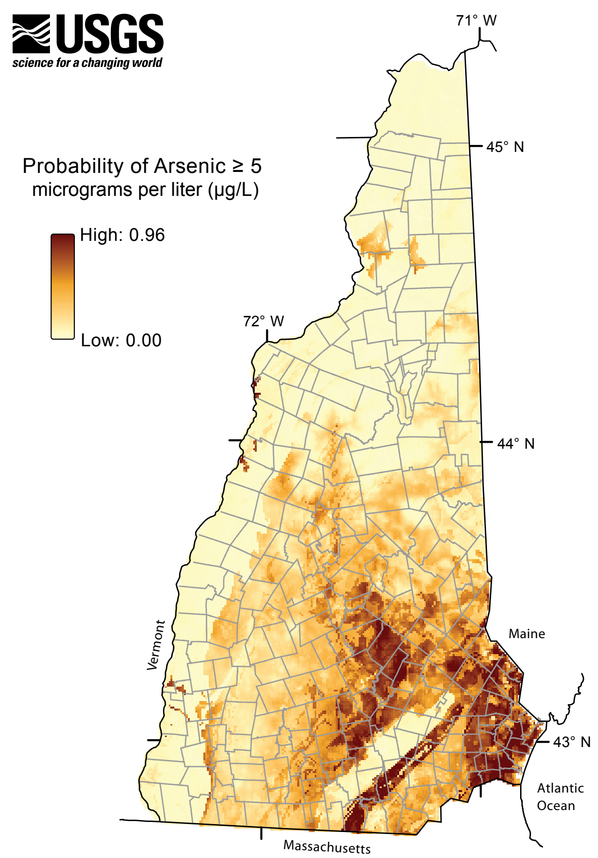


Figure 1-10. Probability that wells in each area of New Hampshire are likely to have water with arsenic concentrations exceeding 5 micrograms per liter (µg/L). ***Source: Ayotte et al. 2006.***

formations. In addition to naturally occurring contaminants, there are many areas of localized contamination due primarily to releases of petroleum and volatile organic compounds from petroleum facilities, commercial and industrial operations and landfills. Due to widespread winter application of road salt, sodium is also a contaminant often found in groundwater. The leading causes of manmade groundwater contamination requiring remediation are spills and leaks at underground storage tank sites (LUST), heating oil storage tank sites (OPUF), hazardous waste facilities, and other motor fuel storage facilities (Figures 1-11 and 1-12).

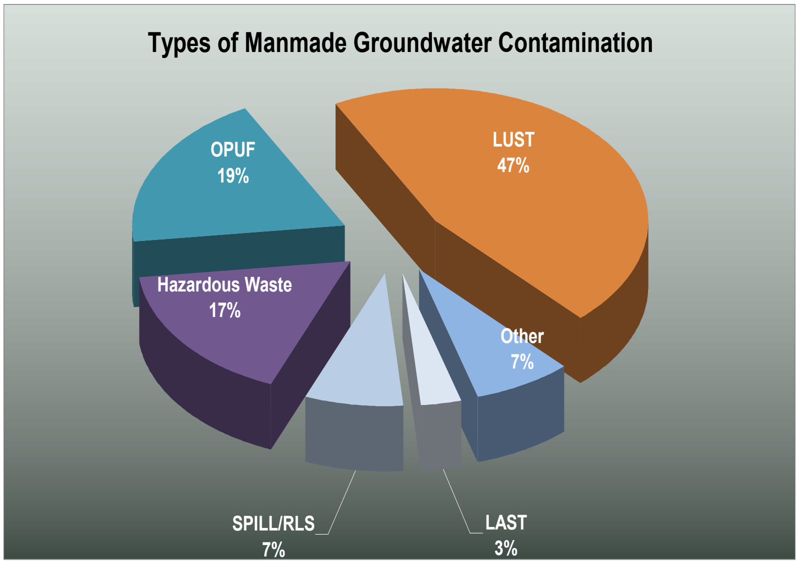


Figure 1-11. Types of manmade groundwater contamination sites that require remediation in New Hampshire. The leading cause of contamination are LUST (leaking underground storage tank) sites, followed by OPUF sites (on-premise heating oil tank) sites, hazardous waste sites, SPILL/RLS (oil spill or release) sites, other types of contamination, and LAST (aboveground bulk storage containing motor fuel) sites. *Source: NH-DES, 2008c.*

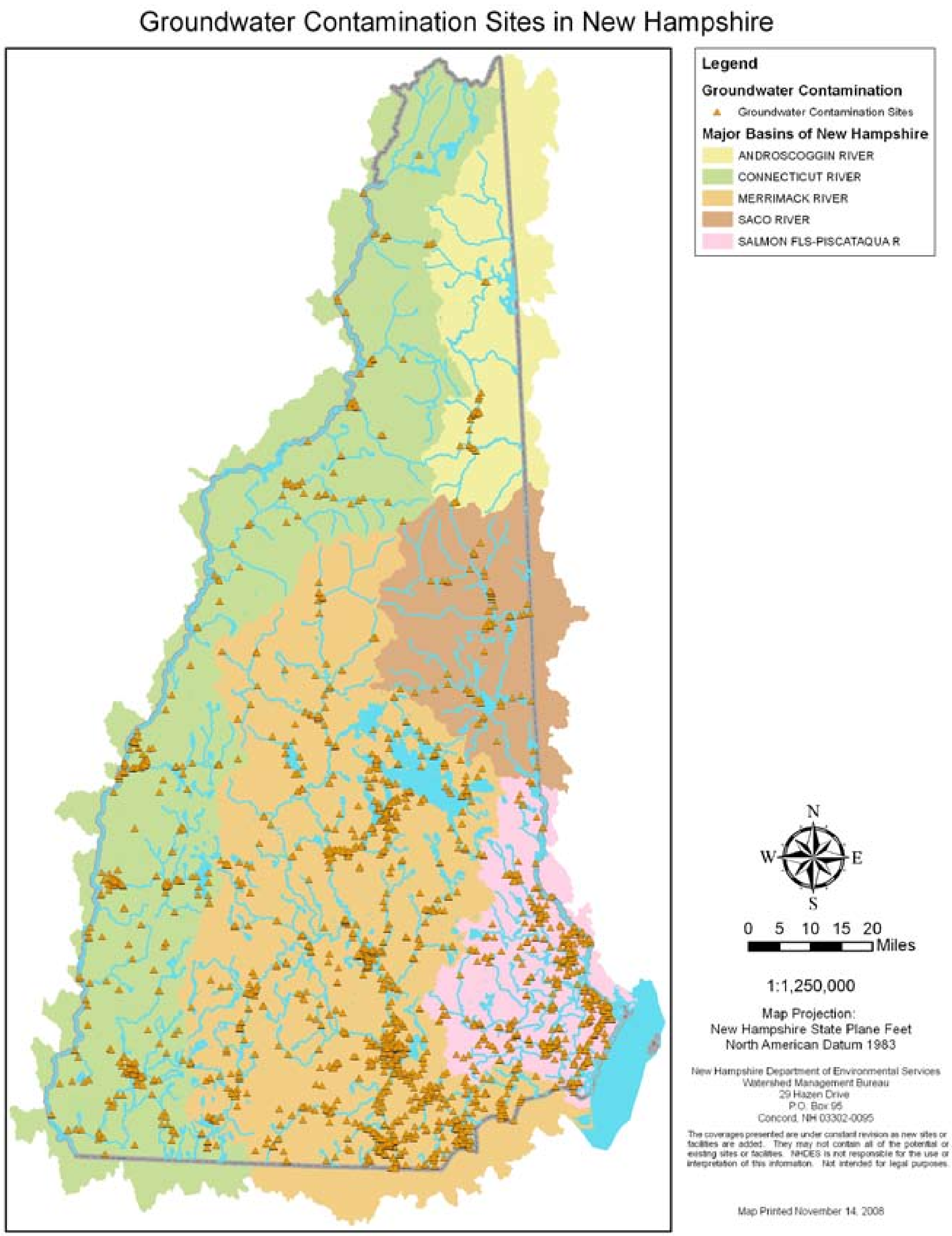


Figure 1-12. Sites in New Hampshire where groundwater contamination management by NHDES has occurred.

1.5.3 Water Use

Based on an estimate made by the USGS for water use in New Hampshire for the year 2000, New Hampshire uses approximately 211 million gallons per day (Hutson et al., 2004). This figure excludes approximately 236 million gallons per day of freshwater that is used at thermoelectric plants where the water is generally not consumed and is returned to the location from which it was extracted. Of the 211 million gallons of water that is used, 127 million gallons per day (60 percent) is extracted from surface water and 84 million gallons per day (40 percent) is extracted from groundwater. Public water suppliers that supply water to homes, businesses and institutions are the largest users of all water and of surface water in the state. Cumulatively, self-supplied domestic water use, typically individual private wells, represents the largest use of groundwater in New Hampshire (Figure 1-13).

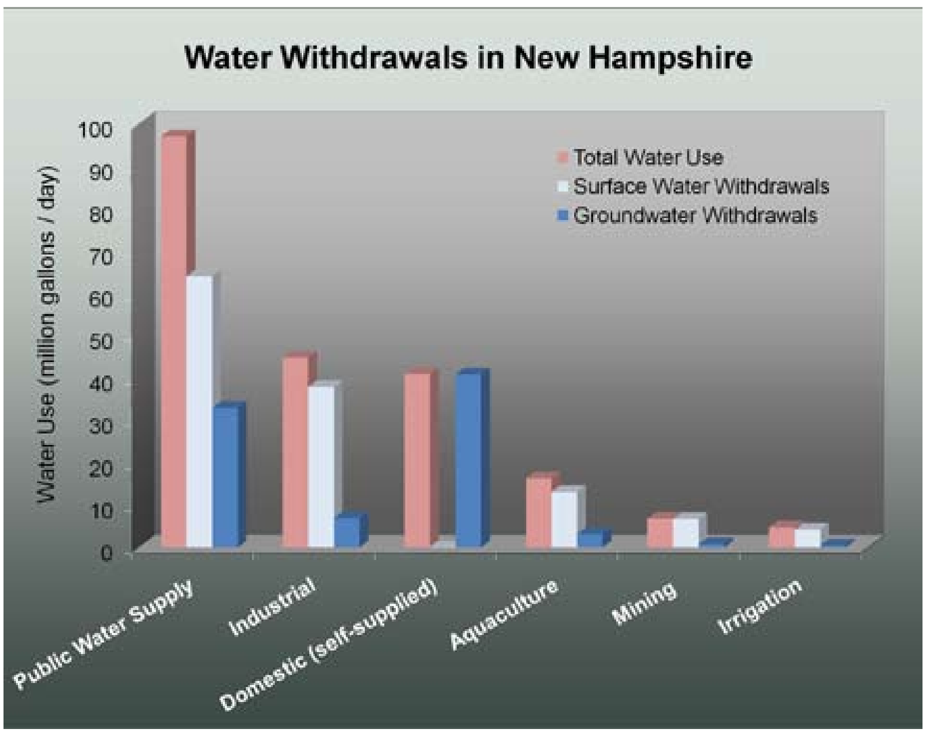


Figure 1-13. Water withdrawals in New Hampshire. ***Source: NHDES, 2008a.***

1.5.4 Water Infrastructure

Figures 1-14 through 1-16 show the geographic distribution of the state's water infrastructure: its public water systems, water and sewer service areas, and dams. Statistics and additional information describing these infrastructure categories can be found in Chapter 8 – Drinking Water, Chapter 9 – Wastewater, and Chapter 11 – Dams.

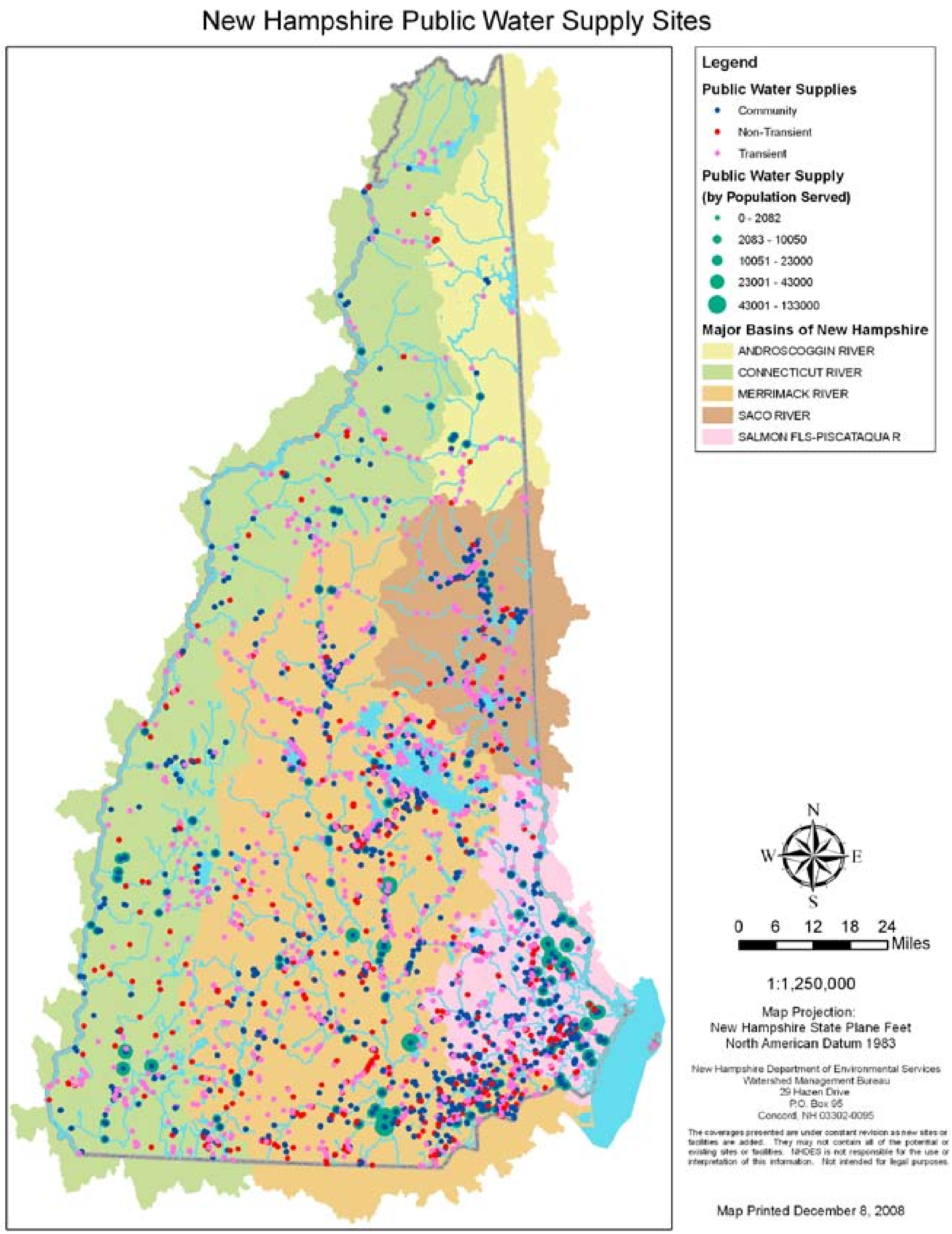


Figure 1-14. New Hampshire public water systems.

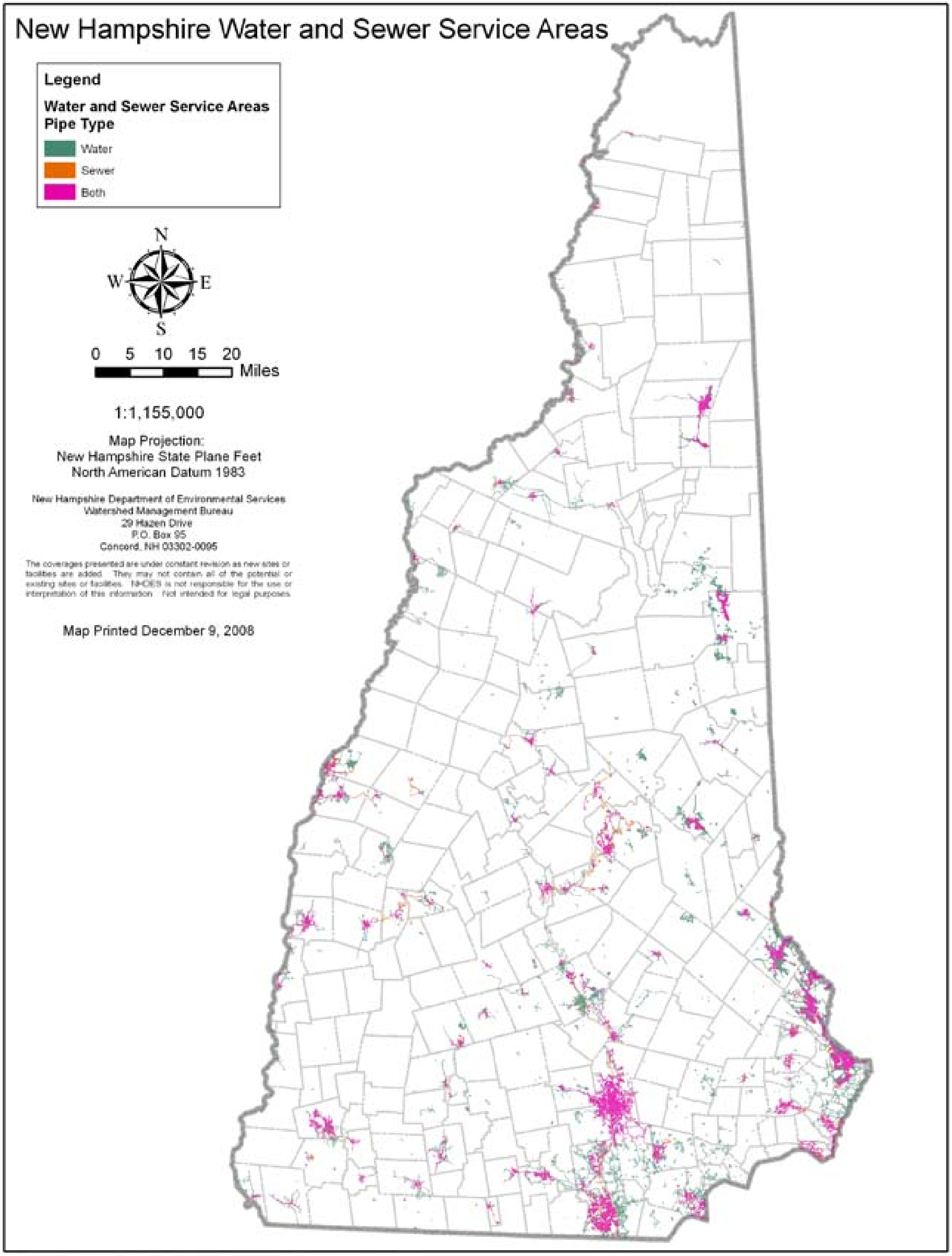


Figure 1-15. New Hampshire's water and sewer infrastructure.

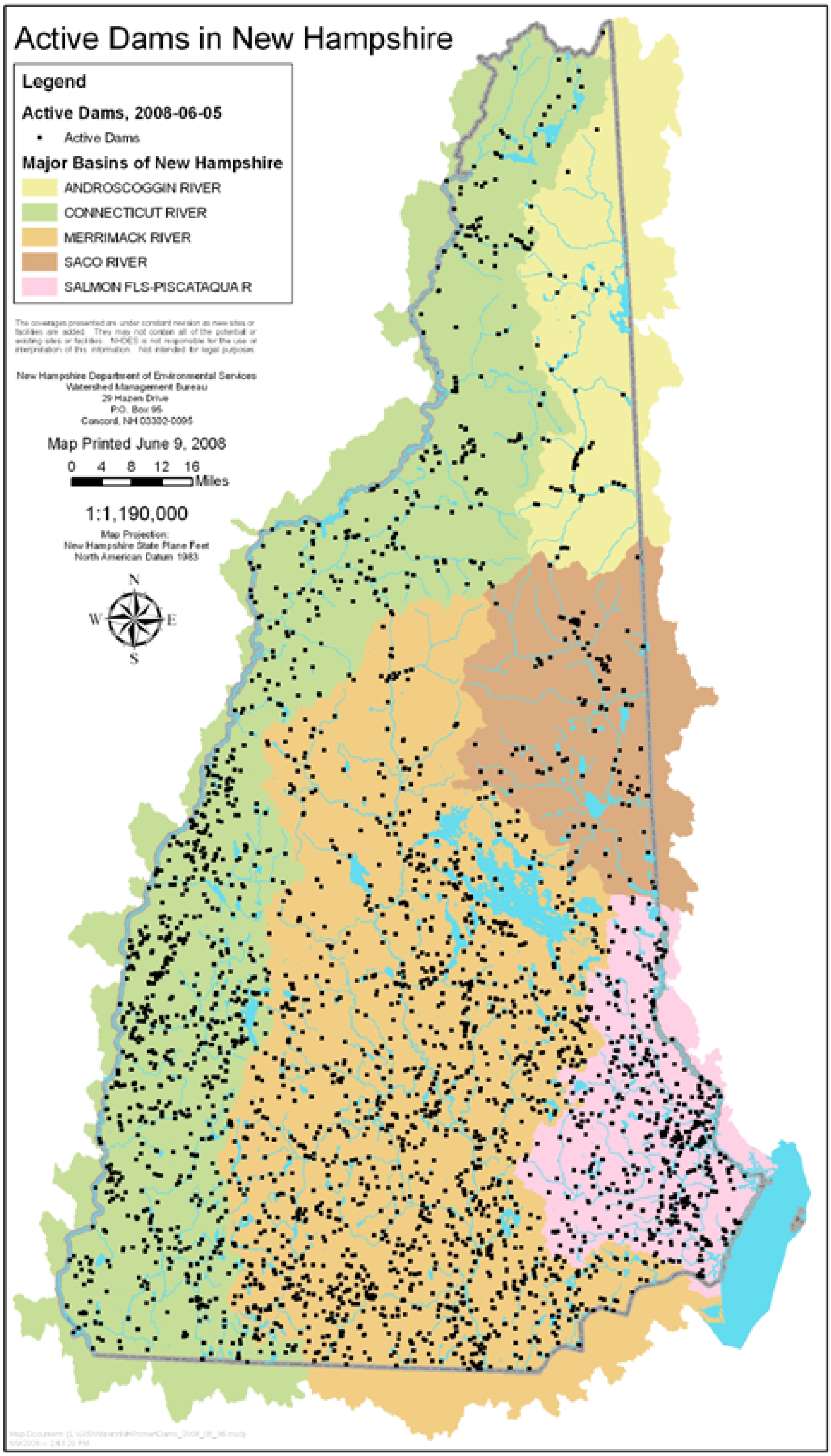


Figure 1-16. New Hampshire's active dams.

1.5.5 Water Law

There are a myriad of state and federal laws related to water resource assessment, protection and remediation. Appendix D contains a table that lists the federal and state authorities that pertain to the state's water-related programs. Federal laws, state laws, and water rights are described briefly below.

Federal Laws

In terms of federal programs, the most significant water related laws include the Clean Water Act, the Safe Drinking Water Act, the Coastal Zone Management Act, and the Resource Conservation and Recovery Act. Superfund and other federal waste site cleanup programs, as well as the federal law governing pesticide use, also serve to protect water. A very brief description of the primary federal statutes is contained in the table below.

Important Federal Water Related Laws

Clean Water Act

Adopted in 1972 this Act protects the quality of waters of the United States. Establishing water quality standards, identifying and designating uses of surface waters, and permitting of discharges to surface waters are cornerstones of this Act. In New Hampshire this permitting is done by EPA with input from the state.

Safe Drinking Water Act

Adopted in 1977 this Act is in place to ensure that water supplied by public water systems is safe to drink. Key provisions include oversight of water system design, operation and water treatment. It also establishes drinking water quality standards and monitoring requirements. In New Hampshire DES administers the Safe Drinking Water Act under a primacy agreement with the EPA.

Coastal Zone Management Act

Adopted in 1972 this Act establishes a voluntary partnership between the coastal states and the National Oceanic and Atmospheric Administration (NOAA) to promote a balance of human use and resource protection through funding for permitting and enforcement, pass-through grants, outreach on non-point source pollution and incentives for program change. Federal Consistency provisions assure that federal permits and activities in the coastal zone are consistent with state policy. DES administers this program.

Resource Conservation and Recovery Act

Adopted in 1976 this Act tracks hazardous waste and regulates underground storage tanks. Land uses with underground storage tanks or that generate hazardous waste are of particular concern for water resources. Solid waste is also regulated under this Act. DES administers this program.

State Laws

New Hampshire's water quality law is largely based in statute and administrative rules that DES administers. The law pertaining to water quantity is a mixture of common law, statutes that DES administers, and statutes that provide water rights to particular entities. Each of these is described below. Water-related state laws and administrative rules are also detailed in Appendix D.

Statutes and Administrative Rules

Important water related state statutes are found under Title L, Water Management and Protection. These statutes and the rules they authorize address both water quantity and water quality related issues. Appendix D lists the specific statutes and programs and regulations related to them. In addition to Water Management and Protection Statutes, there are important state water remediation laws that are also identified in Appendix D.

Public Trust and Reasonable Use Doctrines

New Hampshire's water rights system is based on common law, which is predicated on historic court decisions rather than on statutes passed by the state Legislature. There are two important aspects of common law for water: the Public Trust Doctrine and the Riparian Doctrine of Reasonable Use. (A riparian owner is an owner of property adjacent to water). The Public Trust Doctrine is the concept that water flowing by or through a property is not owned by the property owner, but is held in trust by the state for the benefit of all citizens. The use of such water by property owners is governed by the doctrine of reasonable use. "Reasonable use" is generally taken to mean that one riparian property owner's water use may not unreasonably interfere with the water use of another property owner, regardless of which use was established first. "Reasonable use" is a mixed question of fact and law, and the standard may change over time, so what was once reasonable may over time become unreasonable. These doctrines of common law coexist with federal and state laws. For water, the statutes in some ways regulate what is "reasonable." For instance, RSA 485-C establishes when a large groundwater withdrawal causes an impact that is unacceptable.

Legislative Water Grants

Beginning in 1797 until as recently as the 1990s, there have been legislative acts that grant water rights to particular entities. In most cases the grantee is a municipality, although a number of water companies, both existing and defunct, have been granted water rights. Some of the acts appropriate specific bodies of water while some are more general and refer to water in a certain area or municipality. Research done in conjunction with the report of the Public Water Rights Study Committee (1992) provided a partial list of 166 legislative acts granting water rights. Waters described in these laws are still subject to regulations that proactively determine the reasonableness of a particular use.

Both common law and statutory law have evolved over time to reflect society's uses of water, its goals for sustainable management of the resource, and its scientific understanding of the interactions between human activities and the resources. As the state's economy and population grow and various uses of water resources come into conflict with one another, and as the understanding of water resources improves, the challenge is to incorporate the new reality and knowledge into improved laws, policies and programs to ensure that use of water resources can be sustained for future generations.

1.6 Summary

This primer was written to inform New Hampshire policy makers and citizens about the state's water resources and water resource issues. It is an initial step toward development of a comprehensive water plan that will guide sustainable management of water resources to ensure that there is enough good quality water to support New Hampshire's special quality of life. Although the primer is largely organized by topic areas, water is a complex subject in which most topics are interrelated and there are underlying challenges that are relevant to most, if not all, water body types and management approaches. The four underlying challenges highlighted throughout the primer are:

- Landscape Change and Increased Demand for Water Related to Economic and Population Growth.
- Climate Change: Increasing temperature, more frequent and intense storms, etc.
- Aging and Inadequate Water Infrastructure: Wastewater, drinking water, stormwater and dams.
- Information Needs: Water quantity and quality data collection, analysis and management.

In addition to describing these challenges, this chapter provided a section called "New Hampshire Water at a Glance" that provides an overview of the state's water resources, water use, water related infrastructure, and water law.

While Chapters 2 through 12 focus on particular water topics, the reader is encouraged to keep the underlying challenges in mind. The reader is also encouraged to refer often to this chapter's foldout graphic (Figure 1-17), which illustrates the connectivity between and use of water body types and how land use can influence both water quantity and water quality.

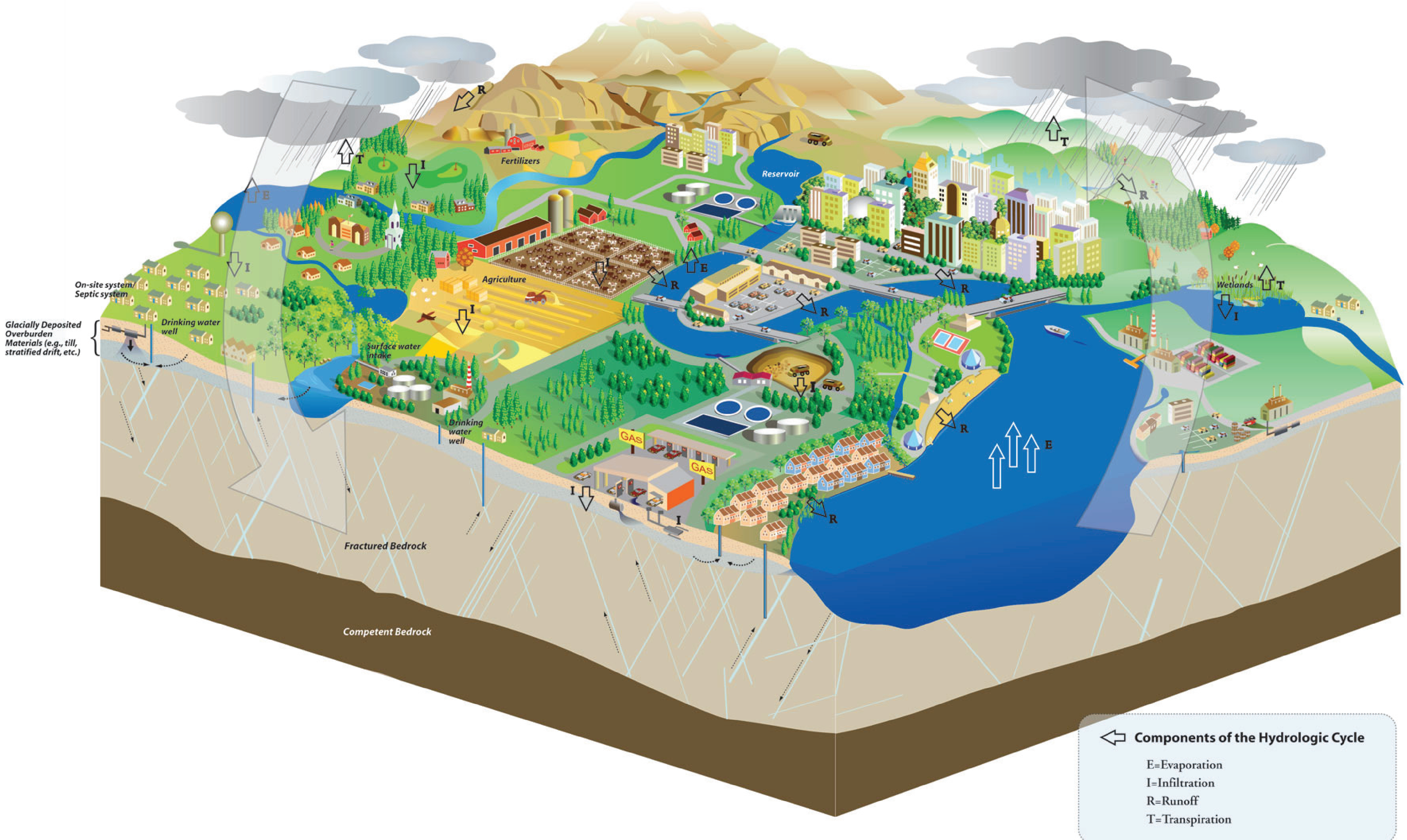


Figure 1-17. Water Occurrence and Use in New Hampshire. (Developed for NHDES and Ground Water Protection Council by Enosis, The Environmental Outreach Group.)

References

Ayotte, J.D., Nolan, B.T., Nuckols, J. R., Cantor, K.P., Robinson, G.R., Jr., Baris, D., Hayes, L., Karagas, M., Bress, W., Silverman, D.T., & Lubin, J.H. (2006). Modeling the probability of arsenic in groundwater in New England as a tool for exposure assessment. Environmental Science and Technology, 40(11), 3578 – 3585.

Commission to Study the Publicly Owned Treatment Plants Needs of New Hampshire and State Laboratory Water Tests and Fees for Such Tests Collected by the Department of Environmental Services. (2007). *Final report*. State of New Hampshire.

Dukes, M. (2007, January 29). *Irrigation system technologies and trends.* Presented at American Water Works Association's Water Conservation Workshop 2007.

Horn, M.A., Moore, R.B., Hayes, L., & Flanagan, S.M. (2008). *Methods for and estimates of 2003 and projected water use in the Seacoast region, southeastern New Hampshire* (U.S. Geological Survey Scientific Investigations Report 2007–5157, 87 p). Available at: http://pubs.usgs.gov/sir/2007/5157/pdfs/front_508.pdf.

Hutson, S.S., Barber, N.L., Kenny, J.F., Linsey, K.S., Lumia, D.S., & Maupin, M.A. (2004). *Estimated use of water in the United States in 2000* (U.S. Geological Survey Circular 1268. Released March 2004, revised April 2004, May 2004, February 2005). Available at: http://pubs.usgs.gov/circ/2004/circ1268/.

Intergovernmental Panel on Climate Change. (2007). *Climate change 2007: The physical science basis. Contribution of Working Group I to the fourth assessment report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge, United Kingdom and New York, N.Y.: Cambridge University Press. Available at: http://ipcc-wg1.ucar.edu/wg1/wg1-report.html.

MacKichan, K.A., & Kammerer, J.C. (1961). *Estimated use of water in the United States, 1960* (U.S. Geological Survey Circular 456). Washington, D.C.: USGS. Available at: http://infotrek.er.usgs.gov/docs/usgs_pubs/pdf/CIR/CIR456_img.pdf.

Madsen, T. & Figdor, E. (2007). *When it rains, it pours: Global warming and the rising frequency of extreme precipitation in the United States*. Environment New Hampshire, Research and Policy Center, Concord, N.H. Available at:http://www.environmentnewhampshire.org/uploads/Rx/_8/Rx_8sa-IUrwjnmsIIL1Xyg/When-It-Rains-It-Pours.pdf.

New Hampshire Department of Environmental Services. (2008a). New Hampshire Geological Survey, Water Use Registration and Reporting Database. Unpublished data.

New Hampshire Department of Environmental Services. (2008b). *New Hampshire 2008 Section 305(b) and 303(d) surface water quality report and RSA 485-A:4.XIV report to the Governor and General Court* (R-WD-08-5). Prepared by G. Comstock and K. Edwardson, NHDES Watershed Management Bureau. Available at: http://des.nh.gov/organization/commissioner/pip/publications/wd/documents/r-wd-08-5.pdf.

New Hampshire Department of Environmental Services. (2008c). Waste Management Division. Unpublished data.

New Hampshire Estuaries Project. (2006). *State of the estuaries*. University of New Hampshire, Durham, N.H. Available at: http://www.nhep.unh.edu/resources/pdf/2006_state_of_the-nhep-06.pdf.

New Hampshire Office of Energy and Planning. (2006, November). *New Hampshire population projections for state and counties 2010 to 2030*. Available at: http://www.nh.gov/oep/programs/DataCenter/Population/documents/populationforcountiesbyageandsex.pdf.

New Hampshire Office of State Planning. (2000). *Managing growth in New Hampshire: Changes and challenges*. In conjunction with The Growth Management Advisory Committee. Available at: http://www.nh.gov/oep/resourcelibrary/referencelibrary/g/growthmanagement/documents/GMReport.pdf.

Public Service of New Hampshire. (2008). *New Hampshire fact book: Quality of life.* Economic and Community Development Division, PSNH. Available at: http://www.psnh.com/SharePDFs/NHFactBook_QualityofLife.pdf.

Public Water Rights Study Committee. (1992). Appendix C: Partial listing of appropriated water rights in New Hampshire 1850-1990. In Report of the Public Water Rights Study Committee (Chapter 148, Laws of 1990; Chapter 356, Laws of 1991). State of New Hampshire, Concord, N.H.

Randall, A.D. (1996). *Mean annual runoff, precipitation, and evapotranspiration in the glaciated northeastern United States, 1951-80* (U.S. Geological Survey open-file report 96-395).

Society for the Protection of New Hampshire Forests. (2005). *New Hampshire's changing landscape 2005: Population growth and land use changes: What they mean for the Granite State*. Concord, N.H. Available at: http://www.spnhf.org/research/research-projects.asp.

Society for the Protection of New Hampshire Forests. (2006). *105th annual report*. Concord, N.H.: Capitol Offset Company Inc. Available at: http://www.spnhf.org/pdf/annual-report-fy06.pdf.

Society for the Protection of New Hampshire Forests. (2008, September 30). SPNHF Research Department. Unpublished data.

U.S. Climate Change Science Program. (2008). *Preliminary review of adaptation options for climate-sensitive ecosystems and resources*. A report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. [Julius, S.H., J.M. West (eds.), J.S. Baron, B. Griffith, L.A. Joyce, P. Kareiva, B.D. Keller, M.A. Palmer, C.H. Peterson, & J.M. Scott (Authors)]. Washington, D.C.: U.S. Environmental Protection Agency. Available at: http://www.climatescience.gov/Library/sap/sap4-4/final-report/.

U.S. Environmental Protection Agency. (2005). *Drinking water infrastructure needs survey and assessment, Third Report to Congress* (EPA 816-R-05-001). Available at: http://www.epa.gov/safewater/needssurvey/pdfs/2003/report_needssurvey_2003.pdf.

U.S. Environmental Protection Agency. (2006). *Protecting water resources with higher-density development* (EPA 231-R-06-001). Washington, D.C.: Development, Community, and Environment Division, EPA. Available at: http://www.epa.gov/smartgrowth/pdf/protect_water_higher_density.pdf.

U.S. Environmental Protection Agency. (2008). *WaterSense*. Retrieved November 24, 2008, from EPA Web site. Available at: http://www.epa.gov/watersense/water/why.htm.

Chapter 2
Rivers and Streams

NEW HAMPSHIRE
DEPARTMENT OF
Environmental
Services

Overview

New Hampshire is fortunate to have an extensive network of rivers and streams. Yet the state's waterways have continued to be adversely impacted by wastewater discharges and nonpoint sources of pollution such as urban and agricultural runoff, septic systems, stormwater from construction activities and urbanized areas, water withdrawals and atmospheric deposition. Water experts have learned that the quality, quantity and ecology of both surface and groundwater are affected by all of the activities occurring within a particular watershed. As a result, there is an increasing need to address water resources on a watershed basis through close collaboration among various state and local organizations.

2.1 Occurrence and Significance

There are approximately 17,000 miles of rivers and streams in the state that appear on 1:24,000-scale topographic maps; all of those watercourses are in need of protection or restoration as critical natural assets for present and future generations (Table 2-1). New Hampshire has five major watersheds: the Connecticut River, the Merrimack River, the Androscoggin River, the Piscataqua River (Coastal), and the Saco River (Figure 2-1). Each watershed has distinct characteristics that offer unique opportunities and management challenges.

Table 2-1. New Hampshire rivers by watershed. ***Source: NHDES, 2008f.***

Watershed	Miles of Rivers and Streams
Androscoggin	1,264
Saco	1,418
Piscataqua (Coastal)	1,711
Merrimack	6,178
Connecticut	6,413
Total	**16,984**

2.1.1 Connecticut River Watershed

The Connecticut River is the largest river in New England. Two-thirds of its length, or 275 miles, runs along the New Hampshire - Vermont border. The Connecticut River Watershed spans approximately 11,250 square miles and drains 3,063 square miles in New Hampshire, about one-third of the state. In 1989 the Connecticut River Joint Commissions (CRJC) was formed as a cooperative effort between New Hampshire and Vermont to protect and preserve the river through an advisory committee representing communities and interests from both states.

2.1.2 Merrimack River Watershed

The Merrimack River Watershed covers 5,010 square miles in New Hampshire and Massachusetts. The river extends 180 miles from Profile Lake in the White Mountains, where it begins as the Pemigewasset River, to Newburyport, Massachusetts, where it empties into the Atlantic Ocean. Seventy-five percent of the watershed is located in New Hampshire. The watershed includes 138 communities and drains approximately 3,834 square miles, about 40 percent, of the state. The Merrimack River Watershed contains most of the lakes and ponds in New Hampshire. The water quality and water quantity of the Merrimack River have been impacted by human activity for hundreds of years; the river has several sections currently impaired for a variety of reasons including mercury, bacteria, heavy metals and low dissolved oxygen.

Figure 2-1. New Hampshire's major watersheds in a New England context. New Hampshire has five major watersheds that extend into other New England states. Source: NHDES Watershed Management Bureau.

2.1.3 Androscoggin River Watershed

The Androscoggin River flows from Lake Umbagog on the New Hampshire - Maine border and runs for 170 miles through 19 communities in northern New Hampshire before crossing into Maine, continuing its course towards the Gulf of Maine and the Atlantic Ocean. The river was used as an industrial route for logging and paper mills for nearly 200 years. It is now being restored to its natural quality through the efforts of several communities and organizations in New Hampshire and Maine. The river drains a total land area of approximately 3,450 square miles (Androscoggin River Watershed Council, 2008) with approximately one-fifth, or 716 square miles, of the watershed in New Hampshire.

2.1.4 Piscataqua River (Coastal) Watershed

Of the 792 square miles that make up New Hampshire's coastal watershed, the Piscataqua River Watershed, including Great Bay and its tributaries, comprises the majority at 730 square miles. Hampton Harbor and direct tributaries to the Atlantic Ocean comprise the rest of the coastal watershed. The Piscataqua River begins at the confluence of the Salmon Falls and Cocheco Rivers between Dover, New Hampshire and Eliot, Maine and flows past Portsmouth into the Gulf of Maine and the Atlantic Ocean. The Piscataqua River itself is relatively short, flowing just over 12 miles. However, its combined drainage area contains approximately 1,495 square miles in Maine and New Hampshire, including Great Bay and six of its tributaries (Seacoast Watershed Information Manager, 2006). The Piscataqua River is entirely tidal and supports habitats and species found only in the coastal portion of the state. Forty-six New Hampshire towns are completely or partially in the Piscataqua River Watershed. The coastal watershed, its tributaries, and the issues facing them are described at length in Chapter 6 – Coastal and Estuarine Waters.

2.1.5 Saco River Watershed

The Saco River is one of the state's most pristine rivers from its headwaters in the White Mountains, flowing 40 miles and draining eight New Hampshire communities before flowing through Maine to the Atlantic Ocean. The Saco River drains 1,293 square miles of Maine and New Hampshire, with 876 square miles in New Hampshire. Approximately half of the watershed in New Hampshire contributes to the mainstem of the Saco River while the other half contributes to the Ossipee River, which joins with the Saco River in Maine. With the exception of the Conway vicinity, land in the Saco River corridor is generally undeveloped and forested. Because the Saco River flows primarily through the White Mountain National Forest, the capacity of the river to support a diversity of wildlife species is largely assured due to the continued presence of a large contiguous forested riparian habitat. However, development pressures exist in Bartlett and Conway that if not managed properly could impact this precious riparian resource.

2.2 Issues

2.2.1 Many Rivers and Streams Fail to Meet Water Quality Standards

Water quality standards are goals and criteria for measuring the health of the state's surface waters. Standards consist of three parts: designated uses, numerical or narrative criteria to protect the designated uses, and an antidegradation policy, which aims to maintain existing high quality water. There are six designated uses for freshwaters, seven for tidal waters: aquatic life, fish consumption, shellfish consumption (tidal waters only), drinking water supply after adequate treatment, primary contact recreation (swimming), secondary contact recreation (boating), and wildlife (NHDES, 2008a). Criteria are established by statute (RSA 485-A) and by administrative rule. Every two years DES assesses surface waters for compliance with the standards (see section 2.3.5).

New Hampshire, like many other New England states, has a statewide advisory regarding the consumption of freshwater fish due to mercury levels in fish tissue. Most of the mercury in New Hampshire waters comes from sources outside the state in the form of atmospheric deposition (NHDES, 1998). When this advisory is taken into account, all fresh surface waters fail to support the water quality standard for fish consumption. Because New Hampshire cannot unilaterally resolve the mercury issue, two assessments are provided for the fish consumption designated use; one that includes the mercury advisory and one that does not. The assessment that *does not account for mercury* conveys information that would otherwise be masked by the mercury advisory and, more importantly, it represents information on impairments for which corrective action can be taken at the state level. Additional information regarding water quality assessments can be found in sections 2.3.5 and 3.1.2 (Chapter 3 – Lakes and Ponds).

For water quality assessment purposes, DES focuses on the 9,659 miles of rivers and streams that appear on topographic maps with a scale of 1:100,000. For 2008 all of those rivers and streams were assessed for the fish consumption and drinking water designated uses, none was assessed for wildlife, 18 percent were assessed on a *site-specific* basis for primary and secondary contact

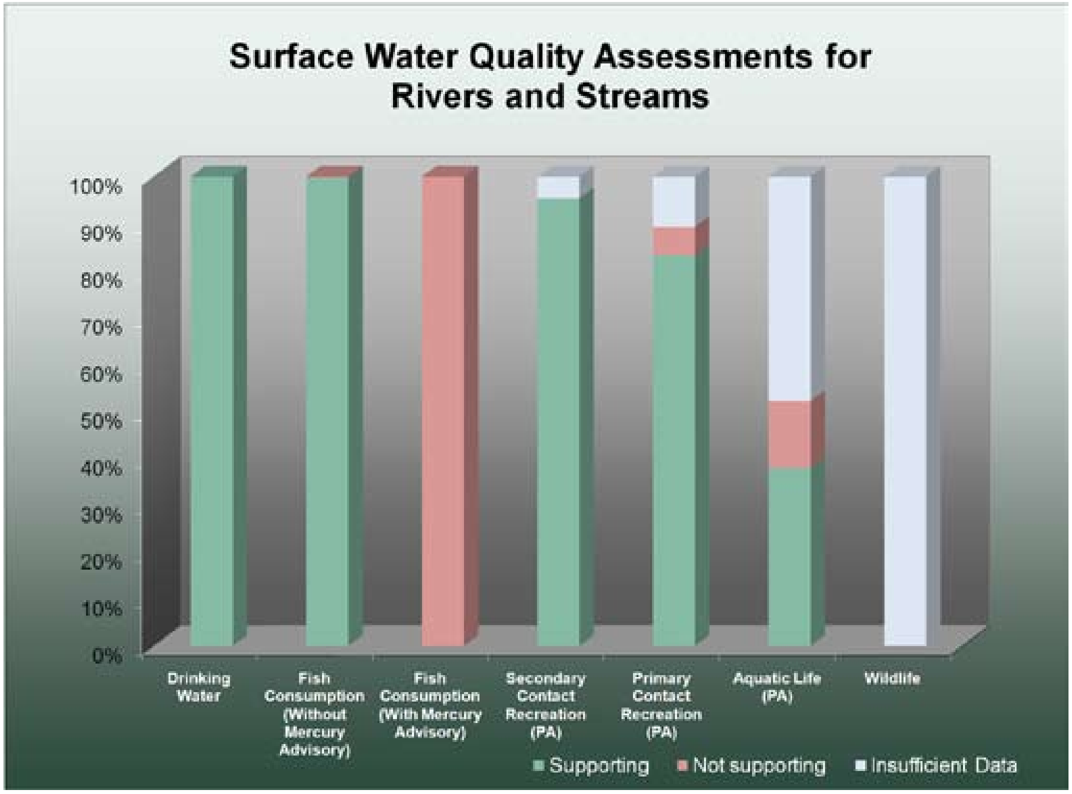


Figure 2-2. Surface water quality assessments for rivers and streams. Percentages of rivers and streams that support designated uses for freshwaters. PA indicates percentages based on probabilistic assessment. *Source: NHDES, 2008b.*

recreation, and 27 percent were assessed for aquatic life. On the basis of that assessment, all rivers and streams fully support the drinking water use and fish consumption use (not accounting for the mercury fish consumption advisory).

Because the site-specific assessments tend to focus on rivers and streams with known problems, the results of the assessments are not indicative of water quality statewide with respect to the recreation and aquatic life uses. To create a broader picture of water quality in the state's rivers for those uses, DES also conducted a *probabilistic assessment* of wadeable (fourth order and smaller) streams for 2008. In other words, streams were randomly sampled to make inferences about the water quality of all New Hampshire's streams. As shown in Figure 2-2, that assessment found that for aquatic life, there was insufficient data for 47.8 percent of the streams, 37.9 percent supported the aquatic life standard, and 14.3 percent did not. For primary contact recreation, the percentages were 10.7 percent insufficient data, 83.2 percent supporting, and 6.1 percent not supporting. For secondary contact recreation, the percentages were 4.6 percent insufficient data, 95.4 percent supporting, and 0 percent not supporting (NHDES, 2008b).

Consequently, the two uses with the highest percentages of impaired waters are fish consumption (100 percent non-supporting if mercury is taken into account) and aquatic life (27 percent of the miles with sufficient data). As noted in Chapter 10 – Stormwater, 83 percent of the water quality impairments listed in DES's 2008 water quality assessment report were attributed wholly or in part to stormwater (NHDES, 2008b).

One impact of stormwater that does show a trend is the concentration of road salt in the state's rivers and streams. Road salt consists primarily of sodium chloride, which dissociates into sodium and chloride ions in water; chloride is of greater ecological concern because of its toxicity to aquatic life. While no studies have examined chloride trends statewide, several regional studies have produced results that are cause for concern. A study conducted by the U.S. Geological Survey found that annual chloride concentrations in the Merrimack River increased ten-fold during the twentieth century, and noted a relationship between road deicing and chloride in rivers (Robinson, et. al., 2003). In a study published in 2005, researchers found that streams in the White Mountains have shown a ten-fold increase in chloride concentrations since the 1960s, with salinity related to impervious surface coverage, deicing being the major source (Kaushal, et. al., 2005). Most recently, a Total Maximum Daily Load study (see section 2.3.6) prepared by DES for Policy Brook in Salem found that chloride concentrations had increased 100-fold since the 1920s (NHDES, 2007).

2.2.2 Lack of Adequate Data

For many of the designated uses, a large percentage of rivers and streams in New Hampshire have not been assessed, nor is it likely that all rivers and streams will ever be monitored using a site-specific approach. Of the approximately 9,659 miles of rivers and streams, 30.3 percent of the mileage and designated use combinations were not assessed. For swimming, 82.1 percent of river mileage remains in the insufficient information or no data category. For boating, 82.2 percent of river mileage remains in the insufficient information or no data category. For aquatic life support, 73.2 percent of river mileage remains in the insufficient information or no data category. In order to meet federal obligations under the Clean Water Act for assessing the state's waters, volunteer data is heavily relied on to assess the water quality of New Hampshire's rivers and streams; 45.4 percent of data collection is from volunteers, 34.7 percent is from DES and 19.9 percent is from a mix of other state agencies, universities, the federal government and private consultants.

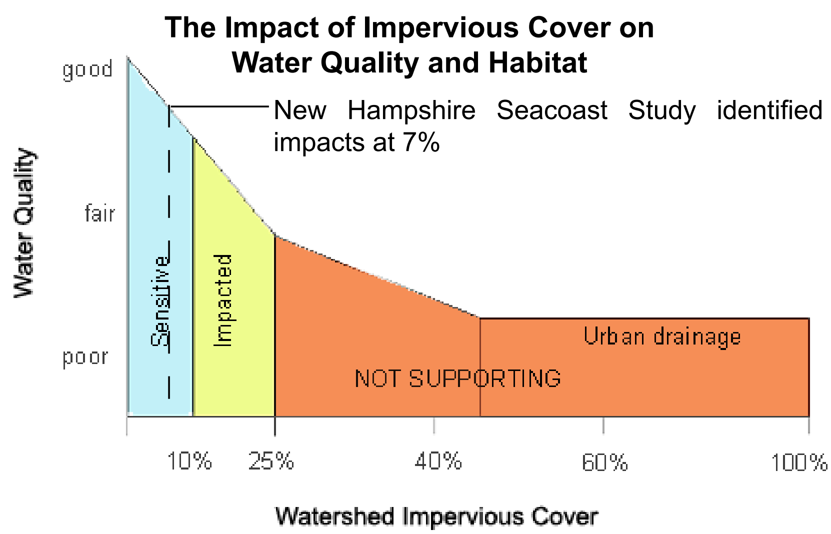


Figure 2-3. Impact of impervious cover on water quality and aquatic habitat. As impervious surfaces increase, water quality is degraded and macroinvertebrate diversity is lost. The threshold at which water quality and wildlife habitat appear to be affected by urban characteristics is between 7 percent and 14 percent impervious surface. Source: Adapted from *Center for Watershed Projection, 2003* and *Deacon et al., 2005*.

2.2.3 Inconsistent Land Use Regulations

Changes in land use, especially from natural forested land to developed, can place great stress on rivers and streams. While high-impact land uses, such as commercial or industrial development, sited near surface waters can have the most obvious impacts, the cumulative effect of less dramatic land use changes can be significant as well. Figure 2-3 shows the relationship between development (impervious cover) in a watershed and typical impacts on water quality and aquatic habitat in streams. The connections among impervious cover, stormwater management and water quality are discussed further in Chapter 10 – Stormwater. Without consistent land use controls throughout a watershed, the efforts of some towns to protect shared water resources may be ineffective as a result of less protective land use policies in other towns. Using a watershed approach considers all activities and their impacts on the ecological health of the entire watershed.

2.2.4 Disturbance of Natural Vegetated Riparian Buffers

Natural vegetated riparian buffers – the undisturbed land bordering rivers, streams and other water bodies – are the most effective protection for New Hampshire's surface waters. They reduce runoff, filter pollutants, and provide transitional zones between aquatic habitat and human land use. Depending on the width and the vegetation in place, 50 to 100 percent of the sediments and nutrients from runoff can settle out or be absorbed by the buffer (Connecticut River Joint Commissions, 2000). Wide, forested buffers are more effective than narrow grassy buffers.

Buffers also provide habitat, stabilize streambanks and regulate stream temperatures. Floodplain areas, which overlap substantially with riparian areas, account for only about 2 percent of New Hampshire's total land, but they are extremely important for maintaining wildlife habitats, protecting water quality and reducing the potential impacts of flooding on property and infrastructure (NHF&G, 2006). Less than 12 percent of floodplain land is currently under some form of protection from development, and almost 30 percent of these valuable floodplains are less than 400 feet from roads and other forms of urban development (NHF&G, 2006).

Figure 2-4. Riparian buffer along Merrimack River. This riparian forest buffer between a corn field and the river helps protect water quality and also provides wildlife habitat. Source: *Natural Resources Conservation Service, 2008*.

A recent study by DES found that of the estimated 16,750 miles of rivers and streams in the state's surface water supply watersheds (representing 80 percent of the state's total area), only 5 percent are substantially protected by local ordinances, 7 percent by the Comprehensive Shoreland Protection Act, and 25 percent by permanent protection measures such as the White Mountain National Forest, state parks, wildlife management areas, land trusts or local conservation land (P.L. Rigrod, NHDES, personal communication, November 7, 2008). While this work does not indicate the extent to which buffers have been removed, disturbed or preserved, it does demonstrate that the majority of stream buffers lack substantial protection.

Regulatory programs such as DES's Shoreland Protection Program and some local shoreland protection ordinances tend to focus on protecting riparian buffers for larger streams. Research, however, indicates that small "headwater" streams are "critical to the healthy functioning of downstream streams, rivers, lakes and estuaries" and that "[t]he goal of protecting water quality, plant and animal habitat, navigable waterways, and other downstream resources is not achievable without careful protection of headwater stream systems" (Meyer et al., 2003, p.24). A team of researchers from USGS and the University of California at Berkeley quantified the role of New England headwater streams and found that headwater catchments contribute about 40 percent and 55 percent, respectively, of the nitrogen loading to fourth- and higher-order streams (Alexander et al., 2007).

2.2.5 Maintaining Natural Flow Conditions

Rivers naturally experience wide fluctuations in flow as a consequence of climate and geology. River flows can be dramatically altered by human activities such as dam operation, watershed development, water withdrawals and wastewater discharges. As watersheds develop, flows in streams and rivers tend to become more "flashy," meaning the flows respond rapidly to runoff (precipitation or snowmelt) events, varying from low to high and back again very quickly. As noted in Chapter 10 – Stormwater, impervious surfaces increase runoff and cause the volume of water stored in groundwater to decline and, consequently, reduce the clean baseflow that provides cool water to streams and rivers in between rain events. This reduction causes stream flows to decrease and stream temperatures to rise, thereby decreasing aquatic habitat during critical summer months and inhibiting the ability of a river or stream to support aquatic life.

Healthy aquatic ecosystems exist where the natural variability in stream flows, including flooding events, is maintained. Aquatic habitats do not require one consistent flow, but a variety of flows that follow the natural pattern with respect to the magnitude, timing, frequency, duration, and rate of change in flows. This means that low flows occur naturally without necessarily impairing aquatic habitat, but that human manipulation of the duration and frequency of these periods must be limited in order to maintain the natural flow regime (NHDES, 2006). River management efforts must account for the needs for a variety of flows that mimic natural patterns. More information on flooding can be found in Chapter 12 – Floods and Droughts.

2.2.6 Fragmentation of Stream Networks by Road Crossings

Road crossings, particularly culvert crossings, alter natural stream morphology (shape and structure), degrade aquatic habitat, disrupt the flow of sediments, and obstruct the movement of fish and wildlife along stream corridors. Upgrading or replacing ineffective structures, such as culverts and bridges, with well-designed ones would enhance connectivity of wildlife populations and would increase population viability (NHF&G, 2006).

2.3 Current Management and Protection

This section describes management and protection efforts that are not described elsewhere in the primer and that are most directly related to the issues facing New Hampshire rivers and streams. Additional programs that are related to rivers and streams issues include the Shoreland Protection Program and Alteration of Terrain Program, both described in Chapter 10 – Stormwater.

2.3.1 Biomonitoring Program

The DES Biomonitoring Program assesses the biological health and integrity of aquatic ecosystems throughout the state. The results of these assessments are used for establishing reference locations for "least disturbed" conditions in the state, identifying areas that are biologically impaired, and prioritizing those areas needing management, restoration or protection efforts. Monitoring activities currently taking place for wadeable streams include: collection and identification of aquatic macroinvertebrates, collection and identification of the resident fish community, assessment of riparian habitat and land uses, and physical and chemical measurements for assessing water quality. Biomonitoring for larger rivers and other water body types is under development.

2.3.2 Exotic Species Program

The DES Exotic Species Program coordinates activities associated with the control of exotic aquatic plants. Although lakes are often the focus of exotic species control efforts, these plants also infest rivers. Recently, didymo, an invasive stalked diatom (a single-celled organism) has been discovered in northern streams. Joint control efforts with Vermont are underway. The Exotic Species Program is described in Chapter 3 – Lakes and Ponds.

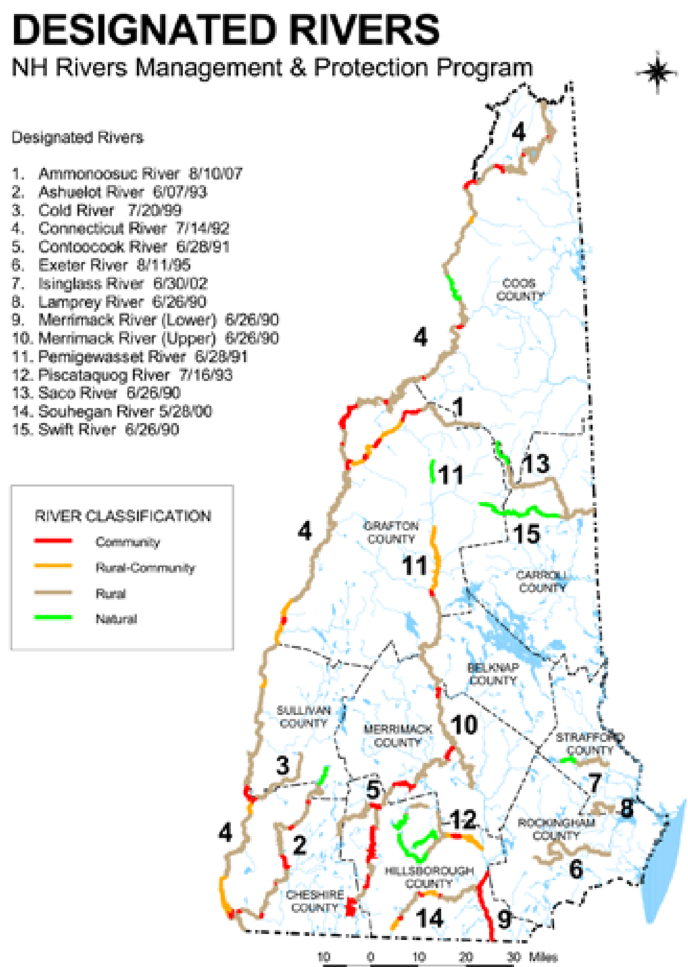


Figure 2-5. Map of designated rivers in the N.H. Rivers Management and Protection Program. Rivers can be designated into four classifications: community, rural-community, rural, or natural. *Source: NHDES, 2008d.*

2.3.3 Rivers Management and Protection Program

The Rivers Management and Protection Program (RMPP) of DES was established in 1988 with the passage of RSA

483 to protect certain designated rivers for their outstanding natural and cultural resources (Figure 2-5). A distinctive characteristic of the RMPP is the partnership created between state government and local citizens through the formation of a local advisory committee (LAC) for each designated river. Each committee plays a vital role in protecting not only the river, but its shorelands as well. The main responsibilities of the LAC are to develop and implement a local river corridor management plan and advise local, state and federal governing bodies and agencies of activities that may affect the water quality or flow of the protected river or segment. There are 15 rivers designated under RSA 483, with two rivers, the Cocheco River the Upper Reach of the Ammonoosuc River, currently going through the nomination process (NHDES, 2008c). In addition to the protection provided by management plans and LACs, rivers that are designated under the program are expected to benefit from protected in-stream flows (see section 2.3.4).

2.3.4 Instream Flow Protection Pilot Program

A requirement of RSA 483, the statute that created the RMPP, is that DES adopts rules to establish standards, criteria and procedures to protect instream flows. In 2002 a broad coalition of New Hampshire business and conservation interests joined together to enact compromise legislation that became Chapter 278, Laws of 2002, calling for an Instream Flow Protection Pilot Program. The goal of the program is to: 1) compile a comprehensive list of instream public uses, for example, navigation, recreation, fishing, conservation, aquatic habitat, water quality, etc.; 2) propose methods to assess their flow dependence by establishing protected instream flows (PISF) to protect the flow dependent instream public uses, outstanding characteristics and resources; and 3) develop a water management plan to implement the PISF. Two designated rivers, the Lamprey and Souhegan Rivers, were chosen, and the pilot program is currently in progress. Protected instream flows were established on the Souhegan River in the spring of 2008. Both pilot projects must be completed by October 2009 with a final report issued to the Legislature by December 2010. The report will detail the activities and results of the pilot program, including the impacts of the protected instream flows and water management plans on water users, wildlife, recreation, and other interests along the rivers and any recommendations for proposed legislation. The other designated rivers will then be assessed using the pilot process amended with lessons identified in the report to the legislature.

2.3.5 Water Quality Assessments

Under the federal Clean Water Act (CWA), each state is required to submit two surface water quality documents to the U.S. Environmental Protection Agency every two years. Section 305(b) of the CWA requires submittal of a report (commonly called the "305(b) Report"), that describes the quality of its surface waters and an analysis of the extent to which surface waters support designated uses. The second document is typically called the "303(d) List," which is so named because it is a requirement of Section 303(d) of the CWA. The 303(d) List includes all surface waters that:

- Are impaired or threatened by a pollutant or pollutants.
- Are 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 nonpoint sources.

- Require development and implementation of a comprehensive water quality study (a Total Maximum Daily Load study), which sets limits designed to meet water quality standards.

2.3.6 Total Maximum Daily Load Program

Section 303(d) of the federal Clean Water Act requires Total Maximum Daily Load (TMDL) studies to be conducted on all surface waters included on the Section 303(d) list of impaired waters. The term "total maximum daily load" refers to the calculation of the maximum amount of a pollutant that a water body can receive and still attain or maintain water quality standards for its designated uses. In the broader sense of the term, a TMDL is a detailed plan that identifies the pollutant reductions needed for a water body to meet state surface water quality standards and describes a strategy to achieve those reductions in order to restore water quality. The general process for developing TMDLs includes identifying the problem pollutants, establishing the water quality goals or target values needed to achieve water quality standards, identifying the specific sources contributing the pollutants of concern, and then assigning a specific load allocation to each source. Follow-up monitoring is needed to ensure that the implemented TMDL results in the attainment of the targeted water quality standard.

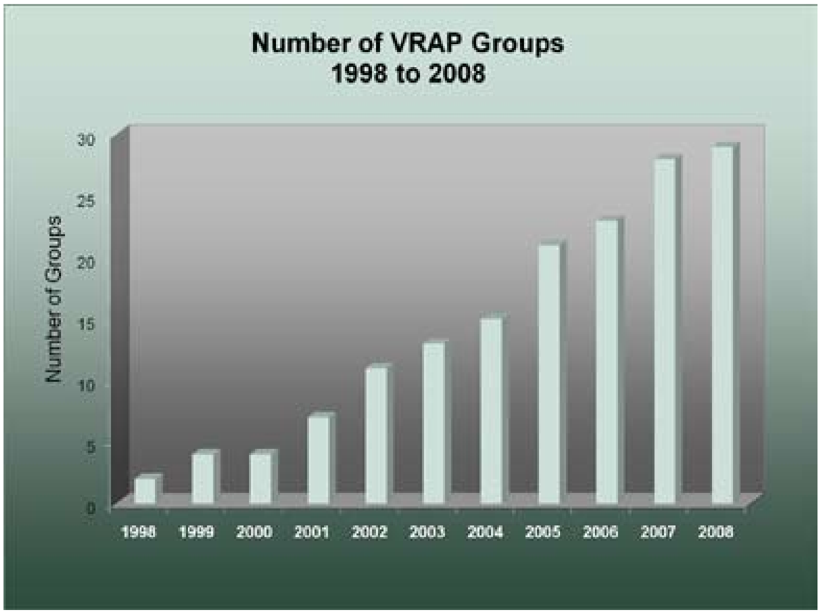


Figure 2-6. Number of Volunteer River Assessment Program groups in New Hampshire, 1998-2008. ***Source: NHDES, 2008e.***

2.3.7 Water Quality Certification

Under Section 401 of the federal Clean Water Act, any applicant for a federal license or permit for an activity that may result in a discharge into navigable waters must obtain the state's certification that the discharge will not violate state surface water quality standards. Projects that require a 401 Certificate include, but are not limited to, projects that need to file notices of intent under EPA's National Pollutant Discharge Elimination System Stormwater Construction General Permit (see Chapter 10 – Stormwater), projects requiring a wetlands permit, and hydroelectric power developments that require licensing. DES's Watershed Management Bureau issues 401 Certificates.

2.3.8 Volunteer River Assessment Program

The Volunteer River Assessment Program (VRAP) was established by DES in 1998 to promote awareness and education regarding the importance of maintaining water quality in New Hampshire's rivers and streams. VRAP is a volunteer-driven water sampling program that assists DES in evaluating water quality throughout the state. VRAP groups have recently been involved in the

Volunteer Biological Assessment Program (VBAP), which aims to supplement VRAP water quality data with biological monitoring of macroinvertebrates, which may indicate long-term changes in water quality. In 2008 29 groups participated in VRAP, and during the 2007 season volunteers took almost 10,000 water quality samples across the state (Figure 2-6).

2.3.9 Watershed Assistance

DES's Watershed Assistance Section (WAS) works with local organizations, other programs within DES, and the U.S. Environmental Protection Agency-New England, to improve water quality in New Hampshire at the watershed level. WAS works with people in their watersheds to identify water resource goals and to develop and implement watershed management plans. Its activities include:

- Providing financial and technical assistance to local watershed management organizations and municipalities specifically through Watershed Assistance Grants.
- Providing ongoing Small Outreach and Education Grants for nonpoint source pollution (water pollution from dispersed sources, as opposed to those discharging from a discrete point).
- Investigating actual and potential nonpoint source water contamination problems and working with the appropriate parties to provide technical and financial assistance for remediation.
- Executing contracts with regional planning agencies for state-funded regional environmental planning projects and federally funded water quality planning projects.
- Working with communities to implement smart growth practices and other techniques to minimize the impact of development on natural resources.
- Assisting regulated New Hampshire municipalities with implementing National Pollutant Discharge Elimination System Federal Stormwater Regulations (see Chapter 10 – Stormwater).

2.3.10 River Protection Groups

In addition to the efforts of federal, state, and local governments, numerous river watershed protection groups play an important role in monitoring, advocating for, and protecting rivers and streams. These groups include the 15 local river advisory committees established for rivers designated under the Rivers Management and Protection Program, as well as at least 22 watershed associations whose focus ranges from local (spanning several towns) to the statewide New Hampshire Rivers Council. Many of these organizations are active in public education, land conservation, volunteer monitoring, advocacy, and stream restoration. Their contributions in these areas have been essential to the protection of state's rivers and streams.

2.4 Stakeholder Recommendations

This section contains recommendations that have been developed in concert with a group of volunteer stakeholders that have reviewed and contributed to this chapter.

2.4.1 Protect Riparian Areas

As noted in section 2.2.4, riparian areas and floodplains are extremely important in protecting water quality and aquatic habitat and in providing unique habitat themselves. Unfortunately, the majority of these areas are not protected under state or local laws and they are often attractive areas for development. These areas must be better protected through conservation, regulation, public education or a combination of the three if our streams and rivers are to be protected. Options include:

- Extending the reach of the Comprehensive Shoreland Protection Act (see section 10.3.4 in Chapter 10 – Stormwater) to third-order and/or smaller streams or providing equivalent protection through local ordinances. The act currently applies to only 14 percent of the state's rivers and streams (Rivers Management Advisory Committee, 2006).
- Strengthening programs that emphasize conservation of riparian areas, such as DES's Water Supply Land Grant program.
- Developing a framework for state agencies such as the Office of Energy and Planning, Department of Fish and Game, and DES to advise on local land use decisions located within riparian areas and floodplains.
- Ensuring that stream crossings are properly designed.

2.4.2 Increase Collection of Physical, Chemical and Biological Data

Although periodic water quality tests, either through volunteer or state agency efforts, can provide a snapshot of the condition of rivers and their aquatic habitats, extended monitoring over longer periods of time is required to truly understand physical, chemical and biological trends. The impact that climate change will have on these trends is unknown at this time, making extensive environmental monitoring all the more important in the future. For more effective and targeted management of rivers and streams, the extent and depth of monitoring information must expand substantially, such as through expansion of the state's existing network of stream gages, increased support and development of volunteer based monitoring efforts such as VBAP, maintaining and integrating data sets developed by university researchers, and by other means.

2.4.3 Reduce the Impacts of Land Use Change

Water quality degradation occurs as land use in the watershed changes from its natural state to a developed state (Center for Watershed Protection, 2003), especially if the growth and resulting changes in runoff are not properly managed. Through watershed-scale planning, controlling the location of new construction, preserving riparian buffers, and incorporating both stormwater management practices and low-impact development techniques (see Chapter 10 – Stormwater) into development and redevelopment projects, the impacts of land use change can be managed to protect water quality and aquatic habitat.

2.4.4 Continue to Develop and Implement Instream Flow Protection

DES should continue its efforts to develop and implement instream flow protection for rivers designated under the Rivers Management and Protection Program, and perhaps additional rivers. The Instream Flow Protection Pilot Program's report to the Legislature, due in December 2010, is expected to provide direction for this effort based on experience from the pilot program involving the Lamprey and Souhegan Rivers.

References

Alexander, R.B., Boyer, E.W., Smith, R.A., Schwarz, G.E., & Moore, R.B. (2007). The role of headwaters streams in downstream water quality. *Journal of the American Water Resources Association*, *43*(1), 41-59.

Androscoggin River Watershed Council. (2008). *An introduction to our watershed*. Retrieved March 14, 2008 from ARWC Web site. Bethel, Maine. Available at: http://www.avcnet.org/arwc/intro.html.

Connecticut River Joint Commissions. (2000). *Introduction to riparian buffers for the Connecticut River Watershed* (fact sheet No. 1). Charlestown, N.H. Available at: http://www.crjc.org/buffers/Introduction.pdf.

Center for Watershed Protection. (2003). *Impacts of impervious cover on aquatic systems* (watershed protection research monograph number 1). Ellicott City, MD. Available at: http://www.cwp.org/Store/guidance.htm.

Deacon, J.R., Soule, S.A., & Smith, T.E. (2005). *Effects of urbanization on stream quality at selected sites in the Seacoast Region in New Hampshire, 2001-03* (U.S. Geological Survey Scientific Investigations Report 2005-5103). Available at: http://pubs.usgs.gov/sir/2005/5103/SIR2005-5103_report.pdf.

Kaushal, S.S., Groffman, P.M., Likens, G.E., Belt, K.T., Stack, W.P., Kelly, V.R., Band, L.E. & Fisher, G.T. (2005). *Increased salinization of fresh water in the northeastern United States*. Proc. Natl. Acad. Sci. U.S.A., 102: 13517-13520. DOI 10.1073/pnas.0506414102.

Meyer, J.L., Kaplan, L.A., Newbold, D., Strayer, D.L., Woltemade, C.J., Zeler, J. B., Beilfuss, R., Carpenter, Q., Semlitsch, R., Watzin, M.C., & Zedler, P.H. (2003). *Where rivers are born: The scientific imperative for defending small streams and wetlands*. Sponsored by Sierra Club and American Rivers. Available at: http://www.sierraclub.org/healthycommunities/rivers/WRABreport_full.pdf.

Natural Resources Conservation Service. (2008). *Examples of buffers in New Hampshire.* Retrieved November 7, 2008 from NRCS Web site. Available at: http://www.nh.nrcs.usda.gov/features/Buffers/how_buffers.html.

New Hampshire Department of Environmental Services. (1998). *Mercury in the environment* (fact sheet BB-21). Available at: http://des.nh.gov/organization/commissioner/pip/factsheets/bb/documents/bb-21.pdf.

New Hampshire Department of Environmental Services. (2006). *Instream protected uses, outstanding characteristics, and resources of the Lamprey River and proposed protective flow measures for flow dependent resources: Final report* (NHDES-R-WD-06-49). Prepared by Normandeau Associates, University of Massachusetts, and University of New Hampshire. Available at: http://des.nh.gov/organization/divisions/water/wmb/rivers/instream/lamprey/documents/20061121_20371.

New Hampshire Department of Environmental Services. (2007). *Public comment draft total maximum daily load (TMDL) study for waterbodies in the vicinity of the I-93 corridor from Massachusetts to Manchester, N.H.: Policy-Porcupine Brook in Salem and Windham, N.H.* (NHDES-R-WD-07-41). Prepared by Phil Trowbridge, P.E., NHDES Watershed Management Bureau. Available at: http://des.nh.gov/organization/divisions/water/wmb/tmdl/documents/chloride_policy_brook.pdf

New Hampshire Department of Environmental Services. (2008a). *2008 Section 305(b) and 303(d) consolidated assessment and listing methodology* (NHDES-R-WD-08-2). Prepared by K. Edwardson, NHDES Watershed Bureau. Available at: http://des.nh.gov/organization/divisions/water/wmb/swqa/2008/documents/appendix_04_calm.pdf.

New Hampshire Department of Environmental Services. (2008b). *New Hampshire 2008 Section 305(b) and 303(d) surface water quality report and RSA 485-A:4.XIV report to the Governor and General Court* (R-WD-08-5). Prepared by G. Comstock and K. Edwardson, NHDES Watershed Management Bureau. Available at: http://des.nh.gov/organization/commissioner/pip/publications/wd/documents/r-wd-08-5.pdf.

New Hampshire Department of Environmental Services. (2008c). *River nominations*. Retrieved September 26, 2008 from NHDES Web site. Available at: http://des.nh.gov/organization/divisions/water/wmb/rivers/nominations.htm.

New Hampshire Department of Environmental Services. (2008d). *Designated rivers.* Retrieved August 8, 2008 from NHDES Website, Rivers Management and Protection Program. Available at: http://des.nh.gov/organization/divisions/water/wmb/rivers/documents/designated_rivers.pdf.

New Hampshire Department of Environmental Services. (2008e). Volunteer River Assessment Program, Water Division, NHDES. Unpublished data.

New Hampshire Department of Environmental Services (2008f). Watershed Management Bureau, Water Division, NHDES. Unpublished data.

New Hampshire Fish & Game Department. (2006). *New Hampshire wildlife action plan*. Available at: http://www.wildlife.state.nh.us/Wildlife/wildlife_plan.htm.

Rivers Management Advisory Committee. (2006). Appendix D: RMAC position paper: Stream mileage calculations. In *Final report of the Commission to Review the Effectiveness of the Comprehensive Shoreland Protection Act, SB 83, Chapter 209, Laws of 2005*. Available at: http://des.nh.gov/organization/divisions/water/wetlands/cspa/commission_final_report.htm.

Robinson, K.W., Campbell, J.P. & Jaworski, N.A. (2003). *Water quality trends in New England rivers during the 20th century*. Water Resources Investigations Report 03-4012. U.S. Geological Survey, National Water Quality Assessment Program, Pembroke, N.H.

Seacoast Watershed Information Manager. (2006). *Piscataqua Watershed*. Retrieved March 13, 2008 from SWIM Web site. Available at: http://swim.wellsreserve.org/watershed.php?ws_id=6.

Chapter 3
Lakes and Ponds

NEW HAMPSHIRE
DEPARTMENT OF
Environmental
Services

Overview

Nearly 1,000 lakes and ponds larger than 10 acres and more than 3,000 small ponds are scattered throughout New Hampshire's watersheds (Figure 3-1). They are an integral part of New Hampshire's quality of life, economy and natural heritage. Lakes are a major attraction for short-term recreational visitors, those who own or rent seasonal homes, and permanent residents.

Some lakes, such as Lake Massabesic in Manchester and Penacook Lake in Concord, are used as public water supplies and have partial or total restrictions on recreational uses, but the most popular uses for most lakes are swimming and boating, followed by fishing. In fact, New Hampshire has approximately 170 public beaches on lakes and ponds. A recent study estimates that as much as $1.1 billion in annual sales result from these recreational uses in New Hampshire (Shapiro & Kroll, 2003).

Although the great majority of lakes and ponds have clear water and relatively low biological productivity, i.e., the tendency to grow algae and aquatic plants, most New Hampshire lakes have other water quality issues. The most common issues result from atmospheric deposition of pollutants, such as mercury and acid deposition, and increasing impacts from road salt. Development threatens lakes and ponds as forest land is converted to homes, businesses, roadways and parking lots. The trend is significant with approximately 13,500 acres of forest land converted to other uses every year in the state (Society for the Protection of New Hampshire Forests, 2006). As described in Chapter 10 – Stormwater, transformation from a forested to a developed landscape produces increased stormwater runoff and greater inputs of phosphorus and road salt into surface waters (streams, rivers, lakes and ponds). Increased phosphorus causes greater growth of algae and aquatic plants because phosphorus is usually the limiting nutrient in lakes. Existing land management efforts and regulations by themselves do not effectively mitigate this risk. Toxic concentrations of chloride from road salt also present a risk to aquatic life.

Carrying capacity is also a significant issue for lakes and ponds. This is the level or intensity of use beyond which impacts to the lake or the visitor experience exceed acceptable limits. Other significant issues include invasive exotic species and climate change.

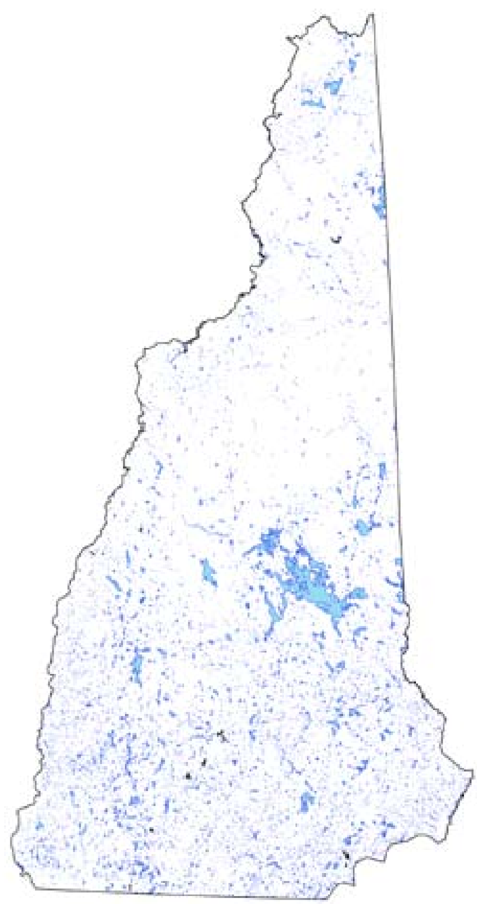


Figure 3-1. The geographic distribution of lakes and ponds in New Hampshire. ***Source: NHDES, 2008d.***

Local lake advocates and state agencies must remain vigilant to arrest the trend of declining health in some lakes, to address water use impairments where they ex-

ist, to maintain water quality where it is good, and to closely watch lakes where water quality trends are not yet clear. This vigilance is particularly important where watershed development continues to progress and as climate change affects New Hampshire's weather patterns and thus its lakes and ponds. The state has a variety of programs dealing with various management aspects of lakes, but a definitive statewide coordinating responsibility is needed.

3.1 Description and Significance

Lakes typically have limited currents, little surface vegetation and depths too great for wading. Some lakes are natural, but most lakes have a dam at the outlet that increases the depth. The words "lake" and "pond" are often used interchangeably, though ponds are usually smaller (NHDES, 2003). Impoundments, which are created by a dam across a river, are also occasionally referred to as lakes. There are nearly 1,000 lakes and ponds greater than 10 acres in the state with a total surface area of almost 165,000 acres (NHDES, 2008a). With the exception of Lake Umbagog and Lake Sunapee, the largest lakes are in New Hampshire's Lakes Region: Winnipesaukee, Squam, Winnisquam and Newfound. However, the majority of the state's lakes and ponds are less than 100 acres in size (Figure 3-2).

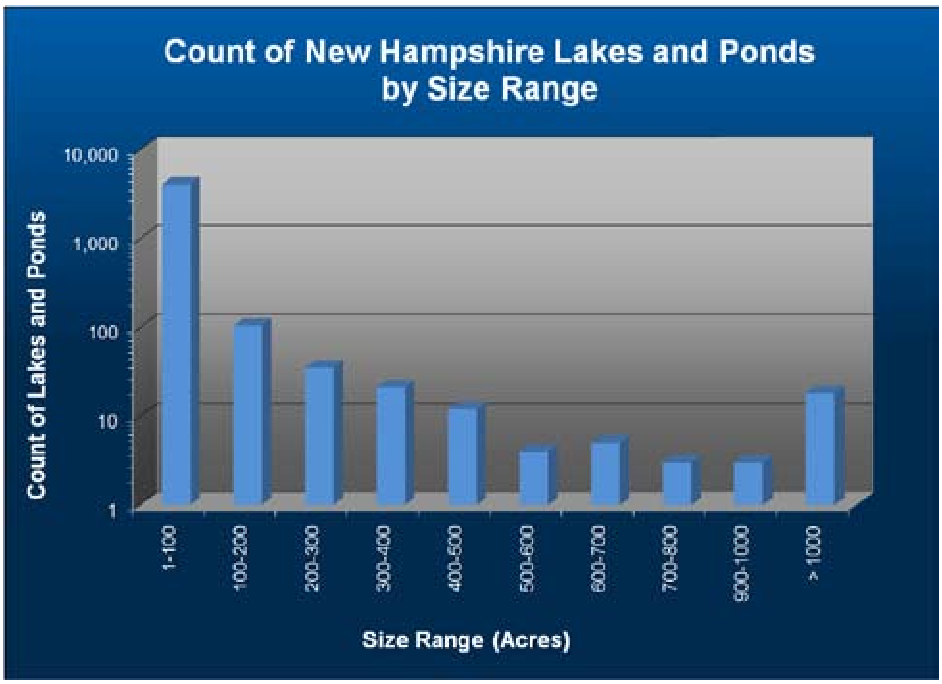


Figure 3-2. The size distribution of lakes and ponds in New Hampshire. *Source: NHDES, 2008d.*

3.1.1 The Lakes and Ponds of New Hampshire Are Valuable Economic and Ecological Resources

New Hampshire's lakes and ponds provide abundant recreational opportunities; historic, cultural and economic values; and critical natural assets. A study conducted in 2002 determined that just four uses of New Hampshire's surface waters – boating, fishing, swimming, and drinking water supply – contribute up to $1.5 billion annually in total sales to the state's economy and surface waters boost property tax revenue by an estimated $247 million per year (Shapiro & Kroll, 2003).

More recently a survey of boaters, anglers and swimmers determined that if these user groups perceived a degradation in water clarity and purity, their use of these surface waters would decline, resulting in an economic loss of $51 million in total sales, $18 million in income, and more than 800 jobs statewide (Nordstrom, 2007).

Lakes are ecological systems made up of many complex interactions and while they may appear to be large basins with uniform conditions throughout, these surface waters are heterogeneous and their physical, biological and chemical characteristics also vary over time. The physical and chemical characteristics support a variety of biological organisms that may be specific to a lake. The abundance of clean and clear water and the diversity of plant communities not only provide habitat for fish and other aquatic wildlife, but also support terrestrial and bird species.

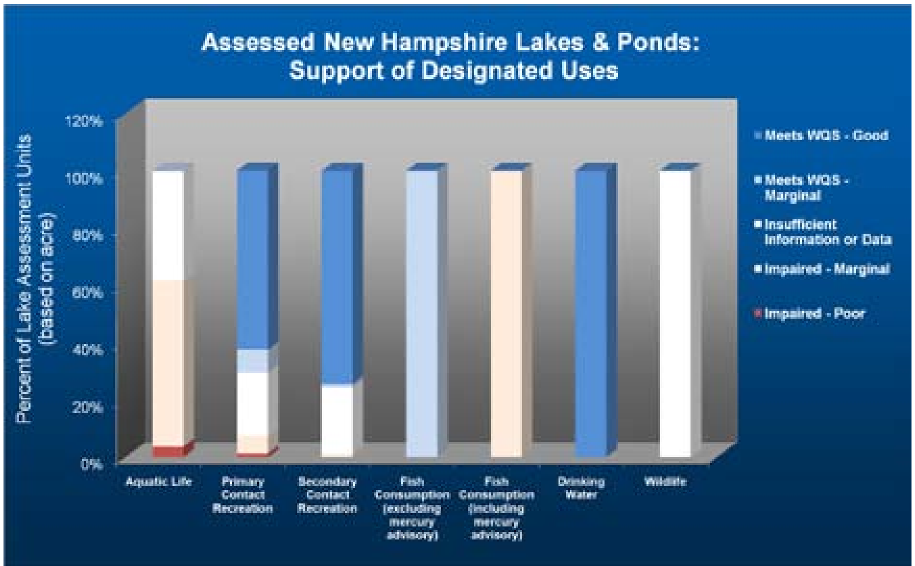
Each lake is also part of a larger ecosystem – its watershed – that includes all of the land that surrounds it and drains into the lake. The land use and development within a lake watershed directly affect the quality and quantity of water in a lake. When excess sediment, nutrients or pollutants are added to the lake, then the lake system is disrupted. If one characteristic of a lake is altered, then other parts of the system will also be affected.

3.1.2 Water Quality Is Generally Good, but Salt Is Becoming a Problem

Section 305(b) of the federal Water Pollution Control Act, commonly called the Clean Water Act (CWA), requires each state to prepare a report every two years that describes the quality of its surface waters and an analysis of the extent to which all such waters support six designated uses: aquatic life, primary contact recreation (swimming), secondary contact recreation (boating), drinking water, fish consumption, and wildlife. The latest comprehensive report, called the 305(b) and 303(d) Surface Water Quality Report, was published in April 2008 (NHDES, 2008b).

New Hampshire's lakes and ponds greater than 10 acres comprise 165,000 surface acres of water. As indicated in Figure 3-3 and the accompanying table, not all of those acres have been assessed for all designated uses due to resource limitations. For example, 22.3 percent of the state's surface water acres have not yet been assessed for the primary contact designated use. While a majority of assessed lakes and ponds in New Hampshire meet water quality standards for recreation and drinking water designated uses, low pH values and exotic species infestations marginally impair a high percentage of assessed waters for aquatic life; and mercury impairs all waters for fish consumption.

The majority (70 percent) of aquatic life impairments in New Hampshire's lakes and ponds are due to pH values that fall below the minimum water quality standard of pH 6.5. In the vast majority of cases (81 percent of pH-impaired lakes) the pH readings were just below the standard of 6.5, meaning these lakes are marginally impaired and are not expected to have any significant adverse impacts to aquatic life. Low pH is primarily attributable to deposition of acids from the atmosphere, i.e., acid rain. The source of acidifying pollutants in the atmosphere is air emissions, primarily from fossil fuel burning power plants and motor vehicles (Swackhamer et al., 2004). Since 1991 New Hampshire has taken active steps to reduce emissions from within the state. While some of these emissions still originate from within New Hampshire, the majority of emissions are from sources outside of the state.



Designated Use	Insufficient Information or No Data	Lake and Pond Acreage Assessed			
		Meets WQS - Good	Meets WQS - Marginal	Impaired - Marginal	Impaired - Poor
Aquatic Life	38.3%	0%	0.2%	57.8%	3.7%
Primary Contact Recreation	22.3%	62.4%	8.0%	6.1%	1.3%
Secondary Contact Recreation	23.0%	74.5%	1.2%	1.3%	0%
Fish Consumption (excluding mercury advisory)	0%	0%	100%	0%	0%
Fish Consumption (including mercury advisory)	0%	0%	0%	100%	0%
Drinking Water After Adequate Treatment	0%	100%	0%	0%	0%
Wildlife	100%	0%	0%	0%	0%

Figure 3-3. Assessments of water quality standards (WQS) of New Hampshire lakes and ponds with respect to designated uses. Source: *NHDES, 2008b.*

New Hampshire, like many other New England states, has a statewide freshwater fish consumption advisory due to mercury levels in fish tissue. The major pathway of mercury to lakes is also atmospheric deposition. This means that fish from remote lakes may contain mercury levels that are similar to fish from lakes in industrialized areas. Most of the mercury in New Hampshire waters probably comes from sources outside the state (NHDES, 1998).

Although useful in summarizing the current status of water quality, the data on impaired versus supporting waters do not depict water quality trends, because the assessment methods, volume of sampling and targeting of sampling have changed over time. However, data collected from New Hampshire lakes and ponds through the Volunteer Lake Assessment Program (VLAP) over the past 30 years have shown an increasing trend in conductivity, sodium and chloride. An analysis of 150 lakes in the VLAP program showed that these parameters increased at least 10 percent in 70 percent of the lakes, that no change occurred in 20 percent of the lakes, and that the parameters decreased more than 10 percent in 10 percent of the lakes. The increasing trends were greatest in urban ponds and in ponds near major roads and highways. The use of deicing salts (sodium chloride) is considered to be the major source of the increasing trend. No change occurred in ponds remote from salted roads or parking lots. While only four ponds violate the water quality criterion for chloride (three Manchester ponds and a Seacoast pond receiving salt spray as well as deicing salts) (R. Estabrook, NHDES, personal communication, September 15, 2008), the trend is troubling because chloride is toxic to aquatic life.

3.1.3 Trophic Status Is Stable or Improving Overall, but a Few Lakes Are in Decline

Lakes are classified into three categories according to their trophic status, which is a measure of a lake's productivity, or tendency to grow algae and aquatic plants. Oligotrophic lakes tend to be clear and deep, with little plant and algae growth; mesotrophic lakes are intermediate in depth, clarity and productivity; and eutrophic lakes are usually shallow and support abundant algae and plant growth, with resulting green or blue-green summer algae blooms and reduced water clarity.

As shown in Table 3-1, 74 percent of surveyed lake area is oligotrophic, more than 21 percent is mesotrophic, and a small percentage is eutrophic. It is important to note that the table only includes information for lakes classified as "significant" for purposes of reporting to the EPA. In general, a "significant" lake or pond is 10 acres or more in size, is not private, and does not have a prohibition on recreational activity. Of the nearly 1,000 lakes and ponds in the state, 663 are defined as "significant," with a total surface area of 155,601 acres.

Table 3-1. Trophic status of significant lakes in New Hampshire. Source: *NHDES, 2008b.*

Description	Number of Lakes	Percent of Lakes	Acres of Lakes	Percent of Area
Assessed	663	100	155,601	100
Oligotrophic	187	28.2	115,075	74.0
Mesotrophic	329	49.6	33,454	21.5
Eutrophic	147	22.2	7,072	4.5

Statewide, there has not been a significant positive or negative trend in trophic status during the last 30 or more years. A statistical analysis of water quality parameters related to trophic status, such as chlorophyll and phosphorus concentrations and Secchi disk transparency, found that while a majority of lakes with at least 10 consecutive years of data are either stable or fluctuating, there are more lakes with improving trends than lakes with degrading trends (NHDES, 2008b). This does not mean that action should not be taken; eight lakes showed a significant decline in transparency over the 10-year period.

3.2 Issues

3.2.1 Landscape Change Threatens Water Quality

As noted in Chapter 10 – Stormwater, research performed throughout the country, including New Hampshire, has demonstrated that impervious cover is a good general indicator of the effects of landscape change on stream hydrology, water quality and biological health. Increasing amounts of impervious surface and shoreland development are negatively affecting many of New Hampshire's lakes and ponds. The primary mechanisms of this process include increased transport of road salt, sediment, and associated phosphorus from land to water. In addition to stormwater runoff associated with development, road salt and nutrients seep into the ground from roadways and parking lots and travel via groundwater to New Hampshire's lakes and ponds.

3.2.2 Toxic Algae (Cyanobacteria) Blooms Are Occurring with Greater Frequency, Causing Concern for Public Health

Cyanobacteria, sometimes called "blue-green algae," are a growing concern in New Hampshire. Cyanobacteria are aquatic, photosynthetic bacteria. Many species of cyanobacteria can proliferate rapidly to form "blooms" in surface water (Figure 3-4). An increase of phosphorus in combination with increased sunlight and warmer water temperatures often accelerates cyanobacteria growth in a lake. Several cyanobacterial species produce toxins (cyanotoxins) that can cause both acute and chronic problems in humans. The possible effects of cyanobacteria on New Hampshire lakes and their natural inhabitants, such as fish and other aquatic life, are under study at this time. The Center for Freshwater Biology (CFB) at the University of New Hampshire (UNH) is currently examining the potential impacts of these toxins upon the lake food web. The potential human health hazards via exposure through drinking water or during recreational water activities are also a concern to the CFB and DES.

Figure 3-4. The effects of development and stormwater degrade the water quality of New Hampshire's valuable lakes. Source: *NH-DES Watershed Management Bureau.*

3.2.3 The Carrying Capacity of New Hampshire's Lakes and Ponds Has Not Been Evaluated

New Hampshire's Lakes Management and Protection statute (RSA 483-A:5 (e)) states: "recreational uses of lakes shall be consistent with the carrying capacity and character of each lake." Carrying capacity refers to the level or type of use beyond which impacts to the lake or the visitor experience exceed acceptable limits. There are three components of carrying capacity:

- Biological carrying capacity: the capability of the lake to sustain certain activities before the degradation of water quality or impacts to aquatic life occur.

- Social carrying capacity: the maximum combinations and intensities of human uses without unacceptable diminishment of people's enjoyment of the lake due to the presence and activities of other users.
- Physical carrying capacity: the maximum intensity of human use that a lake or river can accommodate.

While the Lakes Management and Protection statute mandates consistency between uses and carrying capacity, other statutes encourage greater recreational use of lakes. The New Hampshire Fish and Game Department (NHF&G) has a mandate to carry out the statewide public boat access program (RSA 233-A:4), and other state agencies, by virtue of their land holdings, also provide public access, both passive and active. The 1991 New Hampshire Office of State Planning (NHOSP) Public Access Plan recommended that for great ponds, there should be one public access point for each five miles of shoreline or for every 1,000 acres of surface water and for rivers there should be one public access point for each 10 miles of shoreline (NHOSP, 1991). In connection with this issue, the Public Water Access Advisory Board is planning to review the 1991 Public Access Plan for New Hampshire Waters, with a view to the plan's revision. The N.H. Fish and Game Department currently lists 232 public access points (NHF&G, 2008).

To date, the state has not determined the carrying capacity of its surface waters. In the absence of this information, it is very difficult for the state, municipalities and lake organizations to ensure that lakes are being managed in such a way as to avoid undesirable impacts.

3.2.4 More Data Is Needed to Detect Trends

While the Volunteer Lake Assessment Program (VLAP) and other similar programs in the state collect a wealth of data, water quality and quantity trends for many lakes cannot yet be determined because of information gaps or because there is little or no information on some lakes and ponds. As illustrated in Figure 3-3, more data is needed. Long-term trends can help define the current status of lakes relative to their more natural state. The expansion of lake monitoring and sampling activities would improve the base of information upon which decisions can be made about the future of lake resources in New Hampshire. This would require more staff to assist volunteers in accurate and timely monitoring. Equally important, watershed management programs geared to prevention, i.e., land use planning and regulation to protect lakes and ponds, are needed for cleaner lakes, while watershed restoration programs are needed for those lakes already apparently declining. In order for such programs to be effective, they need to be quantitative and should include carrying capacity analyses, with efforts to meet water quality goals tied directly to the proposed restoration measures. This will require more data on water quality, land use and the connection between the two.

3.2.5 Exotic Aquatic Species Are a Growing Threat

Exotic aquatic species are aquatic plants or animals that are not part of New Hampshire's native flora and fauna. Because exotic plants are introduced from outside of the state, they have no established relationships with native fauna that keep their growth in check. When these exotic plants grow without natural controls they encroach upon and replace the habitats of native plants, disrupting the food chain, stunting fish growth and degrading wildlife habitat.

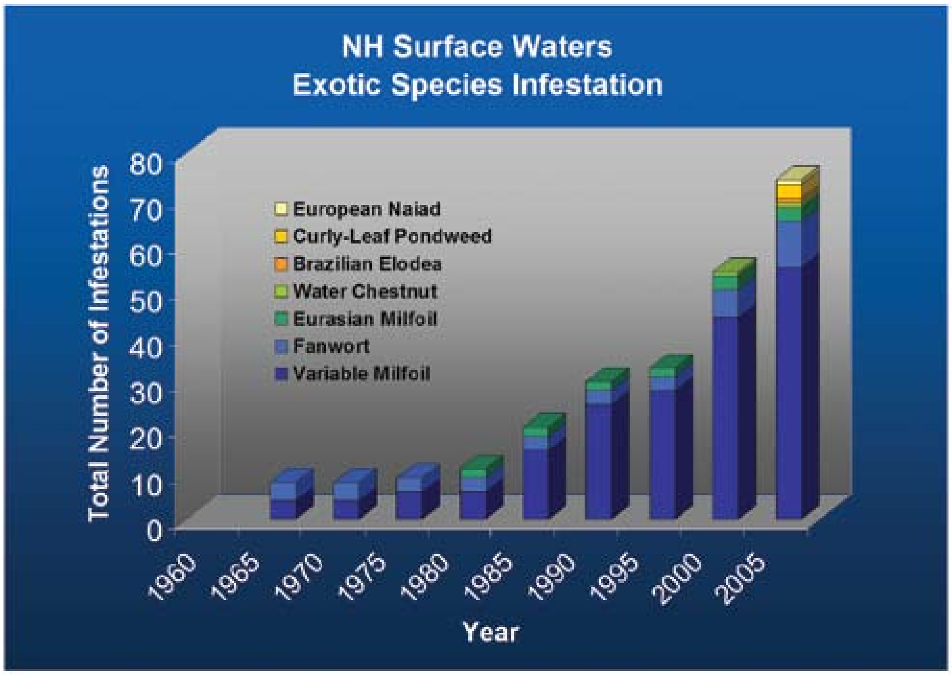


Figure 3-5. The infestation of exotic species and the variety of these new species are increasing in New Hampshire surface waters *Source: NHDES, 2005.*

Since the first exotic aquatic plant infestation in New Hampshire was discovered in 1965, exotic aquatic plant infestations have continued to increase (Figure 3-5). Variable milfoil, by far the most widespread exotic aquatic plant in New Hampshire, was first found in Moultonborough Bay in Lake Winnipesaukee. Today, it has spread to infest approximately 68 water bodies. Fanwort, water chestnut, Eurasian milfoil, purple loosestrife and *Didymosphenia geminata* ("didymo") are also problematic species in the state. There were two new infestations of exotic aquatic plants in New Hampshire in 2008. With these new infestations, there were 74 documented infestations of exotic species, including didymo, in New Hampshire's lakes, ponds and rivers.

Exotic aquatic plant fragments can easily attach to aquatic recreational equipment, such as boats, motors and trailers, and can spread from one water body to another through transient boating activities. Infestations can have detrimental effects on the ecological, recreational, aesthetic and economic values of the state's precious surface waters, limiting use of the water bodies and decreasing shorefront property values by as much as 10 percent to 20 percent according to a UNH study (Gibbs et al., 2002).

Zebra mussels are not yet a problem in New Hampshire, but they are just over our borders in neighboring and nearby states. Vermont has a widespread population of zebra mussels in Lake Champlain, and at least a dozen other waterbodies have had veligers (larval form of the zebra mussel) identified within them. In Connecticut, East and West Twin Lakes are infested with zebra mussels, and Lake George in New York has a small problem at the southern end of the lake. It is anticipated that zebra mussels will initially appear in New Hampshire within the Connecticut River Valley. It is a water body that New Hampshire holds in common with Vermont, where zebra mussels are present, and the water chemistry is such that it could support growths of the mussels based on calcium content and algal densities.

3.3 Current Management and Protection

This section describes management and protection efforts that are not described elsewhere in the New Hampshire Water Resources Primer and that are most directly related to the issues facing New Hampshire lakes and ponds. Additional programs that are related to lake and pond issues include the Shoreland Protection Program and Alteration of Terrain Program, both described in Chapter 10 – Stormwater.

3.3.1 Exotic Species Programs

The DES Exotic Species Program coordinates activities associated with the control and management of exotic aquatic plants; as well as activities associated with the implementation of education programs and volunteer plant monitoring programs.

Since its inception in 1981 with the passage of RSA 487:15, the Exotic Aquatic Plant Program has grown to become a cooperative effort among state agencies, lake organizations and concerned citizens. At the state level this involves a partnership among DES, the N.H. Fish and Game Department, the N.H. Department of Safety, and the N.H. Department of Agriculture, Markets and Food to prevent the spread of exotic plants to new water bodies and to monitor and treat infestations. Many lake associations and other non-profit organizations, such as the New Hampshire Lakes Association and individual lake associations, participate in monitoring, education and control efforts.

Program activities include five focus areas: 1) prevention of new infestations through education and outreach; 2) monitoring for early detection of new infestations; 3) control of new and established infestations; 4) research towards new control methods; and 5) regional or national cooperation with other exotic species programs. The Lake Host Program, long-term management plans, and physical harvesting techniques are effective mechanisms addressing the program's five focus areas.

Lake Host Program

The Lake Host Program is a courtesy boat inspection program implemented by the New Hampshire Lakes Association in cooperation with local participating groups and partially funded by DES to prevent the introduction and spread of exotic aquatic plants, such as variable milfoil, from lake to lake. During 2008 approximately 54,000 courtesy boat inspections were conducted statewide and 515 "saves" have been documented since the program's inception in 2002. A "save" occurs when a Lake Host removes a piece of exotic aquatic plant from a boat that either enters or leaves a water body.

Long-Term Management Plans

Starting in 2006, prior to any herbicide treatment of an exotic aquatic species, a long-term management plan must be prepared by the DES Exotic Species Program for the water body, outlining the problem, the goals of management, and what techniques will be used to achieve those goals. The purpose of these plans is to ensure that there is a strategic, well-organized process that is tailored to best manage growths of exotic aquatic vegetation on a water body-by-water body basis.

Most of these activities will employ concepts of Integrated Pest Management (IPM). By using this management plan approach it is hoped that herbicide applications to control exotic aquatic plants can and will be used only when needed, and at the same time the invasive species is successfully eradicated or controlled for a long-term period. To date, approximately 40 plans have been prepared. DES, in consultation with the Fish and Game Department and the Department of Agriculture, Markets and Food, is currently developing criteria for management plans that involve using herbicides to control native aquatic plants.

Physical Harvesting Techniques

Other newly implemented programs to control exotic aquatic species include the Weed Control Diver Program and the Diver-Assisted Milfoil Machine (DAMM), a watercraft outfitted to suction harvest exotic weeds from a water body. The diver program began in 2007 and 55 divers have since been certified and have worked in approximately 20 lakes over the last two years. These individuals are specially trained to safely extract exotic plants from the lakebed with minimum disruption to the lake bottom and little impact to lake quality. The DAMM, first used in 2008, has harvested exotic weeds from approximately 20 lakes. The combination of these two programs provides very effective means to physically remove exotic aquatic plants from New Hampshire's lakes and ponds.

3.3.2 Lakes Management and Protection Program

The New Hampshire Lakes Management and Protection Program (LMPP) was established with the passage of RSA 483-A in 1990, which also called for the establishment of a Lakes Coordinator and Lakes Management Advisory Committee (LMAC). The LMPP involves the coordination and development of lake management and protection criteria and plans. The LMPP provides technical assistance regarding lakes management to state and federal agencies as well as the public and private sectors. The LMPP also reviews relevant existing statutes and proposed legislation pertaining to lakes.

The LMAC advises the DES Commissioner and Lakes Coordinator regarding the management and protection of lakes. The committee is made up of 18 members from state agencies; municipalities; the conservation community; marine, tourism, real estate, business and industry interests; and academia. Projects directed by LMAC include the following:

- Lakes Management Criteria for New Hampshire State Agencies, completed in 1996 (NHDES, 1996).
- Comprehensive Lake Inventory, a tool to assess lakes and their surrounding watersheds, completed in 2007 (NHDES, 2007).
- New Hampshire Guidelines for Coordinated Lake Management and Shoreland Protection Plans, a step-by-step guide outlining how to develop a lake and watershed management plan, produced in 2008 (NHDES, 2008c).

3.3.3 The Sustainability Initiative

The LMAC and the Rivers Management Advisory Committee (RMAC) recently launched a "Sustainability Initiative for New Hampshire's Surface Waters" (LMAC and RMAC, 2008). This initiative focuses primarily on issues with New Hampshire's changing land uses and watershed activities. One goal of the initiative is to develop recommendations for watershed management using the antidegradation language in the Water Quality Standards, described in Chapter 2 – Rivers and Streams.

The Sustainability Initiative addresses the following eight issues:

- The need to increase the stream gage and water quality monitoring networks and improve data access.
- The need for a clear, well-communicated strategy to address landscape change.
- The need to better protect shoreland and riparian buffers.
- Increasing stormwater impacts on flooding and water quality.
- Carrying capacity of and public access to lakes and ponds.
- Invasive aquatic species research and prevention/eradication.
- Instream flow protection and groundwater withdrawal protections.
- Climate change.

3.3.4 The DES Volunteer Lake Assessment Program and the UNH Lakes Lay Monitoring Program

The New Hampshire Volunteer Lake Assessment Program (VLAP) facilitates the collection of lake monitoring data through an extensive network of volunteers. Aside from providing DES with information to evaluate lake water quality, VLAP serves to empower lake residents and volunteer monitors with information about the health of their water body. VLAP annually publishes reports containing data from participating lakes that are available on the DES website. The reports show the status of each lake or pond and can provide evidence of nutrients, road salt, sediment deposition, and other sources of pollution that may be affecting the water quality.

The UNH Lakes Lay Monitoring Program (LLMP) is dedicated to the preservation and sound management of lakes through citizen-based monitoring and research. Through its integration of research, outreach and teaching, the LLMP provides valuable data on the lakes of New Hampshire, broad community service, local empowerment, and a unique opportunity for hands-on learning and employment for students. The LLMP is administered jointly through the Cooperative Extension and the Center for Freshwater Biology at UNH. Introduced in 1978 as a class project on Lake Chocorua, the LLMP has grown into an internationally recognized volunteer monitoring effort. More than 500 volunteers have been trained to monitor hundreds of lake, tributary and outlet sites each year.

DES uses data from both volunteer monitoring programs to compile water quality assessments.

3.3.5 Water Quality Surveys and Assessments

DES conducts a variety of surveys and assessments to monitor the water quality of New Hampshire's lakes and ponds. The collected information is used to establish baseline conditions for future comparisons and to evaluate long-term trends by comparing current conditions with historical data. The trend analysis is useful for determining general trends in a large number of lakes.

However, because of the limited frequency of sampling and lack of data, only major changes can be detected in any particular lake. More frequently collected data is necessary to detect subtle changes in a given lake.

Trophic Surveys

This program was initiated in 1975 and is designed to measure the trophic state of a lake as required by the federal Clean Water Act. Physical, chemical and biological measurements are made at each lake, once during the winter and once during the summer. Lakes have been sampled once every 15 to 20 years and almost every New Hampshire lake and pond has been surveyed at least once in the program. The program has been suspended since 2007 due to changed EPA and state monitoring priorities.

Acid Pond Surveys

Two groups of lakes – remote ponds and accessible ponds – are routinely monitored for acid deposition-related parameters to evaluate long-term trends. The results for 10 lakes from each of the two groups are provided to the New England Governors-Eastern Canadian Premiers Water Quality Monitoring Network as part of a northeast North American Acid Trend Program.

Each spring the N.H. Fish and Game Department stocks brook trout into remote ponds by helicopter. At the time of the stocking, a water sample is collected from mid-lake at a 0.5 meter depth and analyzed for acid deposition parameters. The program was initiated in 1981. A total of 60 different ponds have been sampled in the program with a core of 23 ponds sampled essentially every year. Many of these ponds are at high elevation and are the most susceptible to the impacts of acid deposition because of small watersheds, shallow to no soils and elevated precipitation rates.

The outlets of 20 accessible headwater ponds are sampled twice a year, at spring and fall overturn when outlet waters are representative of in-lake conditions, and analyzed for acid deposition parameters. The program began in 1983 and is designed to complement the remote pond program by documenting acid deposition trends in low elevation, non-colored ponds.

3.3.6 Mercury in Fish Program

Mercury is highly toxic to wildlife. It accumulates in the tissues of fish and other organisms inhabiting mercury-contaminated waters and builds up in the tissues of organisms higher up the food chain, including humans. With assistance from the N.H. Fish and Game Department, the U.S. Fish and Wildlife Service, and volunteers, 297 fish were collected from the state's lakes and ponds in 2007. The fish were frozen upon collection and analyzed for total mercury in the DES Limnology Center in late 2007 and early 2008. To date there have been 1,561 analyses of freshwater fish, including 1,214 from lakes and reservoirs. Total mercury levels ranged from 0.01 to 2.49 parts per million (ppm) for the 25 fish species sampled, which include 628 yellow perch, 217 largemouth bass, 178 smallmouth bass, and 149 eastern chain pickerel. As noted in section 3.1.2, New Hampshire, has a statewide freshwater fish consumption advisory due to mercury levels in fish tissue.

3.3.7 Public Beach Inspection Program

The DES Public Beach Inspection Program has monitored public beaches for over 20 years in response to the potential health threats associated with waterborne pathogens. These pathogens are responsible for diseases such as cholera, giardiasis, gastroenteritis and cryptosporidiosis. DES also recognizes the threat of toxic cyanobacteria at public beaches. As the use of New Hampshire's inland and coastal waters grows, the continued goal of the program is to protect public health and inform the public of potential health risks at public beaches.

In 2007 DES visited a total of 168 freshwater public swimming beaches on a monthly schedule for a total of 567 inspections. Eleven freshwater beaches were issued cyanobacteria advisories for the presence of a potentially toxic cyanobacteria scum. Swimming use was impaired at 38 of New Hampshire's lakes due to elevated algal or cyanobacterial growth.

Thirty-one freshwater public beaches were issued a total of 37 advisories for exceedances of the public beach water quality standards for E. coli. Fourteen beach advisories were issued at Ahern State Park, Laconia, as a result of a pre-emptive advisory following greater than 0.25 inch of rainfall.

3.3.8 Boat Inspection Program and Clean Vessel Act

The Boat Inspection Program conducts boat inspections on Lake Winnipesaukee and Winnisquam Lake. In 2007 the program conducted 63 inspections. Violations of sink and shower or marine sanitation device regulations were the most common violations. The major source of violations continues to be boats brought in from other states, especially those coming from the ocean. Under pressure from local marine dealers, most manufacturers modify boats destined for New Hampshire to comply with the state's no-discharge law (RSA 487:2).

The primary goal of the federal Clean Vessel Act (CVA) is to reduce overboard sewage discharge from boats by providing pumpout and dump stations for boaters to dispose of human waste in an environmentally safe manner. The CVA provides funds to states for the construction, renovation, operation and maintenance of pumpout and dump stations for pumping out waste from recreational boat holding tanks and emptying portable toilets.

Every year DES requests funds from the U.S. Fish and Wildlife Service for the installation of new pumpout systems and dump stations throughout the state and to operate the mobile pumpout boat service in coastal waters. Dump stations accept only portable toilet wastes, while a pumpout system removes wastes from fixed toilets. Although no new pumpout facilities were funded for the state's inland waters during 2007, an operation and maintenance grant was awarded to Lakeport Landing Marina on Paugus Bay. DES is pursuing a pumpout facility for Lake Sunapee, which is currently served by a dump station.

3.3.9 Lake Associations and Protection Groups

In addition to the efforts of federal, state, and local governments, several hundred lake and pond associations and watershed protection groups play an important role in monitoring, advocating for, and protecting lakes and ponds. These groups range from lakefront property owners associations to environmentally-oriented lake protective associations to the statewide New Hampshire Lakes

Association. Many of these organizations are active in public education, land conservation, volunteer monitoring, control of invasive species, and advocacy. Their contributions in these areas have been essential to the protection of state's lakes and ponds.

3.4 Stakeholder Recommendations

3.4.1 Improve Coordination of Water Quality Programs

New Hampshire's regulations regarding water quality are divided among various agencies, bureaus and programs. Communications are not always ideal, and during periods when significant development is taking place, water quality problems may develop. Recent revisions to the Alteration of Terrain regulations and the Comprehensive Shoreland Protection Act regulations (Chapter 10 – Stormwater) will help address some water quality threats, but do not go far enough to help all lakes, particularly those that are already developed. Since the water quality of lakes and ponds is significantly affected by land use in their watersheds and the associated road salt, phosphorus, and sediment loading, better coordination of state and local programs is needed to manage changing land use.

So far, efforts to reduce salt use have focused on specific areas, such as the portion of the Interstate 93 corridor targeted for expansion. A statewide approach to address the road salt issue is needed, although the issue presents difficult challenges. Salt (sodium chloride) is applied to roads and parking lots by the New Hampshire Department of Transportation, municipal agencies and private companies; therefore any successful management strategy would involve multiple stakeholders. Salt is a very cost-effective de-icing agent; approaches to minimizing its use generally focus on technology that enables more judicious application as well as on partially substituting other deicing chemicals.

3.4.2 Determine Carrying Capacity and Provide Adequate Public Access

Optimizing the use of surface waters, while minimizing the impacts to the resource and conflicts among users, is becoming an increasingly important issue in New Hampshire. While the N.H. Department of Fish and Game and other state agencies have developed and installed public access sites at lakes across the state, the recommendations of the 1991 Public Access Plan have not yet been met, nor has the mandate of the Lakes Management and Protection statute (RSA 483-A) to maintain consistency between carrying capacity and recreational lake use.

A Carrying Capacity subcommittee of the Lakes Management Advisory Committee (LMAC) and the Rivers Management Advisory Committee (RMAC) has been established in an effort to develop an approach to determine carrying capacity on New Hampshire's lakes. The subcommittee is presently working with N.H. Lakes Association; Joshua Carroll, UNH professor of Recreation Management and Policy; and Lori Siegel, ecological risk consultant, to review two methodologies to determine carrying capacity – the Water Recreation Opportunity Spectrum and System Dynamics, respectively. The subcommittee and its partners should be encouraged and supported in their efforts to test these two unique methodologies to determine whether they can be merged into a carrying capacity methodology for the state's lakes and ponds.

3.4.3 Continue New Initiatives to Prevent and Control Invasive Aquatic Species

With climate change and more recreationists using our water bodies, the expectation is that more infestations will occur and an expanded variety of exotic species will be introduced into our lakes and ponds. The state, working with organizations and individuals, will have to maintain and probably increase the existing level of effort to successfully combat invasive aquatic species. Recently implemented initiatives to control invasive aquatic species, specifically the Lake Host Program, long-term management plans, and physical harvesting techniques, show considerable promise and should be continued.

References

Gibbs, J.P., Halstead, J.M., Boyle, K.J., & Huang, J. (2002). An hedonic analysis of the effects of lake water clarity on New Hampshire lakefront properties. *Agricultural and Resource Economics Review*, *31*(1), 39-46. Available at: http://findarticles.com/p/articles/mi_qa4046/is_200204/ai_n9052911.

Lakes Management Advisory Committee and Rivers Management Advisory Committee. (2008). *The sustainability of New Hampshire's waters.* Available at: http://des.nh.gov/organization/divisions/water/wmb/rivers/rmac/documents/surface_water.pdf.

New Hampshire Department of Environmental Services (1996). *Lakes management criteria for New Hampshire state agencies* (NHDES-CO-96-2). Prepared by the Lakes Management and Protection Program and the New Hampshire Lakes Management and Advisory Committee. Available at: http://des.nh.gov/organization/commissioner/pip/publications/co/documents/nhdes-co96-2.pdf.

New Hampshire Department of Environmental Services. (1998). *Mercury in the environment* (fact sheet BB-21). Available at: http://des.nh.gov/organization/commissioner/pip/factsheets/bb/documents/bb-21.pdf.

New Hampshire Department of Environmental Services. (2003). *Lake or pond – What is the difference?* (Fact Sheet BB-49). Available at: http://des.nh.gov/organization/commissioner/pip/factsheets/bb/documents/bb-49.pdf.

New Hampshire Department of Environmental Services. (2005). *Report of the New Hampshire Exotic Aquatic Species Program 2004-2005* (R-WD-05-32). Prepared by A. P. Smagula, Exotic Species Coordinator, NHDES. Available at: http://des.nh.gov/organization/commissioner/pip/publications/wd/documents/r-wd-05-32.pdf.

New Hampshire Department of Environmental Services. (2007). *New Hampshire comprehensive lake inventory* (3rd ed.) (WD-07-31). Prepared by the Lakes Management and Protection Program and the New Hampshire Lakes Management and Advisory Committee. Available at: http://des.nh.gov/organization/commissioner/pip/publications/wd/documents/wd-07-31.pdf.

New Hampshire Department of Environmental Services. (2008a). *2008 Section 305(b) and 303(d) consolidated assessment and listing methodology* (NHDES-R-WD-08-2). Prepared by K. Edwardson, NHDES Watershed Bureau. Available at: http://des.nh.gov/organization/divisions/water/wmb/swqa/2008/documents/appendix_04_calm.pdf.

New Hampshire Department of Environmental Services. (2008b). *New Hampshire 2008 Section 305(b) and 303(d) surface water quality report and RSA 485-A:4.XIV report to the Governor and General Court* (R-WD-08-5). Prepared by G. Comstock and K. Edwardson, NHDES Watershed Management Bureau. Available at: http://des.nh.gov/organization/commissioner/pip/publications/wd/documents/r-wd-08-5.pdf.

New Hampshire Department of Environmental Services. (2008c). *The New Hampshire guidelines for coordinated lake management and shoreland protection plans* (NHDES-WD-08-8). Prepared by the Lakes Management and Protection Program and the New Hampshire Lakes Management and Advisory Committee. Available at: http://des.nh.gov/organization/commissioner/pip/publications/wd/documents/nhdes-wd-08-8.pdf.

New Hampshire Department of Environmental Services. (2008d). Watershed Management Bureau, Water Division, NHDES. Unpublished data.

New Hampshire Fish and Game Department. (2008). *Public-access boating and fishing sites in New Hampshire*. Retrieved October 17, 2008 from NHF&G Web site. http://www.wildlife.state.nh.us/Outdoor_Recreation/access_sites_table.htm.

New Hampshire Office of State Planning (Currently New Hampshire Office of Energy and Planning). (1991). *Public access plan for New Hampshire's lakes, ponds, and rivers.*

Nordstrom, A. (2007). *The economic impact of potential decline in New Hampshire water quality: The link between visitor perceptions, usage and spending.* Prepared for The New Hampshire Lakes, Rivers, Streams, and Ponds Partnership. Available at: http://www.nhlakes.org/docs/Surface-Waters-PhaseIV-Final-Report.pdf.

Shapiro, L. & Kroll, H. (2003). *Estimates of select economic values of New Hampshire lakes, rivers, streams and ponds: Phase II report.* Concord, N.H: Gallagher, Callahan & Gartrell, P.A. Available at: http://www.nhlakes.org/docs/EcoStudyPhaseII.pdf.

Society for the Protection of New Hampshire Forests. (2006). *105th annual report*. Concord, N.H.: Capitol Offset Company, Inc. Available at: http://www.spnhf.org/pdf/annual-report-fy06.pdf.

Swackhamer, D.L, Paerl, H.W., Eisenreich, S.J., Hurley, J., Hornbuckle, K.C., Mclachlan, M., Mount, D., Muir, D., & Schindler, D. (2004). Impacts of atmospheric pollution on aquatic ecosystems. *Issues in Ecology, 12*(summer), 1-24. Washington, D.C.: Ecological Society of America. Available at: http://epa.gov/owow/airdeposition/ESA_Air_Dep_Ecosystems.pdf.

Chapter 4
Groundwater

NEW HAMPSHIRE
DEPARTMENT OF
Environmental
Services

Overview

Groundwater in New Hampshire supplies water to 60 percent of the state's population. In addition, water stored beneath the ground surface replenishes rivers, lakes and wetlands during dry periods, ensuring healthy ecosystems and water for other uses. Groundwater in New Hampshire is both closely connected to surface waters and what occurs on the land surface (see Figure 1-17, the fold-out graphic). Landscape change can negatively impact groundwater quantity and quality if it is not conducted in a water-wise manner. More education is needed for citizens to better understand the occurrence and importance of groundwater. State and, particularly, local efforts to protect this resource are necessary to ensure a plentiful future supply of high quality groundwater. Because it is an unseen resource, ongoing routine monitoring of groundwater levels and quality is also critical to effectively protect this important resource.

4.1 Occurrence and Significance

4.1.1 Occurrence

Groundwater is a key component of the hydrologic cycle depicted in Figure 1-17 (the fold-out graphic) and described in Chapter 1 – Introduction and Overview. Groundwater is the water beneath the surface of the land. In New Hampshire groundwater resides within bedrock fractures and between particles of soil, sediment, and loose rock that lie on top of bedrock. The upper boundary of an underground area that is completely filled with water is called the "water table." The depth to the water table varies based on geology, elevation, precipitation trends, and the season, but it is typically 10 to 20 feet below the land surface in New Hampshire .

New Hampshire, the Granite State, is underlain with fractured crystalline bedrock. Groundwater is stored in and moves through these fractures as well as the unconsolidated material above the bedrock. This material was carried, deposited and shaped by glaciers that covered New Hampshire between 10 thousand and one million years ago.

The overburden material compressed beneath or carried within glaciers is called "glacial till." Glacial till consists of a mixture of materials ranging from clay to boulders and is often very dense. Due to their high density and mixture of particle sizes, these materials generally do not yield large quantities of water to wells. Glacial till underlies most of New Hampshire's landscape.

Some of the surficial materials left by the retreating glaciers were redistributed by glacial meltwater. These materials were transported away from the glacier ice front and deposited as "stratified drift" throughout the landscape. These deposits consist mainly of sand, silt, and gravel-sized particles. Depending on the velocity of the glacial meltwater, the stratified drift may contain very coarse materials such as gravel and cobbles. Saturated, coarser grain, stratified drift materials typically have a large percentage of pore space between the grains, which is very efficient at storing and transmitting ground water. Thus, saturated, stratified drift can yield large quantities of groundwater to wells. The thickness of stratified drift materials throughout the state is generally less than 100 feet. Stratified drift materials underlie approximately 14 percent of the state and are primarily located in lowlands and river valleys because glacial meltwater flowed through these topographic low areas (Medalie & Moore, 1995). Unsurprisingly, 79 percent of the high-capacity wells in New Hampshire are located in stratified-drift materials.

The crystalline bedrock, which can either be exposed or covered by till or stratified drift material, conveys groundwater within cracks (fractures) in the rock. Generally, a bedrock water supply well that is capable of supplying a single household can be developed anywhere in the state. Higher yielding bedrock wells also can be developed in most areas of the state, but identifying networks of fractures that can yield large quantities of water often requires the expertise of hydrogeologists and the use of sophisticated technology. Fractures that contain large quantities of groundwater are typically encountered within the first 400 feet of bedrock. Bedrock is often less fractured with increasing depth, but there are notable exceptions to this generalization.

An aquifer is an area of the subsurface that is water bearing. Accordingly, there are aquifers beneath virtually all of New Hampshire. The amount of space and the connection between spaces varies with the rock and soil type of the aquifer (Figure 4-1). This greatly influences how much water can be stored or withdrawn and the rate at which groundwater moves. The amount of water stored in the subsurface, ability of subsurface formations to transmit the flow of water, and the rate of groundwater recharge to the subsurface determine how much water a well in any aquifer can produce. Stratified drift aquifers left by the glaciers have been extensively mapped and categorized for their ability to transmit water, where as only a preliminary assessment of the more complex bedrock aquifers has occurred.

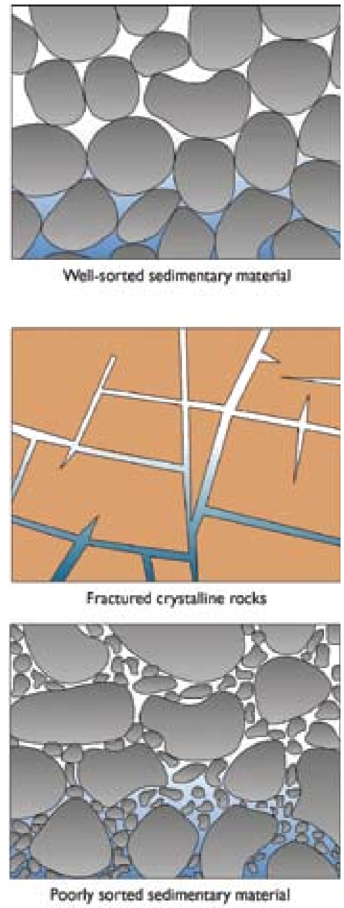


Figure 4-1. Well-sorted sediments and highly-fractured bedrock store some of the most accessible groundwater. Areas with these types of subsurface sediments or bedrock are valuable for water that is more easily withdrawn through wells. *Source: Colorado Geological Survey [CGS], 2003.*

Groundwater, like all water, flows downhill as it is pulled by gravity. Groundwater can also move from areas of higher pressure to areas of lower pressure. As water moves through the overburden and rock fractures towards lower elevations it can interact with rivers, wetlands, lakes, estuaries or the ocean (see Figure 1-17, the fold-out graphic). Generally, groundwater discharges to surface waters in New Hampshire, although under certain conditions, surface waters seep into the ground and replenish groundwater (see figure 4-4).

Groundwater is primarily recharged by precipitation. Unless low impact development techniques are used, the amount of precipitation that enters the ground to replenish groundwater can be significantly reduced as impervious cover increases (see Chapter 1 – Introduction and Overview and Chapter 10 – Stormwater). Groundwater recharge can also be diminished if the groundwater withdrawn from an area for domestic purposes leaves the area where it is used via a sewer line versus being discharged on-site to a septic system.

Aquifers receive the majority of recharge in the spring when the snowpack melts and the growing season is just beginning. Significant recharge also occurs in the fall when the growing season has ended. Less recharge occurs in winter and summer. During the summer a greater portion of rainwater that reaches the soil is taken up by plant roots, just when withdrawals increase for outdoor irrigation. Given the nature and timing of recharge and water use, groundwater levels generally decline from late spring to early fall. Levels typically recover from late fall through early spring. On average, the annual recharge rate for most New Hampshire watersheds is about 14 to 30 inches per year based on a USGS study (Flynn & Tasker, 2004).

In summary, groundwater in New Hampshire occurs in bedrock fractures and the unconsolidated materials left by glaciers. Water beneath the ground in New Hampshire is stored at relatively shallow depths and is well connected to surface waters and the land surface. The nature of New Hampshire aquifers differs significantly from many other parts of the country where aquifers are more uniform and much deeper. Unlike these places, the amount of water that can be stored in New Hampshire as groundwater is limited naturally by the state's climate and geology. Land use change also alters the occurrence of groundwater in the state. More information about the occurrence of groundwater in the environment can be found in Chapter 12 – Floods and Droughts.

4.1.2 Quality

Groundwater quality is influenced by the bedrock and overburden material it moves through. It also can be greatly influenced by land use.

There are a variety of naturally occurring contaminants found in New Hampshire's groundwater. Chapter 8 – Drinking Water describes naturally occurring drinking water contaminants in detail. Briefly, there are contaminants such as iron and manganese that can be bothersome in terms of staining and taste, and there are contaminants that pose a health risk. Radon and arsenic, in particular, are commonly found in groundwater in certain areas of New Hampshire. Fluoride, beryllium, and other radionuclides are much less common but do occur naturally at levels of concern for human consumption in a few places.

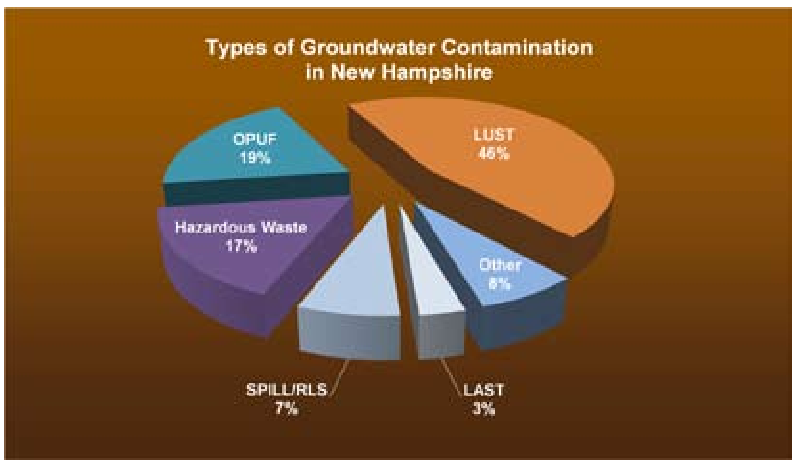


Figure 4-2. Types of manmade groundwater contamination sites that require remediation in New Hampshire. The leading cause of contamination are LUST (leaking underground storage tank) sites, followed by OPUF (on-premise heating oil tank) sites, hazardous waste sites, SPILL/RLS (oil spill or release) sites, other types of contamination, and LAST (aboveground bulk storage containing motor fuel) sites. ***Source: NHDES, 2008b.***

Groundwater quality has also been affected in many locations by land use. According to the New Hampshire Department of Environmental Services Groundwater Hazard Inventory, there are currently 6,939 sites where contaminants have been released to the ground. Of those, 2,294 have or at some time had levels of contamination that required remediation (Figure 4-2) (NHDES, 2008b). These sites are cleaned up and managed in accordance with state and federal remediation programs and the rate of new contaminated site occurrence has slowed significantly with the regulation of certain land uses. At most of the sites, groundwater was contaminated with petroleum constituents, which leaked or were spilled at underground or above-ground storage tank sites. Landfills and old or failed septic systems are other common land uses that have caused groundwater contamination. In addition, road salt and fertilizer have degraded groundwater in some places. For the most part, groundwater contamination at levels of concern for human consumption is limited to localized areas near where the release occurred. A notable exception to this is road salt, which is not a significant drinking water concern but can be a significant concern for surface water ecology when it is carried by groundwater to lakes and rivers and wetlands.

4.1.3 Significance

According to the DES Drinking Water and Groundwater Bureau, 3,000 individual wells and springs are registered as active public water supply sources. Approximately 2,400 wells (or 80 percent) yield water from crystalline bedrock aquifers while the other 600 (20 percent) yield water from stratified-drift aquifers. Although fewer public supplies draw water from stratified-drift aquifers, they tend to yield a higher quantity of water than wells withdrawing from bedrock aquifers (Medalie & Moore, 1995).

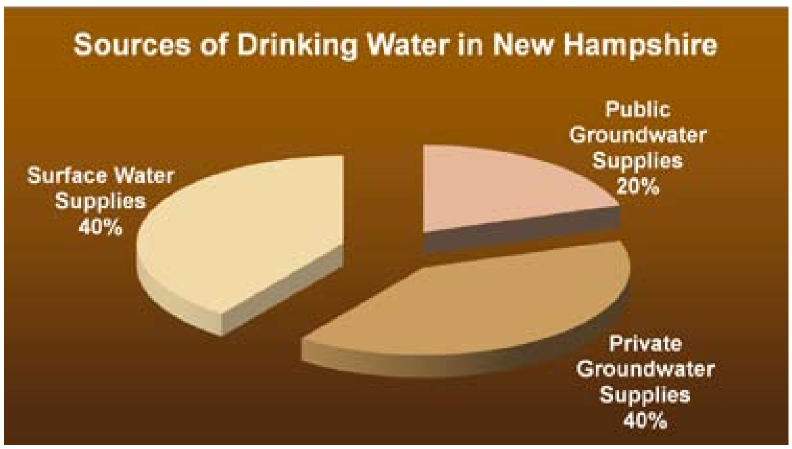


Figure 4-3. Groundwater is the main source of water for approximately 60 percent of New Hampshire's population. *Source: NHDES, 2007a.*

Approximately 60 percent of New Hampshire's population relies on groundwater for their drinking water supply (NHDES, 2007). While there has not been a study of the economic value of groundwater as a drinking water supply, there is a study that estimates the drinking water value of surface water at $151 million (Shapiro & Kroll, 2003). Because surface waters supply only 40 percent of New Hampshire's population with drinking water (Figure 4-3), the amount of groundwater used for drinking water should be in excess of this value. In addition to supplying drinking water, groundwater is also used for irrigation, aquaculture, thermoelectric cooling, and industrial processes. Geothermal wells are increasingly installed to provide heating and cooling for homes and commercial buildings.

Dependence on groundwater is not isolated to humans. Aquifers naturally supply water to streams and ponds where groundwater seeps through the banks and beds of surface water bodies. While most surface water bodies receive much of their water from other surface waters, e.g., streams that feed lakes and rivers, some depend solely on groundwater, e.g., kettle hole ponds. The water in many streams during dry-weather periods is from groundwater. This groundwater derived flow, called base flow, is critical to the sustenance of aquatic habitats as it provides stream flow during dry conditions. Because the average temperature of groundwater in New Hampshire is 55° F, some aquatic organisms, such as trout, depend on base flow to maintain the low water temperatures that can be essential for survival.

4.2 Issues

4.2.1 Groundwater – Unseen and Not Well Understood by Many

Because rivers, lakes, wetlands, and the coast are visible and provide recreation and scenic value, many people in New Hampshire recognize the benefits these surface waters hold for the economy and their own quality of life. However, they do not experience groundwater as directly as they might experience a stream or lake. For example, they may not recognize the significant role that groundwater plays in wetland, stream, and lake ecosystems through base flow (Figure 4-4). In the eyes of someone unaware of this role, it is more likely that the surface water effects of groundwater depletion will be perceived as an intrinsic problem with surface water, rather than associated with groundwater. Because of the invisibility of groundwater in the everyday experiences of New Hampshire residents, effective public education to raise awareness of the significance and issues affecting groundwater is needed.

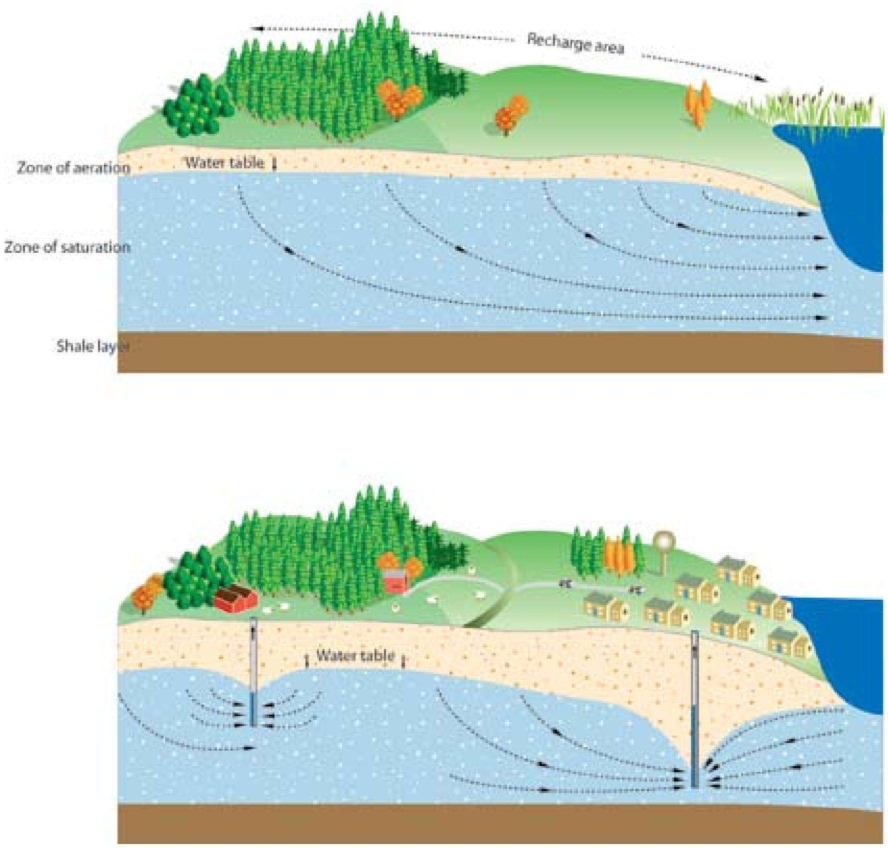


Figure 4-4. Wells withdrawing large volumes of water can have detrimental effects by depleting both groundwater and nearby surface waters. In this case, the well reverses the direction of base flow, in effect drying up local streams and possibly pulling surface water contaminants closer to the well. *Source: Ground Water Protection Council, 2007; Artwork by Poshen Wang.*

4.2.2 Landscape Change Affects Both Groundwater Quantity and Quality

Effect on Quantity

Land use changes pose some of New Hampshire's biggest challenges to groundwater management and protection. Increased development may be affecting long-term groundwater availability by preventing or reducing recharge after precipitation events. This is explained in detail in Chapter 1 – Introduction and Overview and Chapter 10 – Stormwater. Briefly, when land is developed, forest and farmland are converted to buildings, roads, parking lots and lawns. For each acre of impervious area that drains directly to surface water, approximately 250,000-550,000 gallons per year of recharge is lost. Impervious surfaces displace more groundwater than groundwater withdrawals in some areas of the state. Moderate to high rates of land conversion are now found throughout the southeastern third, if not half, of New Hampshire (Society for the Protection of New Hampshire Forests, 2005). Groundwater recharge could be significantly reduced if stormwater management is not designed properly in developing areas.

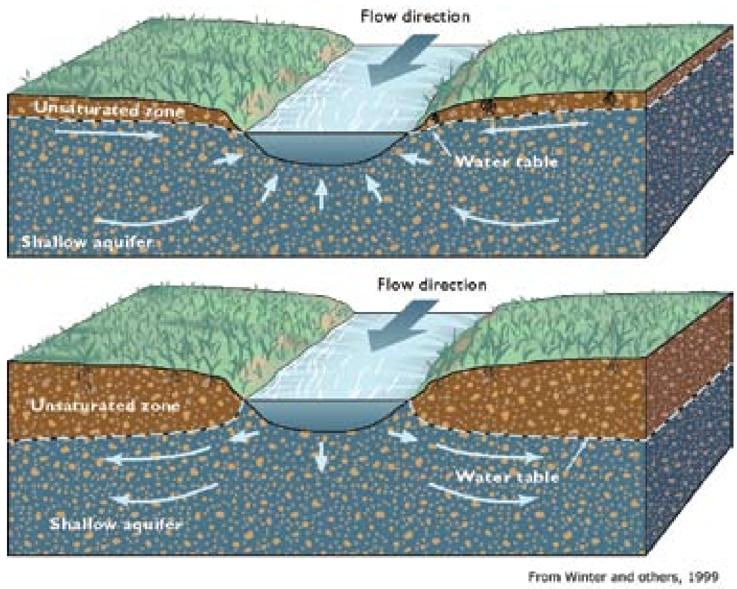


Figure 4-5. Groundwater is essential to providing water for the surface flows in streams and rivers through baseflow. If the water table (groundwater level) is lower than the surface water elevation, water from streams lose water to the ground. ***Source: CGS, 2003; Winter et al., 1998.***

The reduction in groundwater infiltration has had its greatest impact on shallow aquifers without large storage capacities. Wells drawing water from these aquifers rely heavily on infiltration and recharge to maintain sustainable yields. When impervious surfaces impact these shallow wells, they also can cause damage to surface waters that depend on base flow. Excessively low groundwater levels can reverse flow away from surface waters, in effect draining streams, ponds, and wetlands as gravity pulls water towards the voids left by depleted groundwater (Figure 4-5).

Effect on Quality and Well Siting

As previously described, many land uses have caused groundwater contamination, the most common include leaking underground storage tanks, mishandling of industrial solvents, and storage and use of road salt (NHDES, 2007a). In addition to impacting groundwater quality, some contaminants, including road salt and nutrients from fertilizers and septic systems, have been carried by groundwater into surface water and impaired water quality. An emerging concern is the presence of trace amounts of pharmaceuticals and personal care products originating from septic systems.

A significant number of potentially good well sites cannot be tapped because of encroaching development.

Surprisingly, relatively common land uses may be responsible for the loss of more future well sites than the land uses already mentioned. This is because stratified drift aquifers, where water can be extracted with the least chance of arsenic and radon, tend to be located in some of the most developed areas of the state where little space is left for potential future well sites. Because stratified-drift aquifers tend to

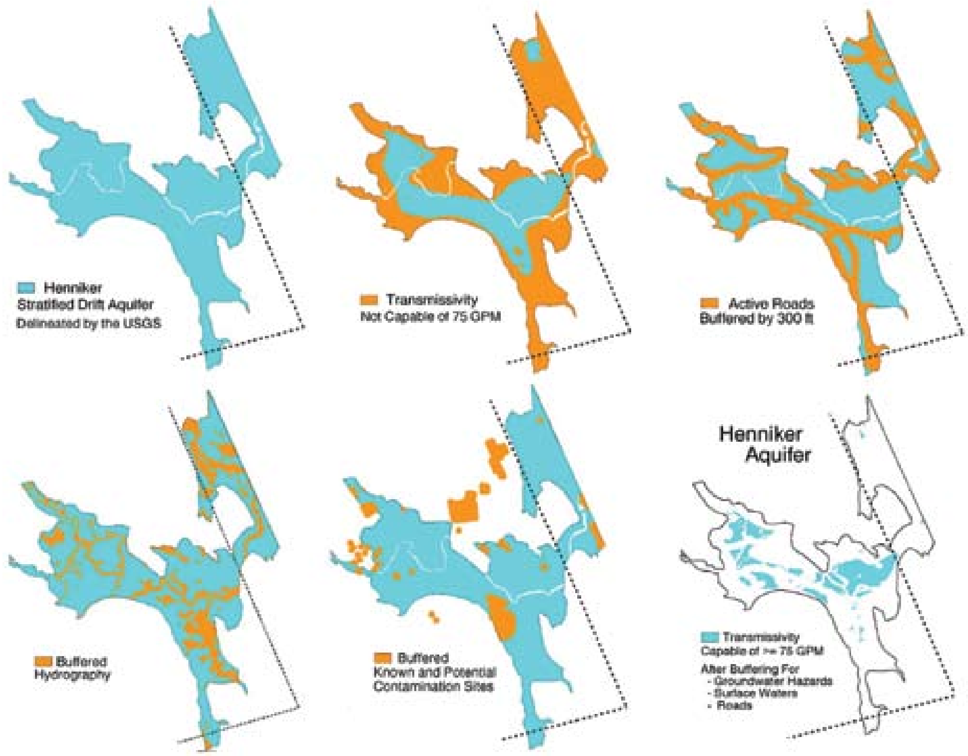


Figure 4-6. Although there are many high-yield, stratified-drift aquifers in New Hampshire, several factors can severely limit the actual areas of the aquifer that can be used for water supply. The above figures show loss of the Henniker Aquifer in New Hampshire due to low transmissivity (ease of water withdrawal), built roads, and necessary buffers for surface waters and potential contamination sites. *Source: Lough & Congalton, 2005.*

occur with rivers and flat land, they are often near a relatively high concentration of roads, villages and other development. Accordingly, the risk of groundwater quality impairment in these areas compromises their suitability as municipal well sites.

The extent to which land development drastically reduces the availability of future well sites was revealed by a statewide study published in 2005 (Lough and Congalton, 2005). The study included an analysis of constraints to the construction of new, large municipal wells (pumping 75 gallons or greater per minute) in New Hampshire's stratified-drift aquifers. Areas with restrictions or limitations to well construction, i.e., developed sites, potential contamination sources, limited yield, etc., were mapped within the state's high yield aquifers (Figure 4-6).

New community wells must be located at least 150 to 400 feet (depending on the yield of the well) from existing development. As a consequence, nearly two-thirds of the 328 square miles of high-yield stratified-drift aquifers in New Hampshire that have the potential to support wells yielding 75 gallons per minute or more are already unavailable as future well sites; not because of ownership, but because of nearby development. Predictably, the situation is worse in areas where water demand is likely to grow the most. Figure 4-7 shows the location of existing high-yield stratified-drift wells and all 1,245 square miles of New Hamsphire's stratified-drift aquifers (Lough & Congalton, 2005).

4.2.3 Data Limits Groundwater Protection Efforts

Key data needed to understand and effectively manage the groundwater resource include a robust groundwater level monitoring network, sufficient stream flow gaging, and a water quality network to identify areas of man-made and naturally occurring contamination. Some limited data is available but more is needed if we are going to be able to understand and address issues related to groundwater withdrawals, reduced recharge associated with landscape change and climate change (see Chapter 1 – Introduction and Overview), and impaired groundwater flowing to wells and surface waters.

The following describes important information the state currently has about the groundwater resource and identifies the current limitations.

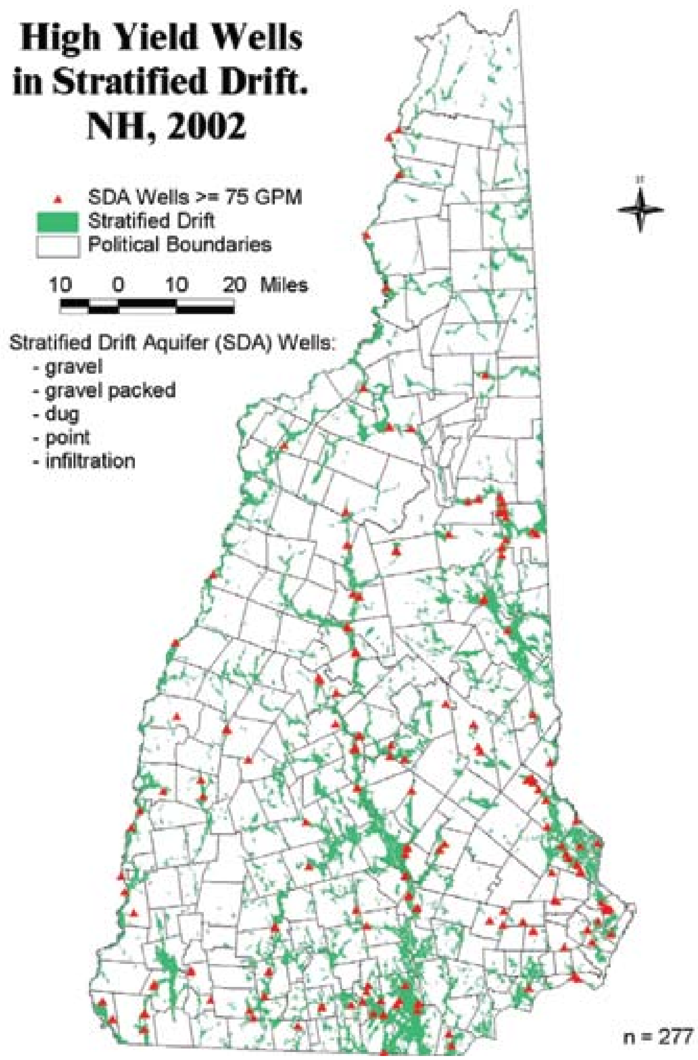


Figure 4-7. New Hampshire's stratified-drift aquifers provide water supplies scattered all over the state. Locations where high-yield wells can be installed, however, are limited. *Source: Lough & Congalton, 2005.*

Groundwater and Stream Flow Monitoring

The monitoring of statewide groundwater levels currently relies on a network of 25 observation wells located at 22 sites throughout the state. Groundwater levels are measured every month on a year-round basis by staff from the New Hampshire Geological Survey at DES. Each well serves as an indicator of regional hydrologic conditions, registering changes in the amount of water stored in the aquifer it represents. If this network were expanded to include more aquifer types throughout the state, it could be used to compare conditions today with those existing at some time in the past or to predict future conditions, helping to inform management decisions. A modest expansion to monitor bedrock at existing sites is underway. In 2007 DES also began groundwater level monitoring at Hubbard Brook Experimental Forest, where numerous other hydrological and environmental indicator data are also being collected as part of the U.S. Forest Service research initiative. In addition to groundwater levels, more stream gaging is necessary to understand the interconnection between groundwater and surface water. In particular, the effect of changes in groundwater levels on the amount of baseflow to small streams is hard to predict since most measured surface water flow data have been collected on rivers that have large, i.e., greater than 50 square miles, drainage areas (see also Chapter 2 – Rivers).

Water Well Board and Well Completion Reports

In 1984 the state of New Hampshire established the Water Well Board and began licensing water well contractors and water well pump installers and requiring the submission of a well completion report for every new water supply well constructed. The well completion reports include information on the total depth of the well, the depth to bedrock, the static water level, and the measured yield. Well records are important for mapping the geology of the state, defining aquifers, and determining the distribution of well yields. They also help well owners with making repairs or improvements to wells. Recently, more accurate data on well location, use, and geologic conditions are required, which will improve the utility of the well information.

Water Quality Data

A great deal of water quality information is currently collected for public water systems under the federal Safe Drinking Water Act. For systems using untreated water from wells, this provides groundwater quality information. Although there is no clear federal or state jurisdiction over testing of private wells, DES has developed a recommended testing schedule for homeowners and many homeowners turn to DES and commercial laboratories for analysis of samples from private wells. While the private well data resulting from these tests are confidential, regional summaries of these data, together with public water supply water quality data, can help scientists understand the condition of New Hampshire's groundwater. Similarly, data collected at waste sites statewide could be mined to provide information on groundwater in some areas of the state.

4.3 Current Management and Protection

Groundwater is a valuable resource for drinking water supply, so some of the relevant regulations and management efforts are outlined in Chapter 7 – Water Use and Conservation and Chapter 8 – Drinking Water. There are also siting criteria for many types of potential contamination sources that are regulated at the local and state levels. Only a few of the most direct programs for groundwater protection are described below.

4.3.1 Quality-Based Regulations and Programs

Source Water Protection Program

The Drinking Water Source Protection Program provides regulatory and non-regulatory tools to protect groundwater and both new and existing sources of public drinking water. The program, within DES's Drinking Water and Groundwater Bureau, provides technical and financial assistance, training, and guidance materials to water suppliers, municipalities, and others regarding all aspects of preventing groundwater contamination. The SWP Program is revising its Source Water Protection Strategy in cooperation with the SB 155 Groundwater Commission and other stakeholders, and plans to have the new strategy complete by spring 2009.

Municipal Groundwater Protection Ordinances

Recognizing that some groundwater resources are highly vulnerable to contamination, or of very high value, or both, and that state siting restrictions for certain high-risk land uses are not sufficient by themselves to protect these resources, many New Hampshire municipalities have adopted groundwater protection ordinances. Most of these ordinances involve land use restrictions over high-yielding stratified-drift aquifers, and have been adopted since the state's aquifers were first mapped in the 1970s and 1980s. Many have been revised over time to reflect more current stratified drift aquifer maps. At least 75 New Hampshire municipalities now have groundwater protection ordinances, 70 of which restrict land uses to protect stratified-drift aquifers, public water supply wells, or both. DES and the New Hampshire Office of Energy and Planning have collaborated on a model groundwater protection ordinance, which has been adopted by approximately 21 of those municipalities (NHDES & NHOEP, 2006).

Groundwater Discharge Permitting and Registration Program

The DES Groundwater Discharge Permitting and Registration Program promotes proper treatment and disposal of wastewater onto or into the ground and implements federal regulations pertaining to underground disposal of non-hazardous fluids other than domestic wastewater, i.e., Class V underground injection wells under the federal Safe Drinking Water Act. The purpose of the program is to prevent and eliminate groundwater contamination that is caused by the improper disposal of waste and wastewater containing solvents, petroleum products, and other industrial and commercial wastes. Any discharge of non-domestic wastewater containing regulated substances requires a groundwater discharge permit and the best available treatment technology, and must meet ambient groundwater quality standards at the boundary of the groundwater discharge zone. Any discharge of domestic wastewater that exceeds 20,000 gallons per day requires a groundwater discharge permit. A discharge of a non-domestic wastewater that does not contain a regulated substance must be registered.

Groundwater Remediation Programs

There are a number of state and federal programs that require the cleanup or containment of contaminated groundwater. These include the Superfund, Leaking Underground Storage Tanks, and Hazardous Waste Cleanup programs. These programs aim to return impaired groundwater to a clean and usable condition.

4.3.2 Quantity-Based Regulations and Programs

Large Groundwater Withdrawal Permitting

In 1998 two state laws, the Groundwater Protection Act and the Safe Drinking Water Act, were amended to ensure that undesirable impacts to water users and water resources from new large groundwater withdrawals are identified and addressed. Any groundwater withdrawal from a new well having a maximum withdrawal of 57,600 gallons or more over any 24-hour period is considered to be a large groundwater withdrawal. New large groundwater withdrawals undergo a comprehensive analysis and testing program in order to study the possible impacts of the withdrawal. New large withdrawals cannot be approved unless it is demonstrated that no unmitigated adverse impacts will occur.

Rewrite of the Alteration of Terrain Rules

The new Alteration of Terrain rules (effective January 1, 2009) represent an important shift in policy for stormwater management at new medium and large developments. While engineered stormwater infiltration structures are discouraged under the old rules, the new rules require infiltration of a prescribed volume of stormwater. This will help to achieve better treatment and minimize alterations to the natural hydrology. The rules also include requirements for well setbacks, stormwater pretreatment, and prohibitions on infiltrating stormwater from certain sites to help avoid the possible contamination of groundwater.

Groundwater Commission

The Groundwater Commission was created in 2003, pursuant to Senate Bill 155, in response to concerns regarding New Hampshire's laws and regulations for groundwater withdrawals. The commission has been extended twice with a current expiration date of 2010. It is comprised of 21 stakeholders including legislators, regulators, water users, environmental advocates and citizens. The purpose of the commission is to find ways to clarify the hierarchy of water uses, bring a balanced approach to water use amongst various sectors (residential, public, industrial, commercial, agricultural, energy, recreational), and improve the current process for the reasonable and efficient use of new water sources (Figure 4-8). The commission's work and accomplishments are summarized each year in an annual report (Commission to Study Issues Relative to Groundwater Withdrawals, 2007).

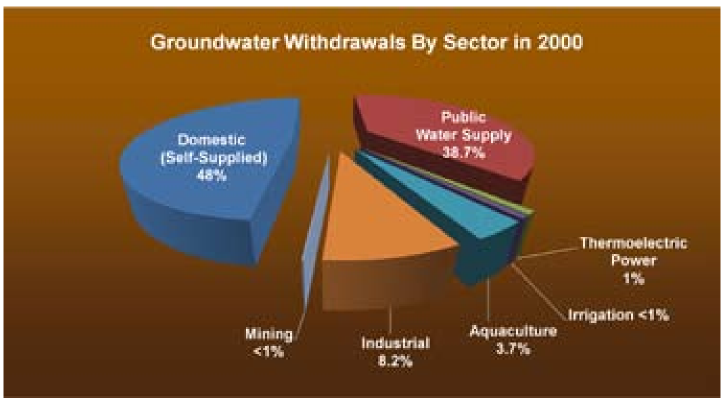


Figure 4-8. While domestic and public water supplies are the most common uses of groundwater, wells withdraw water for several other purposes in New Hampshire. ***Source Data: Hutson et al., 2004.***

Expanded Groundwater Level Monitoring Initiative

Work is currently underway to develop a bedrock aquifer monitoring network. At present, only one of the wells in the state's limited groundwater level monitoring network monitors groundwater conditions in bedrock (Figure 4-9). Resources have been obtained to expand this to 10 wells. Wells in the Seacoast Region will be especially important for monitoring the level of salt water near inland aquifers. Maintaining a long-term water level monitoring network will require dedicated funding sources. Options for funding sources are currently being identified and assessed by the Groundwater Commission.

Seacoast Groundwater Availability Assessment

Concerns about landscape development driven by economic and population growth in the Seacoast Region of the state and increasing reliance on groundwater withdrawals spurred an intense study on water use and the hydrogeology of the Seacoast Region. The study included the development of the following information for 42 seacoast communities (NHDES, 2008a).

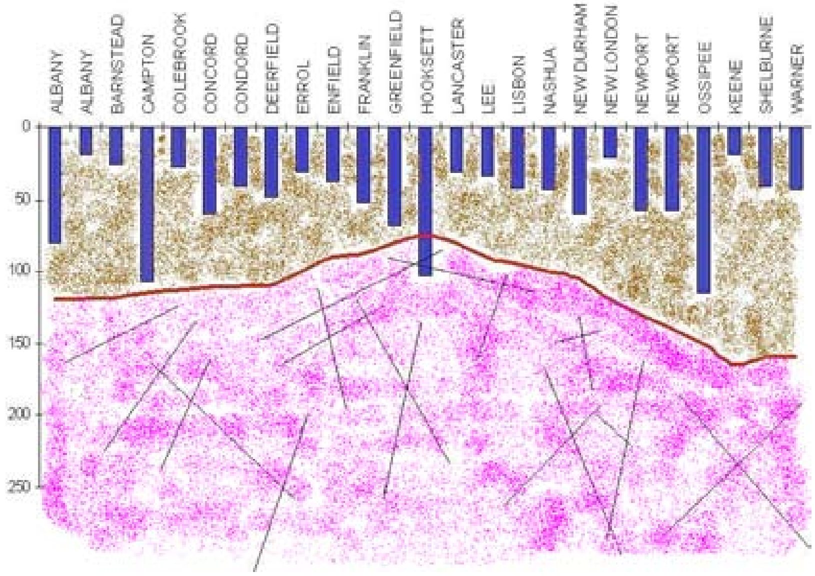


Figure 4-9. Only one of the 22 wells in the state's groundwater level monitoring network is a bedrock well. ***Source: Modified from Wunsch, 2006.***

- Updated seamless map of the surficial geology that can be used to assist in refining the location of aquifers.
- Estimate of water use for 2003 and projected water use (withdrawals, transfers, and discharges) for 2017 and 2025.
- A database linked to a Geographic Information System that provides records of wells and soil borings that have been installed in the region over the last several decades. This information can be used to provide information such as depth to bedrock, aquifer properties, and water level information to support projects and studies throughout the region.
- A map showing potential high and low recharge areas that can be used with supplemental data to assist with ensuring groundwater recharge is preserved as land development and land conservation decisions are made.

As part of the project, a groundwater model is being developed for the area of the Seacoast surrounding Great Bay and adjacent to the ocean. The model will assesses various scenarios including the impacts of climate change, increased groundwater withdrawals, establishment of more impervious surfaces and various wastewater disposal management options. The impacts to river flow, groundwater elevations and the salt water/freshwater interface will all be assessed as part of the model.

Artificial Recharge Guidance

Where existing sources are inadequate to meet growing demand or where yields are limited due to reduced recharge, artificial recharge is likely to be viewed as an option to increase or maintain well yield. The town of Newmarket, for example, recently completed the permitting process that will enable the town to discharge raw river water on the land surface to recharge the Newmarket Plains aquifer. The city of Dover has used a similar artificial recharge system to supplement its water supply for 20 years. In Dover, during the months between November and May when the river water levels are at their highest, water is pumped to a gravel pit and the water then infiltrates into the aquifer, increasing the available storage for use in the high demand summer months. Prompted by the Newmarket proposal, DES has developed guidance documents for artificially recharging aquifers and for discharging treated wastewater to land surfaces for infiltration or irrigation purposes (NHDES, 2006; NHDES 2007b). While artificial recharge projects are driven by quantity concerns, DES's review of such projects typically focuses on groundwater quality concerns.

4.4 Stakeholder Recommendations

This section contains key recommendations that have been developed in concert with a group of volunteer stakeholders that have reviewed and contributed to this chapter.

4.4.1 Improved Monitoring to Support Protection

In order to understand the impacts of land use change, water withdrawals, and climate change, more data on both groundwater levels and surface water resources are needed. Recent studies such as the seacoast groundwater availability assessment and the in-stream flow studies for the Lamprey and Souhegan rivers (see Chapter 2 - Rivers and Streams, Section 2.3.4) have helped set a stage for sustainable management, but such studies are expensive and limited in their geographic scope. As undeveloped groundwater resources available for water supply become increasingly scarce, this information will be crucial for planning in the future. Although groundwater is the supporting base for many surface water resources, its lack of visibility makes trends impossible to perceive without a more consistent and extensive monitoring network. More water level monitoring is required statewide in order to determine historical and current trends and to project changes in the future. Associating the effects of land use, water use, and altered hydrology with certain changes evident in groundwater or the intrinsically linked surface waters will help us predict and avoid future, detrimental impacts to New Hampshire's water resources.

4.4.2 Increased Municipal Land Use Controls to Protect Groundwater Quality and Quantity

Land use decisions, which are largely under the control of local planning and zoning boards, are critical in either protecting groundwater or placing it at risk for contamination or depletion. The protection of groundwater resources, therefore, depends on the ability of planning and zoning boards to make well-informed decisions that balance groundwater protection goals with other local goals such as economic development. In some areas, regional approaches involving multiple communities may be the best option for effective groundwater protection.

Simply restricting development is not always the most feasible or advantageous solution because of existing land uses, competing economic development goals, or other community goals that are inconsistent with stringent land use restrictions. Local land use boards need to consider the full range of approaches to protecting groundwater, from land conservation and land use restrictions (zoning) to better site and facility design and management. Consideration of low impact development techniques explained in Chapter 10 – Stormwater is also needed.

The tension between groundwater protection and economic development goals is particularly acute, for example, where transportation corridors or valuable sand and gravel deposits coincide with valley-bottom stratified-drift aquifer deposits. In such situations, local land use boards need access to expert assistance in order to understand the resources at risk, the nature of the hazards posed by certain land uses, and the range of approaches available to address those hazards. Only then can communities responsibly weigh resource protection alternatives against other community needs.

While the needed expertise and training are available from DES, regional planning commissions, and consultants, the available resources fall short in some respects. For example, while wellhead protection areas and stratified-drift aquifers have been mapped statewide, the accuracy of the mapping is not sufficient in many areas for communities to use on a stand-alone basis to define areas subject to land use restrictions. An increasing number of communities recognize the need to refine this mapping, but the resources are not available on either the local or state level to conduct the required work. While municipalities have the ability to incorporate provisions in their ordinances to shift the costs of such work to development proponents, they are often reluctant to do so.

At the same time, the effectiveness of groundwater protection measures enacted in some communities is compromised when they are not consistently applied, such as when local zoning boards grant variances to land use restrictions. While the solution to this problem is not quite clear, municipalities would probably do well to ensure that their groundwater protection programs are carefully crafted, frequently reviewed and updated, consistently applied, and well understood by officials as well as the public.

4.4.3 Increased Public Education and Awareness

Increased public education and awareness regarding groundwater is needed in several areas. First, improved public awareness of groundwater would enable citizens to make better informed decisions regarding the protection and management of groundwater on the community level.

Second, improved awareness would enable residents to make more responsible decisions regarding their own use and handling of hazardous substances and other potential pollutants. This would help ensure proper storage, use, and disposal of household chemicals and other pollutants with the potential to contaminate groundwater.

Finally, because the quality of water supplied by private wells is not monitored or regulated by state programs and few municipalities require testing prior to occupancy or real estate transfer, the responsibility for testing and monitoring lies solely in the hands of the water user. Improved awareness of private well issues would enable private well users to make better informed decisions about testing and treating their water supply.

Hazardous Materials in the Home

- Gasoline
- Motor Oil
- Other Automotive Fluids
- Auto Batteries
- Paint
- Paint Thinner
- Other Solvents
- Pesticides
- Cleaning Products
- Herbicides

References

Commission to Study Issues Relative to Groundwater Withdrawals. (2007). *2007 SB155 Groundwater Commission interim report.* State of New Hampshire. Available at: http://www.gencourt.state.nh.us/statstudcomm/committees/1723/.

Colorado Geological Survey. (2003). *Ground water atlas of Colorado* (Special Publication 53). Denver Colo., CGS, Division of Minerals and Geology, Department of Natural Resources. Available at: http://geosurvey.state.co.us/wateratlas/index.asp.

Flynn, R.H. & Tasker, G.D. (2004). *Generalized estimates from streamflow data of annual and seasonal groundwater recharge rates for drainage basins in New Hampshire* (Scientific Investigations Report 2004-5019). U.S. Geological Survey. Available at: http://pubs.usgs.gov/sir/2004/5019/.

Ground Water Protection Council. (2007). *Ground water report to the nation: A call to action.* Oklahoma City, Okla. Available at: http://www.gwpc.org/calltoaction/

Hutson, S.S., Barber, N.L., Kenny, J.F., Linsey, K.S., Lumia, D.S., & Maupin, M.A. (2004). *Estimated use of water in the United States in 2000* (U.S. Geological Survey Circular 1268). Released March 2004, revised April 2004, May 2004, February 2005. Available at: http://pubs.usgs.gov/circ/2004/circ1268/.

Lough, J.A. & Congalton, R. (2005, September 26-27). *An assessment of the state of high yield stratified-drift aquifers in New Hampshire*. Abstract presented at National Groundwater Association Focus Conference on Eastern Regional Groundwater, Portland, Maine.

Medalie, L. & Moore, R.B. (1995). *Ground-water resources in New Hampshire: Stratified-drift aquifers* (U.S. Geological Survey Water-Resources Investigations Report 95-4100). Available at: http://pubs.usgs.gov/wri/wrir_95-4100/html/pdf.html.

New Hampshire Department of Environmental Services. (2006). Groundwater discharge permitting guidance document for recharging aquifers with reclaimed wastewater (WD-05-31). Drinking Water and Groundwater Bureau, NHDES. Available at: http://des.nh.gov/organization/commissioner/pip/publications/wd/documents/wd-05-31.pdf.

New Hampshire Department of Environmental Services. (2007a). The DES guide to groundwater protection (WD-07-29). Available at: http://des.nh.gov/organization/commissioner/pip/publications/wd/documents/wd-07-29.pdf.

New Hampshire Department of Environmental Services. (2007b). Guidelines for developing an artificial recharge project. Drinking Water and Groundwater Bureau, NHDES.

New Hampshire Department of Environmental Services. (2008a). Seacoast Groundwater Availability Project. Retrieved December 10, 2008 from NHDES Web site. Available at: http://des.nh.gov/organization/divisions/water/wmb/coastal/restoration/groundwater.htm.

New Hampshire Department of Environmental Services (2008b). Waste Management Division. Unpublished data.

New Hampshire Department of Environmental Services & New Hampshire Office of Energy and Planning. (2006). Model groundwater protection ordinance (WD-06-41). Available at: http://des.nh.gov/organization/commissioner/pip/publications/wd/documents/wd-06-41.pdf.

Shapiro, L. & Kroll, H. (2003). *Estimates of select economic values of New Hampshire lakes, rivers, streams and ponds: Phase II report.* Concord, N.H.: Gallagher, Callahan & Gartrell, P.A. Available at: http://www.nhlakes.org/docs/EcoStudyPhaseII.pdf.

Society for the Protection of New Hampshire Forests. (2005). *New Hampshire's changing landscape 2005: Population growth and land use changes: What they mean for the Granite State*. Concord, N.H. Available at: http://www.spnhf.org/research/research-projects.asp.

Winter, T.C., Harvey, J.W., Franke, O.L., & Alley, W.M. (1998). *Ground water and surface water: A single resource* (U.S. Geological Survey Circular 1139). Available at: http://pubs.usgs.gov/circ/circ1139/.

Wunsch, D.R. (2006, May 7-11). *Developing a ground-water monitoring strategy for half the cost – literally* (abs.). Proceedings, 5th National Monitoring Conference, National Water Quality Monitoring Council, San Jose, Calif.

Chapter 5
Wetlands

NEW HAMPSHIRE
DEPARTMENT OF
Environmental
Services

Overview

New Hampshire's tidal and nontidal wetlands are of great importance for flood control, water filtration, water storage and recharge for both groundwater and surface water. These functions become more valuable with the expected increase in occurrence and severity of storm events associated with climate change (see Chapter 1 – Introduction and Overview). Wetlands also support the food chain, providing food and shelter for a variety of aquatic and upland plants and animals. Although New Hampshire has lost fewer wetlands to filling and dredging than many coastal states, landscape change poses a significant challenge to the protection of New Hampshire's wetlands.

5.1 Occurrence and Significance

5.1.1 Wetlands Occurrence

New Hampshire wetlands share three characteristics: 1) standing water or water at or near the ground surface during some portion of the growing season; 2) soils with characteristics that show they are saturated some of the time; and 3) plants adapted to growing in saturated soils. There is tremendous diversity in the types of wetlands found in the state. Tidal marshes and mud flats, freshwater red maple swamps, bogs, vernal pools, Atlantic white cedar swamps and wet meadows are all wetland types found in New Hampshire (Figure 5-1).

New Hampshire's glacial history is responsible for the occurrence of most of its wetlands. Glaciers carved out basins in rock and sediments, creating depressions and depositing fine material that restricts the drainage of water. The buildup of organic and fine sediments over time created various types of wetlands. Wetlands also form at the edges of rivers, lakes and streams where sediments and organic materials deposit to create shallows with abundant plant growth.

The estimated acreage of wetlands in New Hampshire ranges between 290,000 acres, estimated from the National Wetlands Inventory (NWI) of the U.S. Fish and Wildlife Service (USFWS), and 576,386 acres, estimated from soil surveys by the Natural Resource Conservation Service (NRCS) of the U.S. Department of Agriculture (Tiner, 2007). Accordingly, wetlands occupy between 5 percent and 10 percent of New Hampshire's landscape. An analysis of aerial photography by the New Hampshire Department of Environmental Services indicates that there are approximately 7,500 acres of tidal wetlands, with the vast majority of New Hampshire's wetlands being nontidal. (NHDES, 2002).

According to a study done in 1990 of wetland losses in the United States, New Hampshire had lost 9 percent of freshwater wetlands statewide (Dahl,1990). A more recent 2004 analysis suggests that about 10 percent of nontidal wetlands have been filled or drained for roads, residential development and industrial development (NHDES, 2004). Further, about one-quarter of the state's tidal wetlands have been lost, and conversion of tidal wetlands to freshwater wetlands by tidal restriction appears to be a major concern (Odell et al; 2006). In addition to direct losses, the quality of

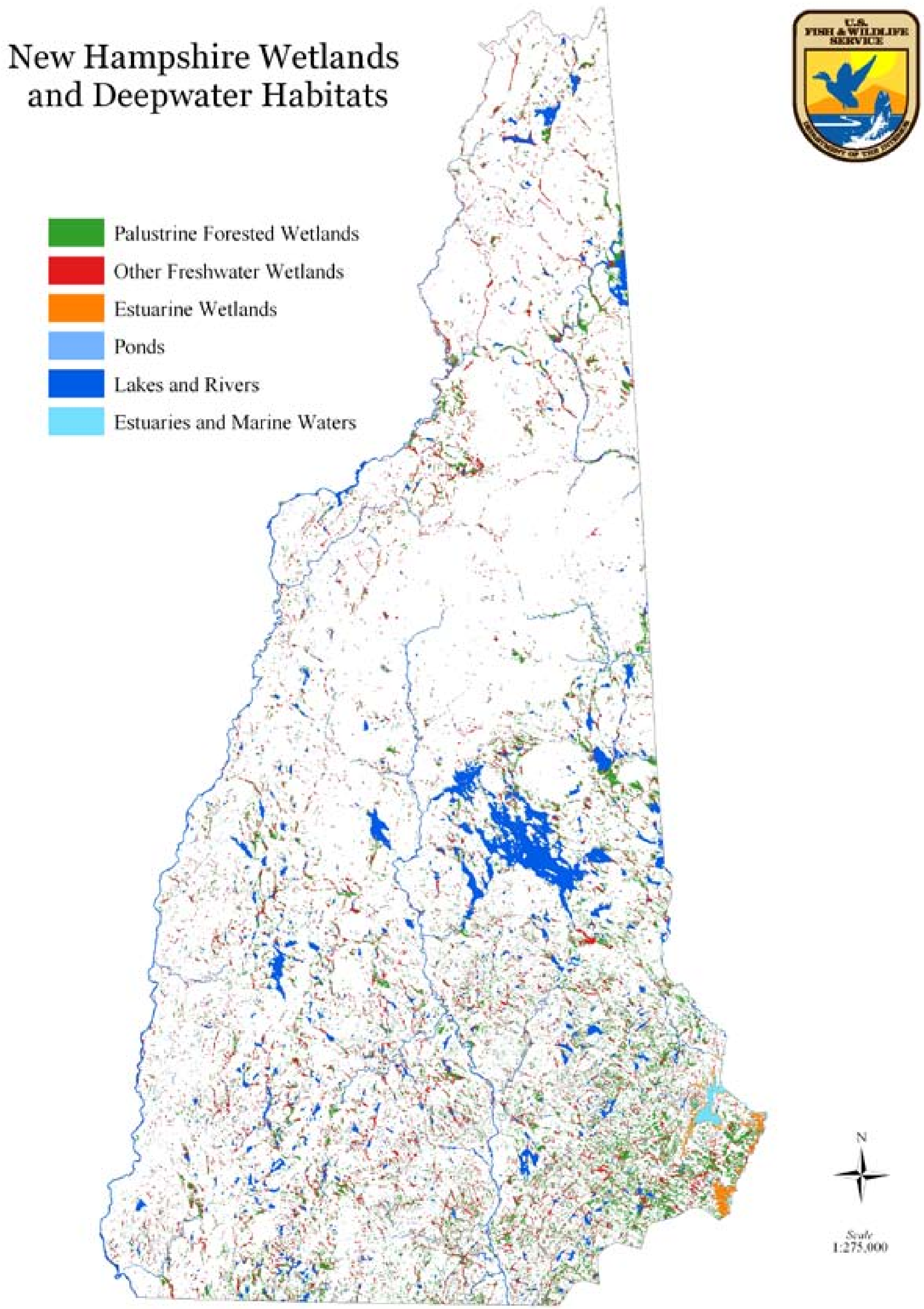


Figure 5-1. New Hampshire wetlands and deepwater habitats mapped by the National Wetlands Inventory. ***Source: Tiner, 2007.***

wetlands can be significantly affected by land use change in upland areas. No quantification of these impacts is available.

5.1.2 Wetlands Significance

Wetlands are an important component of the hydrologic cycle described in Chapter 1 – Introduction and Overview. Although not all wetlands are created equal and the functions and values of wetlands vary significantly, there are some key values attributed to wetlands including flood control, water purification, water storage and recharge to both surface and ground waters, and ecosystem protection. These values, as well as the economic value of wetlands, are outlined in Figure 5-2 and discussed below:

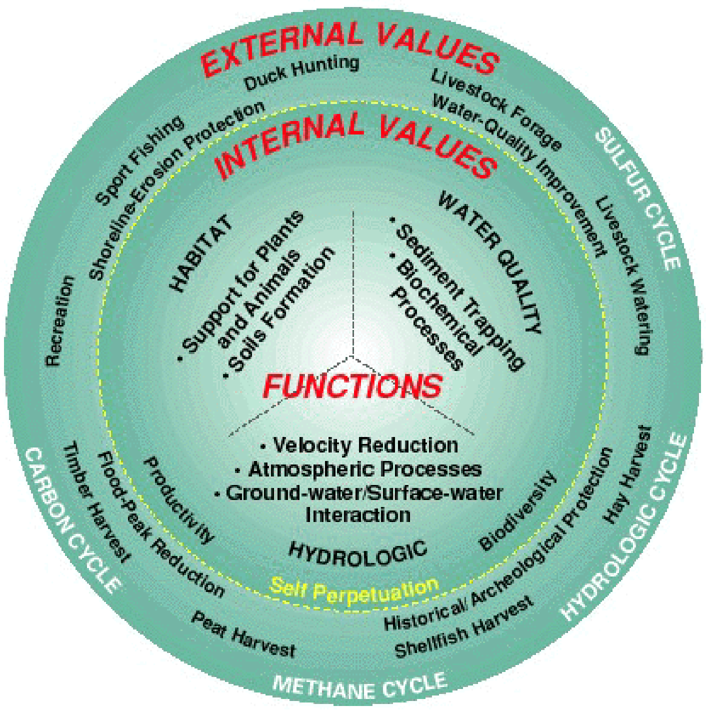


Figure 5-2. Values and functions of wetlands.
Source: Novitski et al., 1997.

Flood Control

A floodplain is flat or nearly flat land adjacent to a stream or river that experiences occasional or periodic flooding (Figure 5-3). It includes the floodway, which consists of the stream channel and adjacent areas that carry flood flows, and the flood fringe, which are areas covered by the flood, but which do not experience a strong current. Floodplains perform important natural functions, including temporary storage of floodwaters, moderation of peak flows, maintenance of water quality, groundwater recharge, and prevention of erosion. Seasonal flooding also maintains biological and physical diversity. The ability to reduce the peak level of floods and delay the flood crest is one of the most widely recognized functions of inland wetlands (Carter et al., 1979; Novitzki, 1979; Tiner, 1984). This function is accomplished chiefly through storage of surface water in wetland basins after snowmelt and major precipitation events, and the reduction in flood flow velocities as water passes through wetland vegetation and over the soil surface. According to the Environmental Protection Agency, an acre of wetland can store 1 million to 1.5 million gallons of floodwater (National Association of Counties [NACO], 2006). This value is of increasing importance given the impacts of landscape change and climate change described in Chapter 1 – Introduction and Overview.

Water Filtration

Many types of wetlands retain, remove, and transform nutrients and contaminants, thus improving the quality of surface water (Golet et al., 1993). Dense wetland vegetation provides friction, slowing down stream and river flows causing sediments to settle out of the water. The EPA notes that as much as 80 percent to 90 percent of sediments in the water column may be removed as they move through wetlands (Madison & Paly, 1994). While excess sediment itself can cause environmental degradation, the reduction of sediment also results in a reduction of sediment-bound pollutants and nutrients, such as heavy metals and phosphorus. Wetland plants also take up nitrogen and phosphorus, decreasing the likelihood of water quality problems downstream. Wetlands host a diverse community of microorganisms that further natural water treatment by transforming nutrients, such as nitrogen and even toxic substances, into less problematic forms. The increased pollutant loadings associated with landscape change and stormwater runoff described in Chapter 1 – Introduction and Overview and Chapter 10 – Stormwater make this function of wetlands particularly important.

Figure 5-3. Floodplain forest along the Merrimack River in Concord. ***Source: NHDES Wetlands Bureau.***

Water Storage and Recharge to Surface Water and Groundwater

As described previously, many wetlands can store a tremendous amount of water. Water moves slowly through wetland soils and vegetation and provides gradual, purified recharge to connected surface waters and groundwater. This function is of particular importance in times of drought as it maintains stream flows and groundwater levels when precipitation is below normal.

Figure 5-4. Example of a vernal pool. ***Source: NHDES Wetlands Bureau.***

Wildlife Habitat and Aquatic Nurseries

Wetlands are essential for a wide variety of plants and animals. They provide birds, mammals, reptiles, amphibians, fish, insects and plants with food, water and shelter, including animal breeding or nesting habitat. Approximately 66 percent of New Hampshire's species of greatest conservation concern are wetland- or surface water-dependent (NHF&G, 2006). More specifically, the state has 34 rare wetland-dependent species, e.g., bald eagle, Atlantic sturgeon, including 24 animals and 10 plants (Clean Water Network

[CWN], 2002). These and other wetland-dependent species need both wetlands and natural upland areas to survive. Many species that inhabit uplands for most of the year depend on wetlands for seasonal breeding habitat. In particular, many amphibian species depend on seasonally flooded vernal pools to provide essential breeding areas but live in upland areas the remainder of the year (Figure 5-4). Additionally, some species that spend their entire lives in upland areas depend on a food source that is wetland-dependent. Hognose snakes, for example, primarily eat toads that require wetlands for their early development.

Wetlands are of particular importance for New Hampshire's fish and shellfish populations. As previously noted, wetlands help maintain consistent stream flows during floods and droughts. By helping to moderate or sustain stream flows, wetlands help prevent habitat degradation and the associated invasion of exotic species. According to USFWS, all wetlands that maintain stream flow should be considered vital to sustaining a watershed's ability to provide in-stream fish and shellfish habitat, regardless of whether those wetlands provide significant habitat themselves (Tiner, 2003). Wetlands also directly provide spawning and nursery habitat for commercially important fish and shellfish. Shellfish beds especially depend on the role of tidal wetlands in reducing fine sediment and silt deposits.

Figure 5-5. Tidal wetland with Pickleplant (*Salicornia*). *Source: NHDES Wetlands Bureau.*

Economic Importance

Given the important functions and values of wetlands described above, there have been a number of attempts to place an economic value on wetland resources. For instance, a 2006 EPA funded study estimated that the economic benefits generated by a single acre of wetland amount to $150,000 to $200,000 (NACO, 2006). The same study found that wetlands increase surrounding real estate values by an estimated 28 percent while also enhancing the quality of life. In 2002 a study by the Clean Water Network estimated the economic value of New Hampshire's remaining wetlands to be approximately $1.2 billion (CWN, 2002).

5.2 Issues

5.2.1 Wetlands Are Threatened by Landscape Change, Fragmentation and Indirect Impacts

New Hampshire is the fastest growing New England state with approximately 260,000 (20 percent) more people expected to move to the state between 2005 and 2030 (New Hampshire Office of Energy and Planning, 2006). To accommodate this growth, most of which is anticipated to occur in the southeast third of the state, more lands abutting and containing wetlands are now being developed. As a result there is increased fragmentation of wetlands for roads and driveways and there is increasing concern for the indirect impact that upland development has on the quality of wetlands. Groundwater withdrawals associated with development are also a concern.

Fragmentation of wetlands interferes with wetland values previously described, particularly wildlife habitat (Figure 5-6). Fragmentation results in some loss of the wetland itself and disrupts migratory and breeding patterns of many wetland-dependent species.

Indirect impacts to wetlands from upland development include increased loads of sediments, nutrients, chlorides (road salt), and other pollutants carried by stormwater. As noted above, excessive sedimentation can interfere with a wetland's water storage and flood control values. Wetlands generally show sharp declines in the diversity of native plant species and animal communities when adjacent uplands are developed (Wright et al., 2006). The development of adjacent uplands is also a concern because many wildlife species need both wetlands and uplands for survival. Unless a wetland is designated a "prime wetland," is contiguous to a lake, river or stream protected by the Comprehensive Shoreland Protection Act (RSA 483-B), or is a tidal wetland, there are no state regulations that specifically provide for wetland buffers. For more information about the importance of upland buffers for wetlands see "Buffers for Wetlands and Surface Waters: A Guide for Municipalities" (Chase et al., 1995).

Figure 5-6. Example of fragmentation of tidal wetlands at Seabrook Harbor. ***Source: U.S. Army Corps of Engineers New England District, 2008.***

Floodplains typically extend beyond the regulatory authority of state permitting agencies because many floodplains are not wetlands. Floodplain development can significantly affect the quality and hydrology of adjacent wetlands by diverting floodwater and increasing runoff and stormwater discharges to them. Finally, draining of wetlands through excavation or pumping of groundwater can also degrade wetlands.

5.2.2 State Wetland Permitting Load Strains DES's Ability to Provide Effective Protection and Customer Service

New Hampshire was one of the first states to regulate the protection of wetlands. Jurisdiction began for tidal wetlands in 1967 and for nontidal wetlands in 1969. Since then, the Legislature has consistently recognized the importance of this resource. New Hampshire's wetlands are protected through a permitting process that is outlined in Section 5.3.1 of this chapter.

As more people move to New Hampshire and development pressures continue, there is less land available that does not require a wetland permit to develop. Consequently, there has been a steady increase in the resources required to effectively protect wetlands. At the same time, there is concern that the wetland permitting process is inefficient, unduly burdensome and inconsistent. DES is working with stakeholders to determine how limited resources can be used most effectively to protect this important resource and improve stakeholder satisfaction.

In addition, compliance with permits is not assessed in a systematic manner; rather it is primarily based on complaints received from the public. Backlogs often exist both in permitting and compliance. The issues with the current wetland regulatory process fall broadly into the following categories: consistency, timeframes, customer service, compliance and tracking. There is also stakeholder concern that the current permitting process is not well integrated with other land use permitting and may not result in the greatest environmental benefit.

5.3 Current Management and Protection

The wetlands described and discussed in this chapter are primarily protected by state regulations with state funding. Municipalities and the federal government also have significant roles in protecting New Hampshire's wetlands. Management and protection at each level of government is described below.

5.3.1 State Management and Protection

The primary state law that authorizes the permitting program to protect wetlands is RSA 482-A, the New Hampshire Fill and Dredge in Wetlands Act (the "Wetlands Act"). The Wetlands Act is administered by DES and it applies to all wetlands, no matter how small the impact. The Wetlands Act and the rules it authorizes have evolved over time and provide for three key components of wetland protection: permitting, mitigation, and prime wetland designation. Each of the three components is described below. Other significant state laws and programs are also identified.

The premise of wetland regulation in New Hampshire is that any destruction of wetlands should be avoided or minimized. As in most states, New Hampshire's wetland laws address direct impacts such as dredging or filling wetlands. Except in the cases of prime wetlands, wetlands adjacent to protected shorelands, and tidal wetlands where protective buffers are required, New Hampshire does not specifically regulate the indirect impact to a wetlands function or value from upland development. In certain instances, generally for large developments and projects, federal involvement under the Clean Water Act requires that indirect impacts be addressed (see Federal Management and Protection Section below).

Wetland Permits

The state's wetland permitting program is the primary means of wetlands regulation in New Hampshire. In addition to permits issued for impacts to wetlands, the DES wetlands program also issues permits for docks and stream crossings. Each of the 2,000+ applications or notifications received annually for alteration of wetlands, surface water, or other jurisdictional areas are reviewed to ensure that wetland dredge or fill impacts are minimized or avoided. Each proposed project is classified according to its potential environmental impact as a minimum, minor, or major impact. The documentation required to obtain a permit is related to the impact classification, with minor and major impact projects possibly requiring mitigation and significantly more technical information and assessment than minimum impact projects. Federal involvement in permitting decisions is discussed below, and is limited to larger projects or to those that impact significant resources. Most wetland applications are screened for impacts to threatened and endangered wildlife, plants, and plant communities, and are reviewed by New Hampshire Fish and Game Department for input on issues related to habitat protection and endangered species and by New Hampshire Department of Resources and Economic Development for issues related to threatened and endangered plant species and plant communities. Permitting decisions made by DES can be appealed to the Wetlands Council, established under the Wetlands Act.

Wetlands Mitigation

For projects with significant wetland impacts, based on either square footage (> 10,000 square feet) or the impact on sensitive species, DES requires the applicant to compensate for the unavoidable loss of wetland functions and values that will result from the proposed dredge or fill. The applicant must have also demonstrated that the project is the least impacting alternative. The applicant may provide compensation, or "compensatory mitigation," through one or more of the following four options.

- Wetland construction in upland areas. This option is seldom selected because construction of new wetlands is complex and expensive.
- Wetland restoration that re-establishes a filled, dredged or drained wetland to its historic condition. Wetlands created by removing fill and restoring hydrology produce more successful habitats than wetland construction. This option is the most viable when the water available historically to feed the wetland is available for restoration.
- Conservation easements that place bordering upland and wetland areas in permanent protection from development to protect function and value of remaining wetlands.

Applicants must document that the above three options are not available before considering the fourth mitigation option.

- The Aquatic Resource Mitigation Fund (ARM Fund), established in 2006, involves payment into one of 16 watershed-based funds in lieu of the other three options. These payments are pooled together to fund projects within the same watershed (Figure 5-7). The ARM Fund seeks no net loss of aquatic resource functions and values using a watershed approach. The DES regulations allow for the funds in each watershed account to accumulate for two years after the first deposit into a specific account. After two years have lapsed, the funds will be advertised to fund restoration projects to permanently protect high-value wetlands in the respective watershed. The ARM Fund provides a means for mitigation of project impacts where a conservation easement holder may not be available and wetlands creation or restoration is not feasible. As of October 2008, 17 projects had made payments into the ARM Fund.

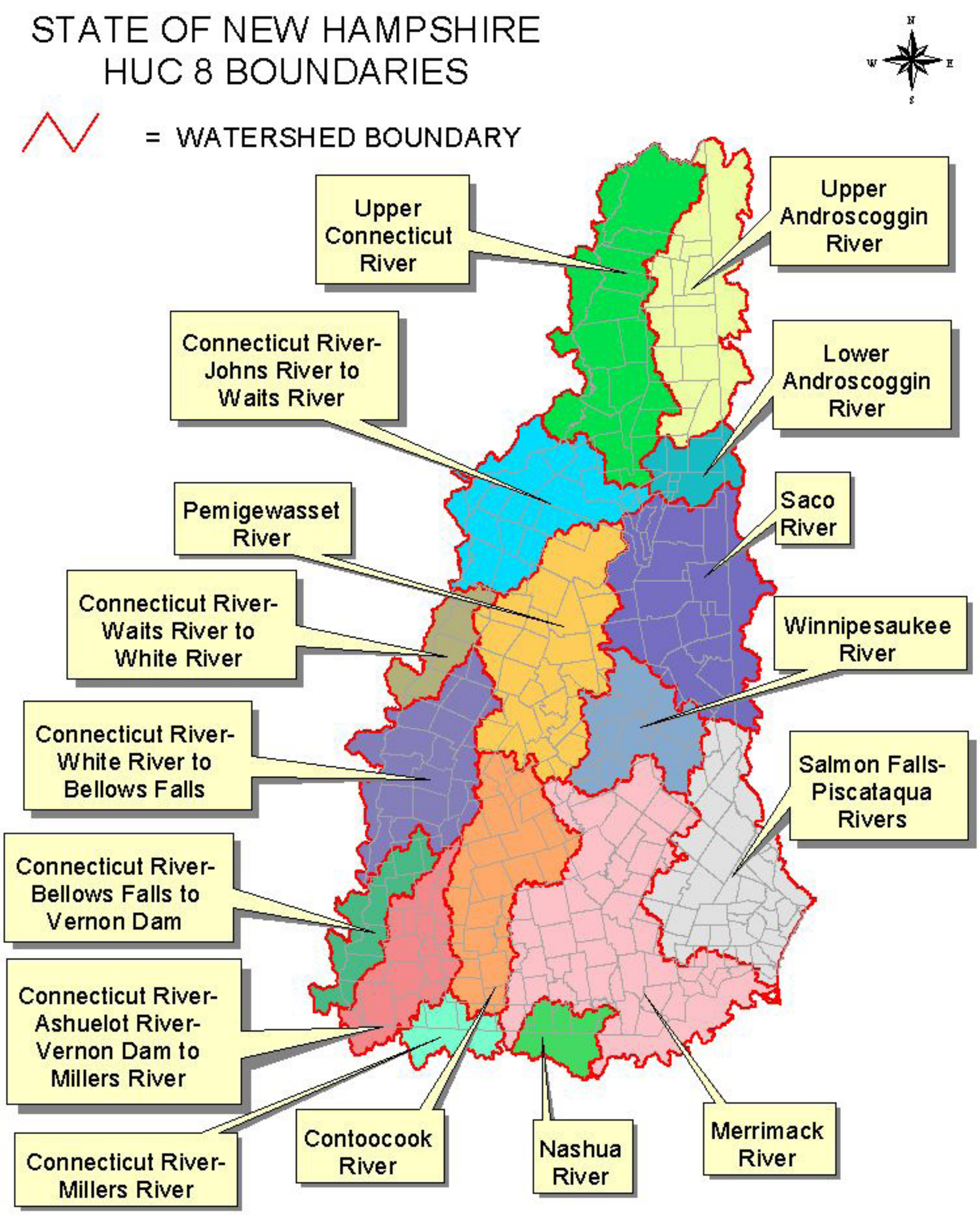


Figure 5-7. New Hampshire's 16 watershed-based fund areas.

With the lack of available restoration sites and limited success of wetland construction, the use of conservation easements has been the most common type of mitigation for projects with significant wetland impacts. Figure 5-8 shows the total permitted acreage of wetland impacts for the period 2001 – 2007, along with the total acreage for each type of mitigation required for larger projects.

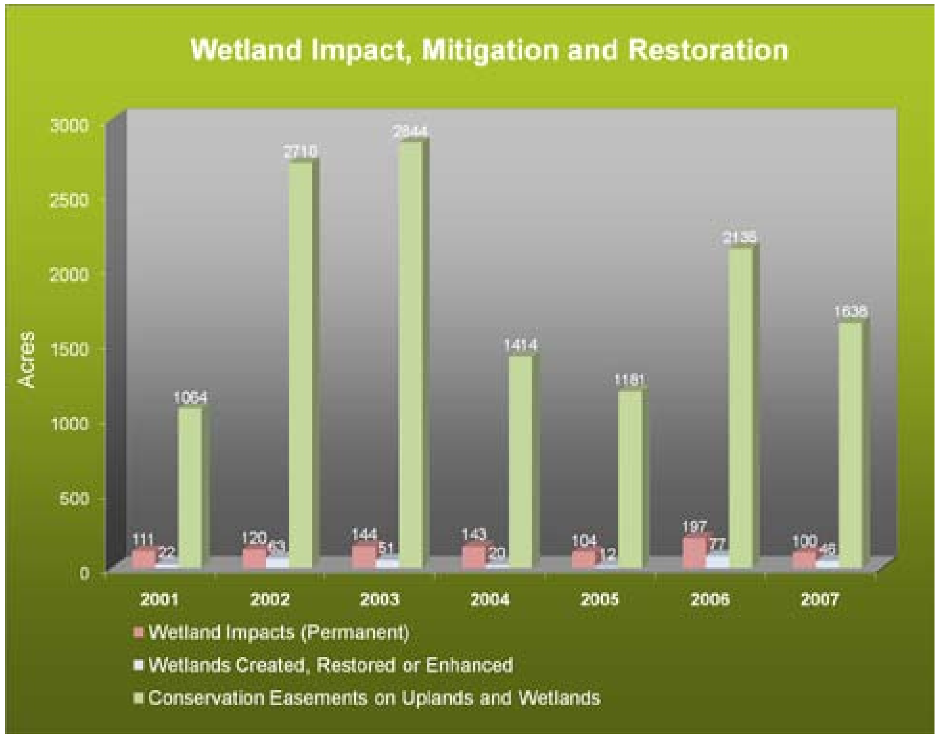


Figure 5-8. Total permitted acreage of wetland impacts and mitigation type for the period 2001 – 2007. ***Source: NHDES, 2008.***

Prime Wetlands Designation

In 1979 New Hampshire's wetlands law was amended to provide an option for municipalities to designate high value wetlands for greater protection. Wetlands are evaluated for designation using the "New Hampshire Method" as detailed in two manuals, one for nontidal wetlands and the other for tidal wetlands (Ammann & Stone, 1991; Cook et al., 1993). The designation of these wetlands must then be adopted by the municipality by vote of the residents after undertaking a process comparable to the adoption of zoning ordinances. The mapping and a report of the evaluation of the wetland(s) is submitted to DES for acceptance. Once DES formally accepts the designation, the designated prime wetland and a 100 foot buffer around it are afforded special protection by DES under the wetlands law.

Projects involving impacts to prime wetlands or the prime wetland buffer are classified as major impact projects, requiring a more stringent burden of proof that the project is the least impacting alternative and that the proposed activity, either alone or in conjunction with other human activity, will not result in the significant net loss of any of the values identified by law. As of November 2008, 26 municipalities have designated prime wetlands to take advantage of the additional protections. Over the years some municipalities have designated wetlands in addition to those initially designated as prime.

Other State Regulations

Comprehensive Shoreland Protection Act – This law establishes 250 feet of protected area for lakes, large rivers and large ponds. It is administered by the DES Wetlands Bureau. Because of the co-occurrence of these surface waters with wetlands, the act also serves to protect wetlands from indirect impacts. This program is described in section 10.3.4 of Chapter 10 – Stormwater.

Alteration of Terrain – This law requires a permit for any project that disturbs 100,000 square feet of land or 50,000 square feet of protected shoreland. The permit is intended to limit the negative impacts associated with increased stormwater runoff at developed sites. To the extent that projects requiring these permits are adjacent to wetlands, this law protects wetlands from indirect impacts caused by stormwater. This program is described in section 10.3.3 of Chapter 10 – Stormwater.

Rivers Management and Protection Program – For rivers that have been designated by the Legislature for protection under this program, local advisory committees routinely comment on development projects. Again, because of co-occurrence of rivers and wetlands, this also serves to protect wetlands, although not through any specific regulatory or permitting authority. This program is described in section 2.3.3 of Chapter 2 – Rivers.

Large Groundwater Withdrawal Permitting Program – This program is administered by DES and serves to prevent impacts to wetlands and other water resources from large withdrawals of groundwater from wells sited after July 1998. This program is described in section 4.3.2 of Chapter 4 – Groundwater.

401 Water Quality Certification – Section 401 of the federal Clean Water Act requires state certification that a federal permit for a proposed activity will not violate state water quality standards. A 401 certificate is usually only necessary for wetlands when the U.S. Army Corps of Engineers decides to issue an individual 404 permit in conjunction with a state wetlands permit. In these cases there can be more consideration of indirect impacts to wetlands caused by development of upland portions of the project.

5.3.2 Federal Management and Protection

Federal Clean Water Act

The U.S. Army Corps of Engineers is the lead agency under Section 404 of the federal Clean Water Act responsible for wetland protection. The Corps has issued a general permit in New Hampshire that allows the state to regulate direct impacts to wetlands via the state permitting program previously described (U.S. Army Corps of Engineers New England District, 2007). The Corps, however, retains the right to issue an individual 404 permit. This is generally done when a project involves particularly significant impacts. The EPA is involved with all individual 404 permits through oversight of the issuance of Section 401 water quality certifications by DES described above. The EPA may also determine that any state permit requires a 401 water quality certification, regardless of Corps involvement, although this is not typically done. Federal involvement in the wetland permitting process allows for far greater consideration of indirect impacts than state permitting authorized by the New Hampshire Wetlands Act.

Endangered Species Act

As noted above, New Hampshire's Fish and Game Department and the Department of Resources and Economic Development's Natural Heritage Bureau review wetlands permit applications to comment on compliance with the federal Endangered Species Act, in addition to the parallel state Endangered Species Conservation Act and Native Plant Protection Act.

5.3.3 Local and Regional Protection

In addition to the key role described above that municipalities play in designating prime wetlands, they are also integrated into the state permitting process in an advisory role through conservation commissions, established under RSA 36-A. State wetlands law provides for consideration of conservation commission comments for wetland permits and notifications. As described in Chapter 1 – Introduction and Overview, local land use regulation is key to water quality protection. Many communities have gone beyond state regulation by establishing local requirements to protect wetlands, such as the establishment of setbacks or buffers. In addition, municipalities and regional planning agencies have played a key role in conducting inventories of wetland resources.

5.4 Stakeholder Recommendations

This section contains key recommendations that have been developed in concert with a group of volunteer stakeholders who have reviewed and contributed to this chapter. For this particular chapter, the first recommendation also reflects the work done under a DES initiative to engage stakeholders to identify changes to the current wetlands permitting process in order to improve environmental results and increase stakeholder satisfaction.

5.4.1 Improve Wetland Permitting to Increase Efficacy and Stakeholder Satisfaction

Make Wetlands Regulation Simpler and More Consistent

In 1969 New Hampshire became one of the first states to create comprehensive wetland regulations. These regulations have been revised and expanded over time to reflect advances in wetland science and to address the realities of New Hampshire's economic growth. Like an old New England farmhouse that has been expanded piece-meal over the years as needs arose and resources allowed, the current structure of the rules no longer has a very coherent form. Further, the plain meaning of some rules has been "adjusted" by various policy pronouncements over the years, and the not-so-plain meaning of other rules has been subjected to changing interpretations. For many practitioners, applicants, and conservation-minded citizens, the wetlands rules are confusing and difficult to interpret and need to be rewritten. DES has committed to rewriting these rules in the near term. In addition, although DES's wetlands program has many documents such as applications, fact sheets, and guidelines for wetlands permitting, the program does not have a comprehensive set of standard operating procedures. Such a document would improve consistency and make the permitting process far more transparent.

Integrate Wetlands Regulation with Other Regulatory Processes

The environment is an integrated system, but land use permitting is not. A new development typically needs permits for wetlands, alteration of terrain, on-site disposal systems, and possibly shoreland protection and water supply. Each of these currently requires a separate permit through a separate DES program. DES should look at the various environmental aspects of a project and coordinate permitting so as to achieve the best environmental outcome. This would require changes in staff responsibilities and expertise, improved data management capabilities and even changes in legislation.

The Level of Wetland Regulation Should Correspond to the Level of Impact

Consideration should be given to dedicating more state resources to permitting projects in undeveloped settings with greater impacts and less resources to smaller impact projects in already highly developed settings. DES should work with stakeholders to investigate the use of permit-by-rule or general permits and third party verification. The goal would be to achieve the same level of compliance while focusing DES's technical expertise on reviewing those projects which pose the greatest threats to wetlands, especially those with complex designs, restoration activities, and potential indirect impacts.

Wetlands Need to Be Protected from Indirect and Cumulative Impacts

Many people now understand that the biggest threat to wetland values is not through destruction by direct filling or dredging but through impacts from adjacent activities. The quality of wetlands is strongly influenced by the quality of the adjacent uplands. The issues related to urban and suburban runoff to wetlands, wetland-dependent wildlife species, groundwater recharge, and flooding all point to the upland areas around wetlands as being critical to the ecological functions of those wetlands. There are three suggestions for better addressing this issue of indirect and cumulative impacts.

First, there is a need for a common set of methodologies for assessing wetland functions and values relative to changes in the upland landscape. EPA is now requiring all states to create a methodology to assess wetlands on a statewide basis in the same way that the state assesses water quality in streams and lakes (see Chapter 2 – Rivers section 2.2.1 and Chapter 3 – Lakes and Ponds section 3.1.2). Water quality assessment includes evaluation of aquatic habitat and water-dependent wildlife habitat as well as hydrology, sediment, and pollutant loading. The process is similar to the analysis of wetland functions and values, and includes evaluation of most factors identified by the U.S. Army Corps of Engineers as secondary impacts. This effort will take several years and significant resources but will provide a way of characterizing and assessing wetlands. The current work underway by the UNH Cooperative Extension to update the "New Hampshire Method" will also help in this process.

Figure 5-9. Forested wetland in Bow. ***Source: NHDES Wetlands Bureau.***

Second, the Legislature should define the extent of unacceptable indirect impacts to wetlands and water bodies. This could be done in the context of revising legislative language for water quality standards in RSA 485-A to be explicitly consistent with the federal Clean Water Act language on indirect impacts. RSA 482-A, the Wetlands Act, could also be revised to include indirect impact thresholds and protection authority.

Third, the state needs to make an informed and intentional decision regarding the best way to regulate the indirect impacts of development. Recent New Hampshire Supreme Court decisions have demonstrated the limited reach of state wetlands legislation to regulate indirect impacts. The state should work toward a consensus regarding the impacts that are of concern, the manner in which they should be regulated, and at what level: federal, state or local. Indirect impacts are not specific to wetlands; surface waters are also subject to them as development changes the landscape. Implementation of DES's surface water antidegradation policy is one possibility for addressing this. Floodplain development is another area in which indirect impacts can severely impact human life and property and may be an appropriate area to regulate under the state wetlands law.

5.4.2 Increase and Improve Local Involvement

The protection of wetlands and their functions and values is dependent on local involvement, as New Hampshire has no state-required buffer on most wetlands. There is a need for improved local land use planning, inventory of wetlands, and surveillance of activities in and around wetlands. Additional resources should be directed at educating and supporting this vital local role. The goal of this effort should be to produce well-informed local experts who can provide constructive input to regulatory decisions, to develop better local ordinances, and, most critically, to guide individual property owners to the correct course of action. DES should pursue various measures to improve communications with conservation commissions.

References

Ammann, A.P. & Stone, A.L. (1991). *Method for the comparative evaluation of nontidal wetlands in New Hampshire* (NHDES-WRD-1991-3). Concord, N.H.: New Hampshire Department of Environmental Services. Reprinted March 2003, Durham, N.H.: Natural Resources Conservation Service. Available at: ftp://ftp-fc.sc.egov.usda.gov/NH/Ecological_pubs/NH_Method_Part1.pdf.

Carter, V., Bedinger, M. S., Novitzki, R. P., & Wilen, W.O. (1979). Water resources and wetlands. In P. E. Greeson, J. R. Clark, & J. E. Clark (eds.), *Wetland functions and values: The state of our understanding* (pp. 344-376). Minneapolis, Minn.: American Water Resources Association.

Chase, V., Deming, L., & Latawiec, F. (1995). *Buffers for wetlands and surface waters: A guide for municipalities* (rev. ed. 1997). Audubon Society of New Hampshire and New Hampshire Office of State Planning. Available at: http://www.nh.gov/oep/resourcelibrary/documents/buffershandbook.pdf.

Clean Water Network. (2002). *New Hampshire waters*. Retrieved November 7, 2007 from CWN Web site. Available at: http://www.cleanwaternetwork.org/docs/publications/factsheets/states/nh.pdf.

Cook, R.A., Stone, A.J.L., & Ammann, A.P. (1993*). Method for the evaluation and inventory of vegetated tidal marshes in New Hampshire (coastal method)*. Concord, N.H.: The Audubon Society of New Hampshire.

Dahl, T.E. (1990). *Wetlands losses in the United States, 1780's to 1980's*. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. Jamestown, ND: Northern Prairie Wildlife Research Center Online. Available at: http://www.npwrc.usgs.gov/resource/wetlands/wetloss/index.htm#contents.

Golet, F.C., Calhoun, A.J.K., DeRagon, W.R., Lowry, D.J., & Gold, A.J. (1993). *Ecology of red maple swamps in the glaciated Northeast: a community profile* (U.S. Fish and Wildlife Service Biological Report 12). Washington, D.C.: U.S. Department of the Interior. Available at: http://www.nwrc.usgs.gov/techrpt/93-12.pdf.

Madison, S. & Paly, M. (1994). *A world in our backyard: A wetlands educational & stewardship program*. New England Interstate Water Pollution Control Commission. Chapel Hill, N.C.: Environmental Media Center.

National Association of Counties. (2006). *Benefits of wetlands*. Retrieved November 7, 2007 from NACO Web site. Available at: http://www.naco.org/Content/ContentGroups/Programs_and_Projects/Environmental1/Water1/Benefits_of_Wetlands_Brochure_Web_withpagenumbers.pdf.

New Hampshire Department of Environmental Services. (2002). *Wetlands Bureau annual report: FY 2002* (NHDES-WD-03-3).

New Hampshire Department of Environmental Services. (2004). *2004 Section 305(b) and 303(d) consolidated assessment and listing methodology* (NHDES-R-WD-04-5). Prepared by G. Comstock, NHDES Watershed Bureau. Available at: https://www.airquality.nh.gov/WMB/swqa/2004/documents/CALM.pdf.

New Hampshire Department of Environmental Services. (2008). Wetlands Bureau. Unpublished data.

New Hampshire Fish & Game Department. (2006). *New Hampshire wildlife action plan*. Available at: http://www.wildlife.state.nh.us/Wildlife/wildlife_plan.htm.

New Hampshire Office of Energy and Planning. (2006, November). *New Hampshire population projections for state and counties 2010 to 2030*. Available at: http://www.nh.gov/oep/programs/DataCenter/Population/documents/populationforcountiesbyageandsex.pdf.

Novitzki, R.P. (1979). Hydrologic characteristics of Wisconsin's wetlands and their influence on floods, stream flow, and sediment. In P. E. Greeson, J. R. Clark, & J. E. Clark (eds.), *Wetland functions and values: The state of our understanding* (pp. 377-388). Minneapolis, Minn.: American Water Resources Association.

Novitzki, R.P., Smith, R.D., & Fretwell J.D. (1997). *Wetland functions, values, and assessment, in restoration, creation, and recovery of wetlands* (U.S. Geological Survey Water Supply Paper 2425). Retrieved June 27, 2008 from: http://water.usgs.gov/nwsum/WSP2425/functions.html.

Odell, J., Eberhardt, A., Burdick, D., & Ingraham, P. (2006). *Great Bay restoration compendium.* The Nature Conservancy and University of New Hampshire. Durham, N.H.: New Hampshire Estuaries Project. Available at: http://www.nhep.unh.edu/resources/pdf/great_bay_restoration-tnc-06.pdf.

Tiner, R.W. (1984). *Wetlands of the United States: Current status and recent trends*. National Wetlands Inventory, U.S. Fish and Wildlife Service. Available at: http://wetlandsfws.er.usgs.gov/status_trends/national_reports/1983_1984_Status_Report.pdf

Tiner, R.W. (2003). *Correlating enhanced National Wetlands Inventory data with wetland functions for watershed assessments: A rationale for Northeastern U.S. wetlands*. National Wetlands Inventory, U.S. Fish and Wildlife Service, National Wetlands Inventory Program, Northeast Region, Hadley, Mass.

Tiner, R.W. (2007). *New Hampshire wetlands and waters: Results of the National Wetlands Inventory*. U.S. Fish and Wildlife Service, Northeast Region 5, Hadley, Mass. Available at: http://des.nh.gov/organization/divisions/water/wetlands/documents/wetlands_summary.pdf.

U.S. Army Corps of Engineers New England District. (2007). *Department of the Army Programmatic General Permit, State of New Hampshire* (General Permit No: NAE-2007-461). Available at: http://www.nae.usace.army.mil/reg/NH%20PGP%20-%20Final%20PN%20&%20PGP%20for%20Website.pdf.

U.S. Army Corps of Engineers New England District. (2008). *A tradition of service in New England*. Retrieved July 3, 2008 from USACOE Web site. Available at: http://www.nae.usace.army.mil/missorga/corps.htm.

Wright, T., Tomlinson, J. Schueler, T., Capiella, K., Kitchel, A., & Hirschman, D. (2006). *Article 1 of the wetlands & watersheds article series: Direct and indirect impacts of urbanization on wetland quality.* Prepared for Office of Wetlands, Oceans, and Watersheds, U.S. Environmental Protection Agency. Ellicott City, Md.: Center for Watershed Protection. Available at: http://www.cwp.org/Resource_Library/Special_Resource_Management/wetlands.htm.

Chapter 6
Coastal and Estuarine Waters

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

Photo by Mike Morrison

Overview

Land development activities in coastal watersheds are creating uncontrolled stormwater runoff and increasing the danger to scarce and environmentally sensitive resources. Rising nutrient and bacteria levels threaten the natural and human environment while head-of-tide dams block fish migration. Troubling declines in seagrass beds in Great Bay may signal that a point of no return could lie ahead. Much depends on reversing these trends, and time is of the essence.

6.1 Occurrence and Significance

Although New Hampshire has just over 18 miles of Atlantic coastline, the state's two major estuaries, Great Bay Estuary and Hampton-Seabrook Harbor, have nearly 220 miles of estuarine shoreline. These two estuaries differ in geology, hydrology and history, but both are valued for their beauty and rich array of natural resources that, along with Rye Harbor and Little Harbor, provide numerous commercial and recreational opportunities. New Hampshire's coasts and estuaries can be categorized into three parts: Hampton-Seabrook Estuary, Great Bay and its tributary rivers, and the ocean coast line. The coastal zone also can be divided into several different watersheds (Figure 6-1). Because these land areas contribute water to fragile estuarine resources, issues regarding estuarine and coastal water quality involve communities in these upstream watersheds.

Individual Seacoast communities tend to have the highest percentage of impervious surfaces relative to other New Hampshire communities due to the dense population and development in the southeastern region of the state.

Although the coastal watersheds of New Hampshire represent only 9 percent of the state, these areas provide essential habitat for more than 130 rare species, including many that occur nowhere else in New Hampshire (Zankel et al., 2006). There are also 1,800 miles of rivers and streams ranging from cold brook trout headwaters in the upper watershed to large, meandering tidal rivers near the coast. In addition to the habitat value of this area, it is also the fastest growing area of New Hampshire and is significant tourist destination.

6.1.1 Great Bay Estuary

Great Bay Estuary, the state's largest estuary, is a tidally dominated system with a water surface area of approximately 13,500 acres, or 21 square miles, including Little Bay and the Piscataqua River. Approximately three-quarters of the estuary's 1,023 square mile watershed is located within New Hampshire; the rest is in Maine. Several New Hampshire communities border Great Bay Estuary, which has more than 144 miles of shoreline made up of steep wooded banks with rock outcroppings, cobble and shale beaches, and fringing salt marsh. As shown in Figure 6-1, the estuary's tributaries include the Isinglass, Cocheco, Salmon Falls, Oyster, Exeter, and Lamprey rivers. The phase of the tide lags significantly as one moves from the ocean up the estuary, with slack

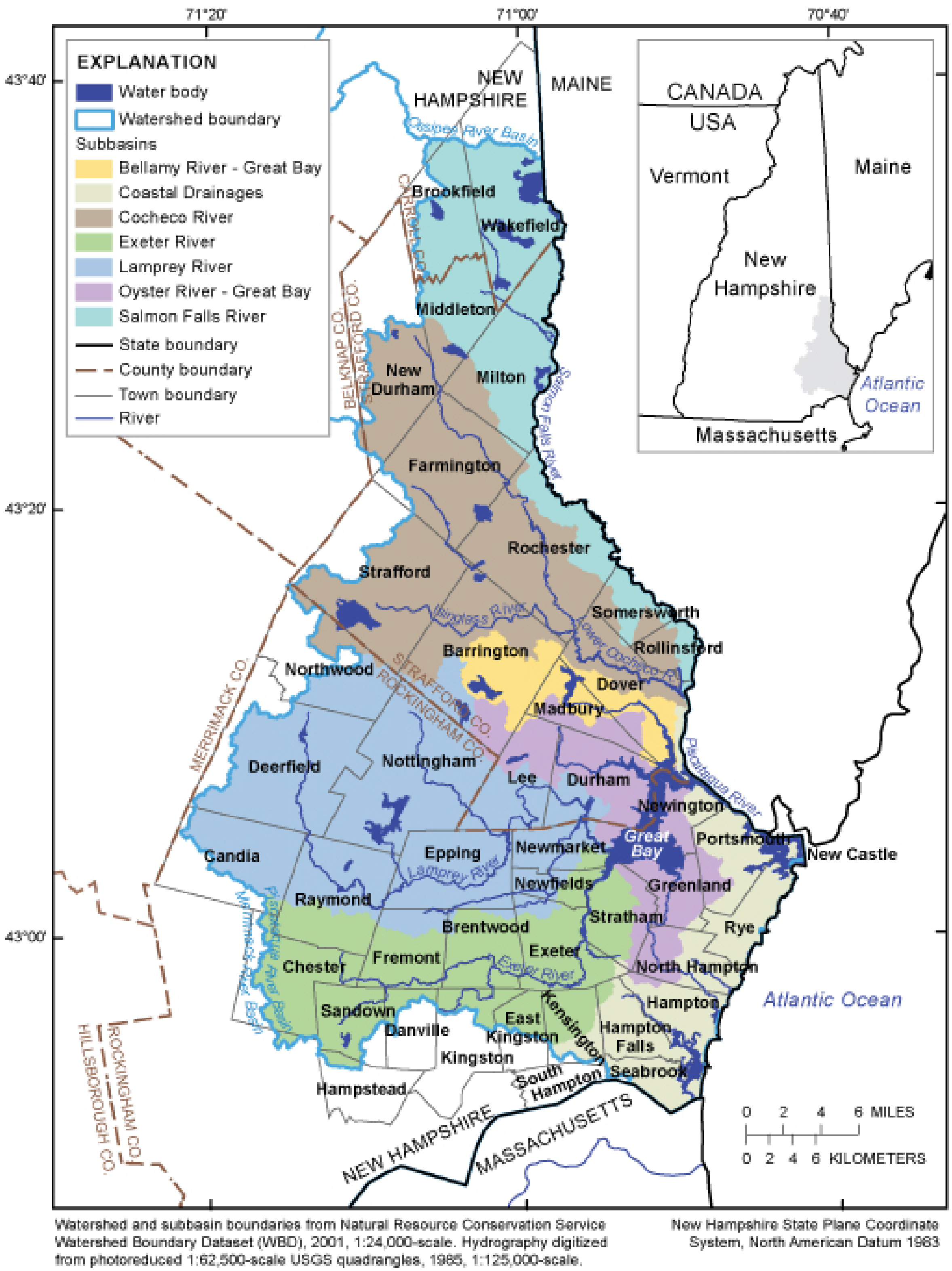


Figure 6-1. New Hampshire's coastal zone watersheds. New Hampshire's coastal watershed consists of a large network of streams, rivers and estuaries. ***Source: U.S. Geological Survey, 2008.***

tides as much as 2.5 hours later in the Squamscott River than at the mouth of Portsmouth Harbor (New Hampshire Estuaries Project [NHEP], 2007). It can take up to 39 tidal cycles, or 20 days, for water from Great Bay to migrate to the open ocean (Bilgili et al., 2005).

6.1.2 Hampton-Seabrook Harbor

Hampton-Seabrook Harbor is a smaller bar-built estuary that formed as sandbars built up along the coastline. It is situated behind barrier beaches and surrounded by over 5,000 acres of salt marsh. In New Hampshire this estuary has approximately 72 miles of tidal shoreline (Jones, 2000) and covers approximately 1152 acres at high tide (NHEP, 2007). Sandy beaches, with some of the last remaining sand dunes in coastal New Hampshire, are a popular tourist attraction adjacent to and within the estuary. The Hampton-Seabrook Harbor also serves as a popular clamming destination and has the most productive clam flats in the state.

6.1.3 The Ocean Coast Line

Dominated by barrier beaches, dunes and maritime forests, the ocean coast line is where European settlers first arrived in New Hampshire. From the productive salt hay fields to the cod drying racks on the Isles of Shoals, to the protected inlets and natural jetties, the seacoast has always been special to the people of the state. Today, 78 percent of New Hampshire's coastal sand beaches are preserved for public use in state parks. Route 1A is a scenic byway traveled by thousands of tourists and New Hampshire's history is told at places such as Odiorne State Park and the Wentworth Coolidge Mansion.

6.2 Issues

6.2.1 Climate Change Expected to Hit the Coast Hard

The defining characteristic of New Hampshire's coast and estuaries is the tide. One of the unique issues that the coast faces is flooding, aggravated by tidal inundation and storm surges. The Patriot's Day storm of 2007 was a spectacular example of coastal flooding that occurred because of a strong Nor'easter combined with astronomical high tides. The offshore waves during the peak of the storm were more than 30 feet high (NOAA, 2007).

A recent study through the National Oceanic and Atmospheric Administration (NOAA) identified 96 major coastal inundation or storm surge events in New Hampshire and Maine between 1914 and 2007, and 37 between 1980 and 2007 (Cannon, 2007). This study revealed a number of facts about the way storm surges occur on New Hampshire's coast.

- Eighty-three percent of storms happen in the colder months of October through March.
- Tidal flooding, although relatively infrequent, tends to cluster with two or more events in a single year.
- While most flooding occurs with high tides (above 12 feet), many happen at lower tides due to wind, wave, and tidal water "piling."

- Storm surge can be very difficult to predict due to the complex shape of New Hampshire's coast and variable meteorological data.

With current and projected climate trends, the associated rise in sea level is expected to exacerbate tidal flooding in the future. For the period of 1921 to 1999, sea level as measured in Boston rose at a rate of at 2.65 millimeters per year (Kirshen et al., 2008), or about 10.4 inches per century. The Intergovernmental Panel on Climate Change projects that by the year 2050 global sea levels will rise between 7 and 14 inches under a lower greenhouse gas emissions scenario and between 10 and 23 inches under a higher emissions scenario (Figure 6-2). With this magnitude of sea level rise, a storm surge that now occurs only once every 100 years will instead occur once every two to 15 years (Ward & Adams, 2001; Kirshen et al., 2007).

Sea level rise may also cause a large increase in the area of land susceptible to flooding. A two-foot rise in sea level by the end of this century is likely to increase the amount of New Hampshire seacoast land at risk for the 10-year and 100-year tidal floods by 34 percent and 100 percent, respectively (Ward & Adams, 2001).

In addition to raising sea level and increasing storm surges, climate change is also expected to increase the frequency and severity of intense rainstorms and corresponding flooding, conditions which the current drainage infrastructure (culverts, etc.) is not designed to handle (see Chapter 10 – Stormwater). In addition to damaging infrastructure and private property, disrupting transportation, and creating health hazards, large coastal floods can have significant ecological impacts. Large volumes of water from tributary rivers can cause salinity levels in estuaries to plummet. Depending on the timing, length, and severity of such an event, a great many seacoast species could be impacted. For example, lobsters may migrate out of the estuary and juvenile lobster and other fish may be injured or killed.

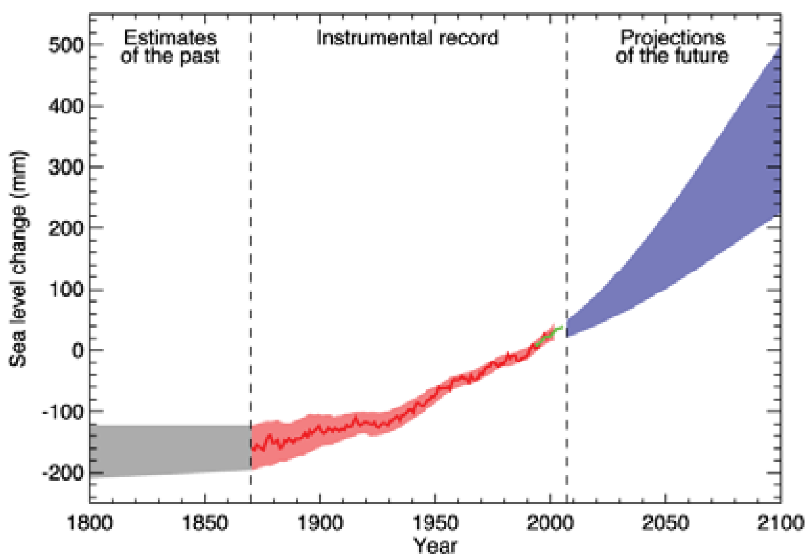


Figure 6-2. Past and projected global average sea level. The gray shaded area shows the estimates of sea level change from 1800 to 1870 when measurements are not available. The red line is a reconstruction of sea level change measured by tide gauges with the surrounding shaded area depicting the uncertainty. The green line shows sea level change as measured by satellite. The purple shaded area represents the range of model projections for a medium emissions growth scenario. *Source: Intergovernmental Panel on Climate Change, 2007; U.S. Environmental Protection Agency, 2007.*

6.2.2 Growth in Water Demand

Seventy-three percent of New Hampshire's population growth in the next 20 years will be concentrated in the four southeastern counties, which make up about one-third of the state's land base (OEP, 2006). The population of the seacoast counties, Rockingham and Strafford, has increased rapidly in recent decades (Figure 6-3). Predicted growth is likely to further strain

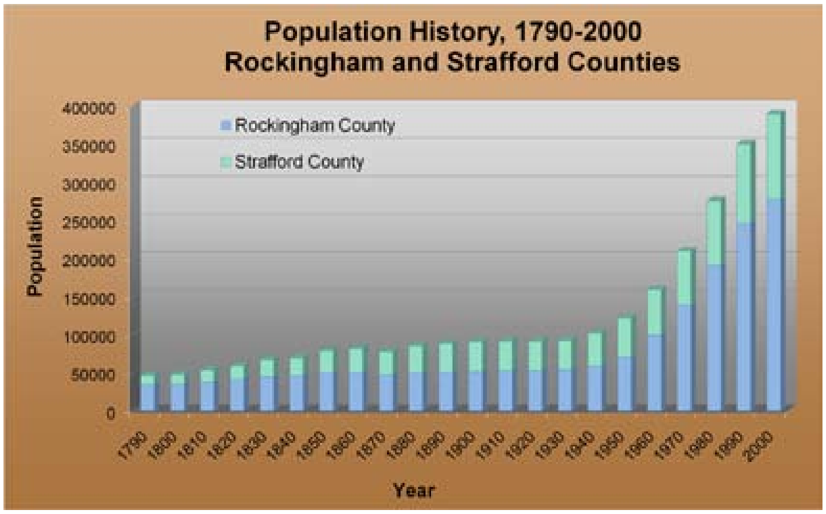


Figure 6-3. Population of New Hampshire's coastal counties. ***Source: Zankel et al., 2006.***

seacoast water supply systems that are already having difficulty locating new sources. The seacoast contains 84 public water supply systems, which include over 300 individual wellheads or surface intakes. These systems serve more than 172,000 people. By 2025 demand for water in the Seacoast Region of New Hampshire is expected to grow by more than 50 percent. In the past five years, water use was estimated at 26.3 million gallons per day. By 2025 the demand may be more than 40 million gallons per day (Horn et al., 2008).

6.2.3 Land Use Development Activities Threaten Sensitive Estuaries

Although most New Hampshire communities review individual development proposals with a view to managing the impacts associated with stormwater, the cumulative impact of land use changes driven by economic and population growth is not addressed adequately on a watershed level. In 2005 8 percent of the coastal watershed was covered by impervious surfaces (roofs, streets, sidewalks and parking lots), compared to 4.7 percent in 1990, almost doubling the impervious coverage in 15 years (Justice & Rubin, 2006; NHEP, 2006b). As described in Chapter 1 – Introduction and Overview and Chapter 10 – Stormwater, the cumulative effects of impervious surfaces on water resources can be significant.

Nutrient Load from the Watershed Is Increasing

Plant nutrients, primarily phosphorus and nitrogen in the context of aquatic ecosystems, are naturally occurring substances in water; however, they do not originate from natural sources alone. Landscape change, fertilizer use, air pollution, and wastewater disposal all contribute nutrients. The great concern in salt water systems is excessive nitrogen, which can cause algal blooms, decrease water clarity, and deplete essential dissolved oxygen. The primary areas of concern in New Hampshire tidal waters are Great Bay, Little Bay, and their tributary rivers. Water travels more slowly through these areas than in areas near the coastal shore, allowing ample time for the ecosystem to be impacted by excess nutrients.

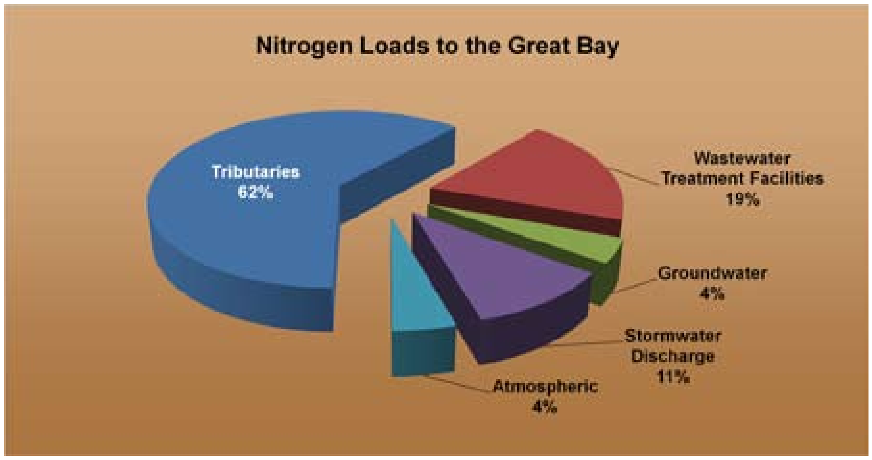


Figure 6-4. A large portion of the total nitrogen load to Great Bay is carried by tributaries from upstream locations. It is likely that nonpoint sources of stormwater pollution are significant contributors to this pollution. These nutrients are a common cause of nuisance algal blooms and possibly low dissolved oxygen problems. *Data Source: NHEP, 2006a.*

An analysis of several sets of historical data show that dissolved inorganic nitrogen concentrations have increased by 59 percent in the past 25 years in Great Bay (NHEP, 2006a). The majority of nitrogen reaching Great Bay, 62 percent, originates from nonpoint sources via tributaries (Figure 6-4). Stormwater pollution contributes nutrients to these tributaries, indicating that nutrient pollution in the coastal zone occurs on the watershed scale and must be addressed in communities and locations upstream of the estuaries. Wastewater treatment facilities contribute the second largest amount of nitrogen reaching Great Bay at 19 percent (NHEP, 2006a).

Excess Nutrients May Be Linked to Other Water Quality Declines

Dissolved oxygen is essential for aquatic habitats because prolonged periods of low levels can be severely detrimental to an ecosystem. Low dissolved oxygen concentrations are evident in the tidal tributaries where levels consistently fail to meet state water quality standards. Although the direct cause is unknown, excessive nutrient levels can increase the demand for dissolved oxygen. As algae and other organisms grow and reproduce in response to the nutrients, they deplete the oxygen in the water. Nonpoint source pollution and discharges from wastewater treatment facilities are both possible causes of algal blooms and, consequently, low dissolved oxygen levels.

There have also been declines in eelgrass coverage, which may signify declining water quality (Figure 6-5). Eelgrass is a type of seagrass essential to the ecology of estuaries because it filters water, stabilizes sediments, provides food for wintering waterfowl, and furnishes habitat for juvenile fish and shellfish. Eelgrass is especially sensitive to water clarity and, in turn, helps to improve clarity by preventing erosion and filtering particulates. There have been rapid, temporary drops in eelgrass stands due to wasting disease events in the past; however, a consistent, decreasing trend in eelgrass, unrelated to wasting disease, is also evident in New Hampshire estuaries. Recent surveys have shown that eelgrass has completely disappeared from the estuarine portions of the Squamscott, Lamprey, Oyster, and Bellamy rivers. Following these surveys, DES designated much of Great Bay Estuary as "threatened" or "impaired" due to the significant eelgrass declines (NHDES, 2008a). The coverage of eelgrass in Great Bay declined by 17 percent between 1996 and 2004 (NHEP, 2006b). This trend cannot be linked directly to the water quality in Great Bay, though increases in sediment concentrations have been observed. The changes in eelgrass strongly suggest that New Hampshire's estuaries may be on the verge of entering a danger zone from which there may be no recovery.

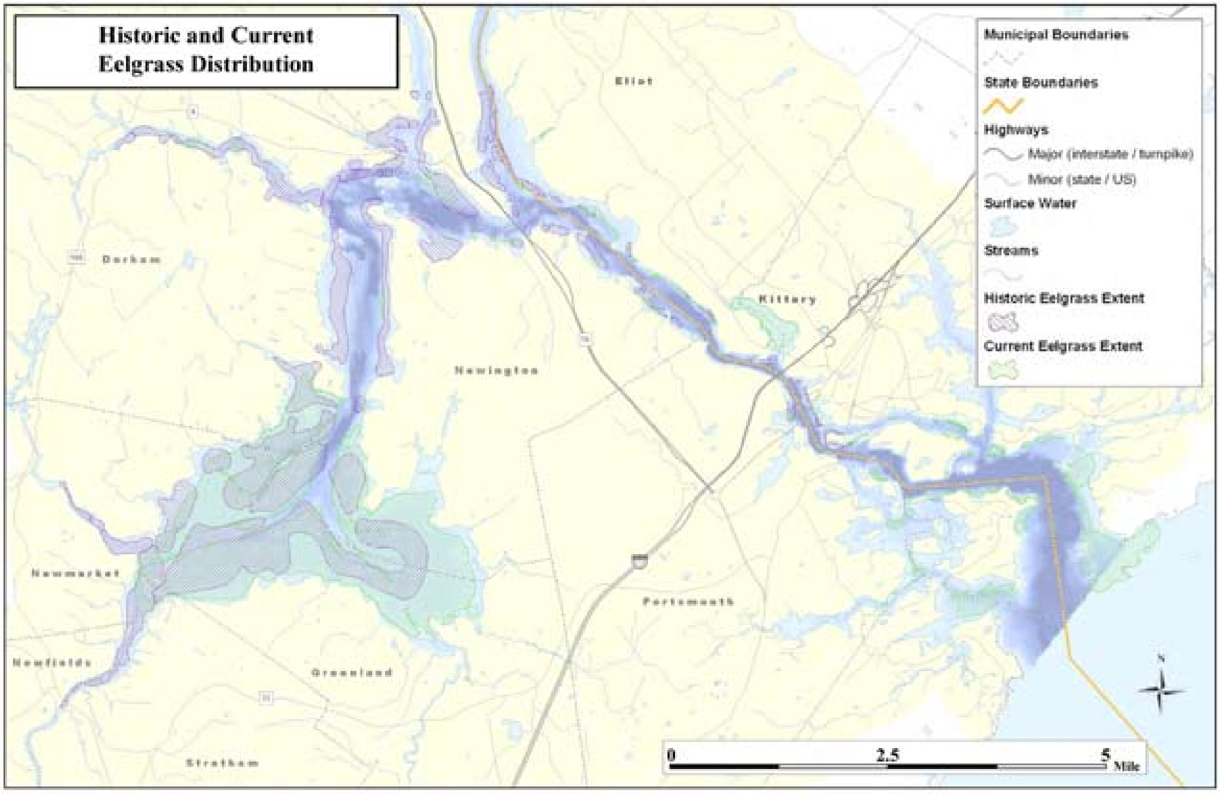


Figure 6-5. The extent of eelgrass habitat has decreased significantly since the maximum area, recorded in 1996. This change likely indicates broad scale water quality issues involving suspended sediments (cloudy water) and nutrient pollution that affect the coastal zone on the watershed scale. ***Source: Odell et al., 2006.***

Water Quality and Shellfish Abundance in Great Bay Are Declining Together

It is estimated that the historic (colonial) shellfish populations in Great Bay were capable of filtering a volume of water equivalent to the entire bay in less than four days. "The current oyster population may be capable of filtering a volume of water equivalent to the entire estuary in about 137 days" (Odell et al., 2006, p. 31). At the same time, sediment inputs to the Great Bay system are increasing. Concentrations of total suspended solids (TSS) in Great Bay increased from an average value of 8.8 mg/L to 15.9 mg/L (an 81 percent increase) between 1976-1981 and 1999-2004. Between 1994 and 2004 TSS increased by approximately 20 percent at three major tributaries over a period when annual river flows went down. Sediment yield nearly doubled in that time period for the Oyster River (NHEP, 2006b).

Taken together, these two trends are worrisome. Inputs of sediment are increasing at exactly the same time the natural buffering capacity is decreasing. Beginning around 1995, oyster populations became greatly impacted by the parasites Dermo and MSX. As the Great Bay Estuary Restoration Compendium points out, "The current poor status of oysters in Great Bay is attributed to multiple factors, including accumulation of fine sediments, mortality due to MSX, removal of shell and lack of preferred substrate for settlement, and poor recruitment. (Odell et al., 2006, p. 27).

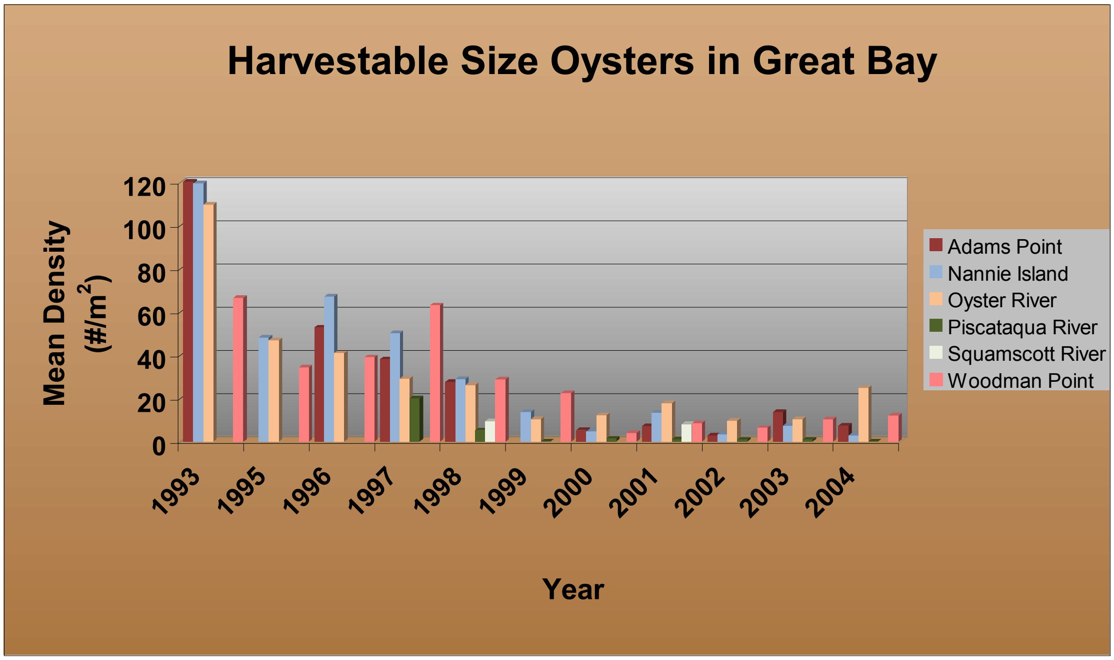


Figure 6-6. Harvestable size oysters by year in New Hampshire's Great Bay. *Source: NHEP, 2005.*

Thus, the lack of shellfish (Figure 6-6) may be exacerbating the impacts of upland development within the Great Bay watershed, which, through increased turbidity, is a significant factor limiting light penetration to eelgrass and other underwater habitats.

6.2.4 Bacterial Contamination from Wet Weather Sources Continues to Impact Coastal Resources

Fecal coliform bacteria in water may indicate the presence of sewage contamination and, consequently, disease-causing microorganisms. A majority of shellfish harvesting areas, 53 percent, are currently closed due to the measured or potential presence of fecal coliform bacteria. These areas are either near major pollution sources, in areas where high bacterial levels are consistently measured, or unclassified because their potential contamination level is uncertain (Figure 6-7). The areas that are open for harvest, the remaining 47 percent, can also be intermittently closed if conditions for bacterial contamination exist (NHDES, 2008b).

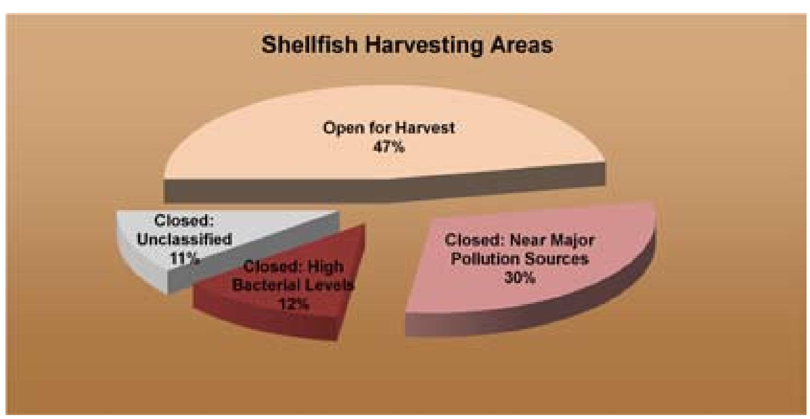


Figure 6-7. Over 50 percent of shellfish harvesting areas are closed, and a majority are due to evidence of or nearby pollution sources. *Source: NHDES, 2008b.*

Over the past 20 years, bacteria sampling has been conducted intensively in the Great Bay system. The bacteria concentrations in Great Bay have decreased by 73 percent over the past 16 years, but the trend has slowed recently (NHEP, 2006b). Upgrades to wastewater treatment facilities and stormwater management projects funded by the New Hampshire Estuaries Project are likely major contributors to the decreasing trend. However, this conclusion is based on only two of the seven tributaries to the Great Bay Estuary and only four data-collecting stations. The observed trend may have been driven by large decreases in the late 1980s and early 1990s, with smaller changes occurring in the past decade. Alternatively, continued land development in the coastal watershed may be counteracting the ongoing pollution control efforts (NHEP, 2006a).

Wet weather bacteria counts are usually much greater than those found during dry weather. Sources of bacteria in stormwater samples often include wastes from pets, waterfowl, malfunctioning septic systems or sewer overflows, and a multitude of other potential sources. These nonpoint sources of pollution are usually linked to impervious surfaces carrying untreated stormwater directly towards surface waters and the absence of stormwater management practices to improve water quality. Combined sewer overflows are also sources of wet weather bacteria.

6.2.5 Head-of-Tide Dams Harm Fish Populations

The obstacles to upstream fish migration created by dams can harm fish populations by fragmenting populations and habitats and preventing reproduction. Several dams in New Hampshire's coastal zone impound water just above the head-of-tide, the location farthest upstream affected by tidal changes. The bodies of water created above dams often have decreased dissolved oxygen levels, which also limit fish populations and adequate habitat for aquatic species.

These head-of-tide dams especially impact populations of anadromous fish species, those that depend on both fresh and salt water ecosystems for habitat. Adult anadromous fish swim upstream to spawn in freshwater habitats. Largely due to dams, anadromous fish populations and the extent of area they inhabit have decreased significantly in New Hampshire. The map in Figure 6-8 shows the current extent of alewife populations and the estimated historical extent of the coastal watershed streams that these fish inhabited. Alewife is just one species among several that require access to upstream freshwater habitats from the marine coast including Blueback herring, American shad, American eel, Atlantic salmon, Rainbow smelt and Atlantic sturgeon. All of these fish species are important to the overall health of the Gulf of Maine ecosystem, providing forage for many commercially harvested fish.

6.2.6 Boat Access and Moorings Present Ecological and Water Quality Issues

The increasing presence of boats on coastal waters, while a source of recreational value for New Hampshire residents and visitors, also damages eelgrass beds and endangers shellfish harvesting areas. Increased mooring permits may also affect water quality and habitat through fuel or oil contamination, sewage contamination, and the direct physical damage caused by the moorings themselves. The risk of boat sewage contamination is becoming a particular threat to shellfish harvesting. The number of mooring permits in the Great Bay Estuary has grown from 475 in 1990 to approximately 650 today.

Most of the 5,400 acres of estuarine shellfish waters are already subject to intermittent bacterial pollution and temporary closures, largely from wet weather sources of pollution such as stormwater runoff. Mooring fields are also beginning to encroach on recreational oyster beds, as a new

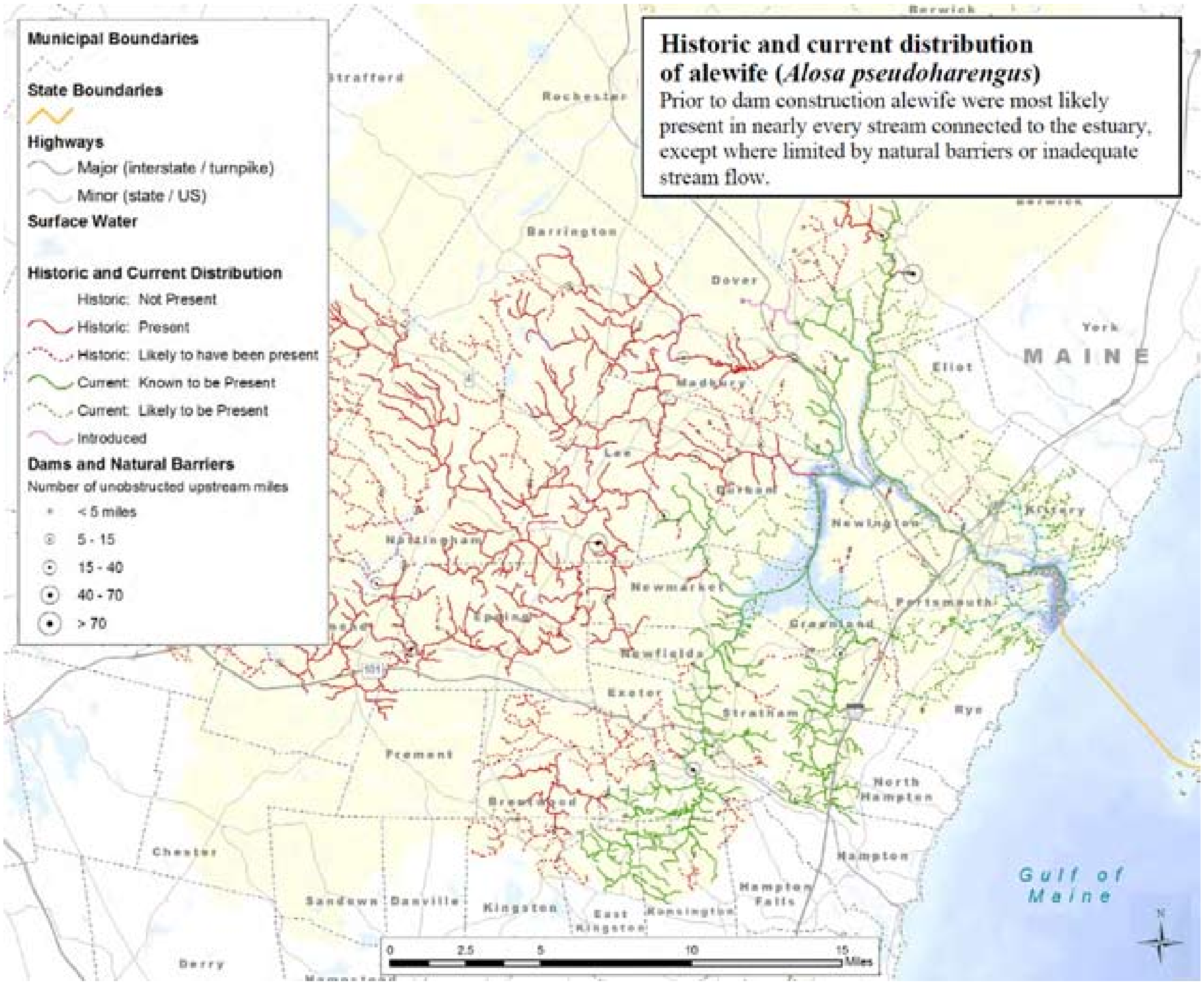


Figure 6-8. Dams placed at the head-of-tide, or the farthest point upstream of the coast affected by tidal changes, limit the movement of several species of fish that depend on both fresh and salt water habitats. Alewife, for example, are found today (green) in a much smaller network of streams than expected historically (red). Atlantic salmon, as another example, are no longer found anywhere in the stream network in the Great Bay watershed. *Source: Odell et al., 2006.*

mooring field was established in 2004 just south of Adams Point, adjacent to a major oyster bed. Although the recent "No Discharge" designation for all New Hampshire waters will help reduce the risk of contamination by sewage, balancing competing uses in the coast remains an ongoing challenge.

6.3 Current Management and Protection

A tremendous amount of work has been done for New Hampshire's coast and estuaries by the municipalities, federal government, and New Hampshire state government. Efforts by non-governmental organizations, the University of New Hampshire, and hundreds of volunteers have also helped immensely. All these agencies and organizations working together make the seacoast one of the best studied and monitored places in New Hampshire.

6.3.1 New Hampshire Coastal Program

The New Hampshire Coastal Program, administered by DES, is one of 34 federally approved coastal programs authorized under the Coastal Zone Management Act. Its mission is to balance the preservation of coastal resources with the social and economic needs of this and succeeding generations. The Coastal Program creates and sustains partnerships with local, state, and federal agencies as well as businesses and nonprofit groups to complete planning, restoration, and education projects. In 2007 the Coastal Program celebrated 25 years of bringing together people, talent, and resources for the coast.

In 1972 Congress passed the Coastal Zone Management Act (CZMA) in recognition of the importance of the nation's coastal resources. The Coastal Program gained federal approval in 1982. Section 307 of the CZMA, known as the federal consistency provision, provides a mechanism for states to manage coastal uses and resources and to facilitate cooperation and coordination with federal agencies. The review process ensures that federal activities affecting any land or water use, or natural resource in New Hampshire's coastal zone will be conducted in a manner consistent with the Coastal Program's enforceable policies. The Coastal Program has a restoration program which is dedicated to working on degraded salt marshes and rivers, and to address the problems associated with invasive species. The Coastal Program has distributed more than $12 million in grants over its history and actively supports the Strafford and Rockingham regional planning commissions with funding on an annual basis.

6.3.2 Coastal Nonpoint Pollution Control Program

The Coastal Program developed and oversees the implementation of the state's Coastal Nonpoint Pollution Control Program (CNPCP). The CNPCP was created to augment EPA's Section 319 (nonpoint source pollution) program with specific focus on enforceable policies in the coastal watershed. Activities for the program include coordination of state and local organizations and agencies, technical assistance, monitoring, and public education. The focus of the CNPCP in New Hampshire has been on bacterial contamination, biomonitoring, and municipal activities.

6.3.3 Coastal and Estuarine Land Conservation Program

As undeveloped land becomes increasingly rare, seacoast towns look to the federal Coastal and Estuarine Land Conservation Program (CELCP) to fund local land protection efforts. CELCP, a tremendously competitive program where states vie for space on a national priority list, aims to protect coastal lands with significant ecological value. CELCP requires a one-to-one match for all projects.

6.3.4 Public Beach Program

DES has operated a Public Beach Inspection Program, or Beach Program, for over 20 years. Fifteen coastal and estuarine beaches are inspected and monitored for the presence of fecal bacteria on a weekly or bi-weekly basis during the swimming season.

6.3.5 Dredge Management Task Force

The New Hampshire Dredge Management Task Force (DMTF) is an interagency work group formed in 1993 to review existing and proposed dredging projects and to develop policies, rules, and guidelines for dredging activities in New Hampshire's coastal waters. The DMTF provides technical and regulatory expertise to ensure that dredging projects are conducted in a manner consistent with state and federal rules and regulations.

6.3.6 Natural Resources Outreach Coalition

The Natural Resources Outreach Coalition (NROC) is a collaboration of 10 state, regional, and non-profit organizations that provides natural resources planning assistance to communities in New Hampshire's coastal watersheds. NROC provides guidance and technical assistance to help communities deal with the impacts of economic and population growth on natural resources. Over a period of a year or more, the NROC team meets with municipal officials and interested community members to focus their natural resource protection goals, develop an implementation strategy, and locate the technical and financial assistance needed to accomplish goals.

6.3.7 New Hampshire Estuaries Project

The New Hampshire Estuaries Project is part of EPA's National Estuary Program, which is a joint local, state, and federal program established under the Clean Water Act with the goal of protecting and enhancing nationally significant estuarine resources. The NHEP receives its funding from the EPA and is administered by the University of New Hampshire. Approved in 2001 and updated in 2005, the NHEP Comprehensive Conservation and Management Plan is an approach to protect and enhance the state's estuaries. Spanning three years, the collaborative process to develop the watershed plan involved the work of researchers, planners, resource managers, concerned individuals, and other coastal stakeholders. The resulting plan describes actions to be undertaken throughout New Hampshire's coastal watershed to achieve and sustain healthy estuarine systems. The Management Plan identifies priority actions in five areas: 1) water quality; 2) land use, development, and habitat protection; 3) shellfish resources; 4) habitat restoration; and 5) public outreach and education.

6.3.8 Great Bay National Estuarine Research Reserve

Great Bay National Estuarine Research Reserve is part of a national network of protected areas established for long-term research, education and stewardship. This partnership program between NOAA and the coastal states protects more than one million acres of estuarine land and water. These areas provide essential habitat for wildlife, serve as living laboratories for scientists, and offer educational opportunities for students, teachers and the public.

6.3.9 Great Bay Resource Protection Partnership

The Great Bay Resource Protection Partnership was formed in 1994 to identify and protect significant habitat areas in the Great Bay region. This successful partnership is comprised of statewide, regional and local non-profit conservation organizations, municipalities, and state and federal agencies. As of September 2008 the GBRPP has protected 5,837 acres of critical habitat around Great Bay (GBRPP, 2008). Local communities and other organizations have protected an additional 3,020 acres that the GBRPP has been able to use as a match to leverage federal funding.

6.3.10 New Hampshire Corporate Wetlands Restoration Partnership

The goal of the New Hampshire Corporate Wetlands Restoration Partnership is to facilitate corporate interest, involvement and support for the state's aquatic resources. Funds collected by the NHCWRP are used to restore coastal and freshwater wetlands and rivers degraded by human activities such as fill, pollution, or changes in water flow. The program has been adopted by the federal government as a national initiative (Corporate Wetlands Restoration Partnership, n.d.).

6.3.11 Volunteer Programs

There are numerous volunteer monitoring and cleanup programs in the seacoast watershed. These include not only the Volunteer River Assessment Programs, as in other watersheds, but also four volunteer river biomonitoring assessment groups, the Great Bay Coastwatch, Marsh Monitors, and Blue Ocean Society monthly beach cleanup teams.

6.3.12 No Discharge Program

New Hampshire's coastal waters were designated as a "No Discharge Area" in 2005, prohibiting the discharge of treated and untreated boat sewage. Federal law additionally prohibits the discharge of untreated sewage from vessels within all navigable waters of the United States, which include territorial seas within three miles of shore.

6.3.13 Land Conservation Plan for New Hampshire's Coastal Watersheds

The Coastal Program and NHEP recently teamed up with The Nature Conservancy, the Society for the Protection of New Hampshire Forests, and the Rockingham and Strafford regional planning commissions to create a Land Conservation Plan for New Hampshire's Coastal Watersheds. This plan identifies the 70 most ecologically significant areas of the watershed. Those 70 priority areas contain some 190,000 acres of undeveloped land in the 42 towns of the watershed (Figure 6-9). Approximately 40,000 acres have already been protected (Zankel et al., 2006).

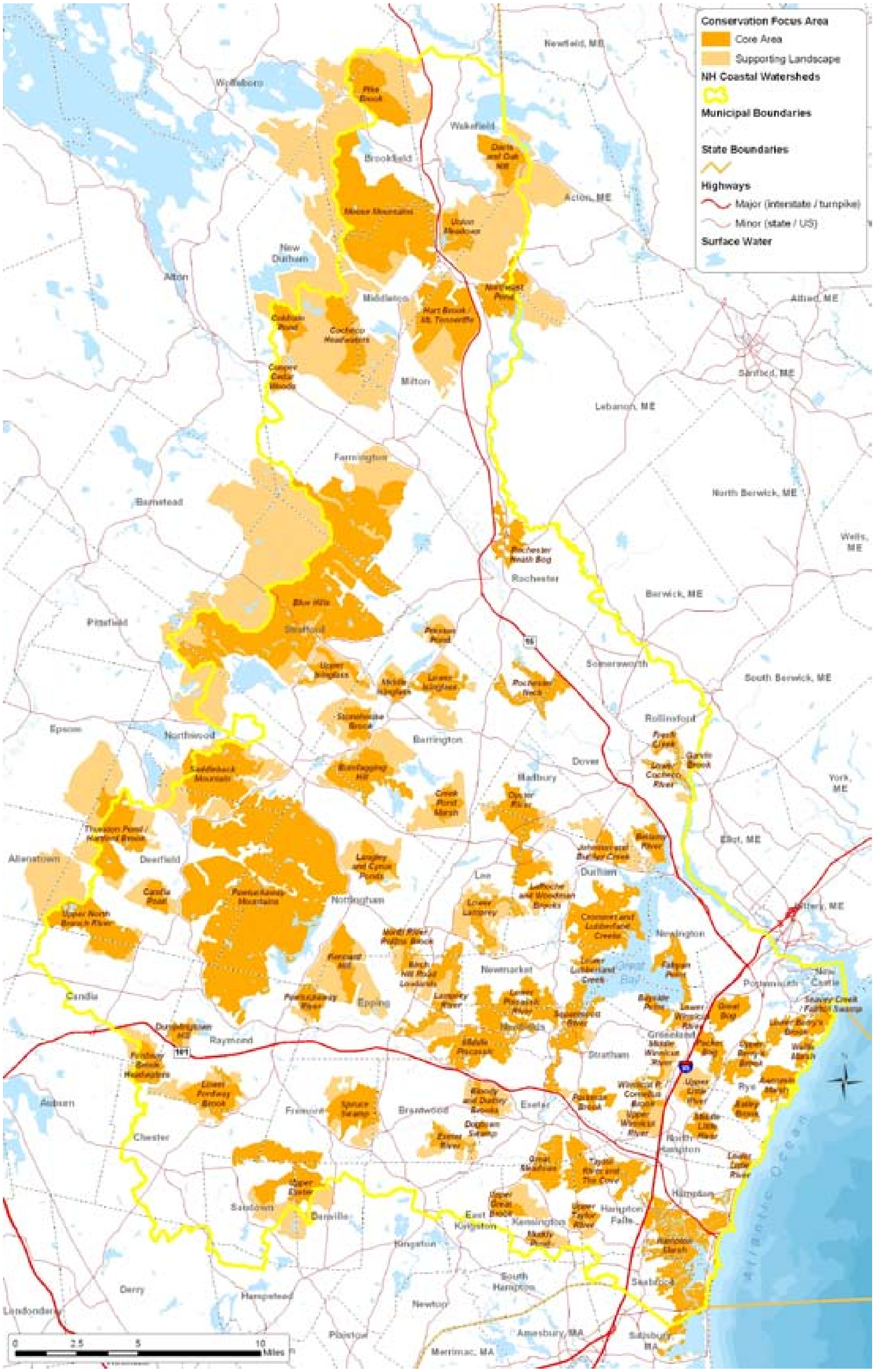


Figure 6-9. Conservation focus areas and supporting landscapes in the coastal watershed. ***Source: Zankel et al., 2006.***

6.4 Stakeholder Recommendations

This section contains key recommendations that have been developed in concert with a group of volunteer stakeholders that have reviewed and contributed to this chapter.

6.4.1 Develop a Strategy to Adapt to the Impacts of Climate Change

In light of the extensive impacts coastal areas are expected to experience as a result of climate change, an adaptation strategy for this area is a priority.

6.4.2 Reduce Nutrient and Sediment Loads to the Estuaries

Current nutrient loading to coastal waters is creating serious issues with water quality that must be addressed if the estuaries are to be preserved. Much of the loading likely results from increasing stormwater runoff, which results from the pace, pattern, and method of development, and from wastewater treatment facilities, which are increasingly stressed as a result of population growth. Large tracts of forests and farmlands are being converted to sprawling residential and commercial land uses with more compacted lawns, roads, and parking lots and greater runoff. The construction process itself often produces significant uncontrolled sediment loads to downstream waters. While population growth may be inevitable, the increases in total runoff and sediment loads do not have to be because runoff can be handled onsite much more effectively than at present. Changes to DES's Alteration of Terrain regulations, discussed in Chapter 10 – Stormwater, will help substantially, but significant progress must be made before the hydrology of new development resembles pre-development conditions. Additionally, the existing developed landscape should be retrofitted for stormwater runoff treatment where feasible.

6.4.3 Limit Boat Moorings

To protect sensitive coral reefs, some countries limit the number and location of boat moorings since these have been repeatedly shown to disrupt and even destroy otherwise intact reefs. While New Hampshire does not have reefs, the estuary habitats along New Hampshire's coasts are nearly as sensitive to moorings and disruptions that may include damage from anchors, sewage dumping, and propeller disturbance. Existing moorings have already encroached on valuable shellfish habitat, and new moorings increase the encroachment. The best locations and carrying capacity of moorings in New Hampshire's estuaries along with potential limits on boat access should be evaluated to protect these resources.

6.4.4 Make Removal of Head-of-Tide Dams a Priority

As discussed in Chapter 11 – Dams, New Hampshire has a dam removal program. Because head-of-tide dams are in the most sensitive locations possible for fish passage, any of these dams that could be removed should be a priority and the others should receive additional attention for fish passage as they are upgraded or repaired.

6.4.5 Expand Shellfish Resources and Harvesting Opportunities Through Improved Management of Estuarine Areas

There continues to be great interest in opening more shellfish harvesting areas either by gathering more environmental quality data to determine whether additional areas can be classified as safe, or by pursuing studies to investigate and remediate pollution sources and improve the management of the shellfish areas. Significant effort and investment are also needed in restoring large self-sustaining shellfish populations. Healthy native oyster populations, for example, will not only improve harvest opportunities, but also enhance water quality since oysters filter large volumes of water.

When DES began classifying shellfish waters in 2000, New Hampshire did not have a coordinated program to implement the National Shellfish Sanitation Program; thus, interstate sale of commercially grown shellfish was not possible. In February 2002 New Hampshire was officially recognized as a shellfish producing state by the U.S. Food and Drug Administration. New opportunities to harvest shellfish have been realized not only by opening new areas but also by improved management. Most estuarine areas open for harvest still require temporary closures due to high bacteria levels associated with rainfall, season or other factors. Augmented monitoring to develop information to support more accurate classifications has led to more opportunities for shellfish harvesting. Continued expansion of monitoring and better management will expand the available economic shellfish harvesting opportunities.

6.4.6 Support Land Conservation and Stormwater Best Management Practices to Help Reverse Trends in Coastal and Estuarine Degradation

In some ways the seacoast is a model for land protection. Currently 54,622 acres in the coastal watershed are protected, which amounts to 10.7 percent of the land area. An additional 21,790 acres of watershed land need to be protected in order to achieve the NHEP goal of protecting 15 percent of the watershed area by 2010 (NHEP, 2006b). However, the Land Conservation Plan for New Hampshire's Seacoast Watersheds has identified 190,000 acres of land that make up the core ecologically important areas (Zankel et al., 2006). Achieving this goal will require a substantial increase in the rate of land protection. More importantly, land protection efforts must be targeted to maintain natural buffers on the streams and rivers that feed estuaries and to protect water quality, as guided by the plan.

Although conserving land in its natural state does help to lessen stormwater impacts downstream, it does not directly alleviate the sources of stormwater pollution already present. In addition to conserving coastal lands, stormwater best management practices must be implemented to alleviate problematic pollution from existing development, and low impact development site design (see Chapter 10 – Stormwater) must be employed for new development in the seacoast watershed.

References

Bilgili, A, Proel, J.A., Lynch, D.R., Smith, D.W., & Swift, M.R. (2005). Estuary/ocean exchange and tidal mixing in a Gulf of Maine estuary: A Lagrangian modeling study. *Estuarine, Coastal and Shelf Science, 65*, 607-624.

Cannon, J.W. (2007). *Northern New England coastal flooding (*NOAA Eastern Region Technical Attachment, No. 2007-03). National Oceanic and Atmospheric Administration. Available at: http://www.erh.noaa.gov/er/hq/ssd/erps/ta/ta2007-03.pdf.

Corporate Wetlands Restoration Partnership. (n.d.). *Corporate Wetlands Restoration Partnership fact sheet*. Retrieved July 2, 2008 from Vanasse Hanglin Brustlin, Inc. Web site. Available at: http://www.vhb.com/bellamy/CWRP_Fact_Sheet.pdf.

Great Bay Resource Protection Partnership. (2008). *Summary of protected and restored lands, Jan. 1996 to Sept. 18, 2008*.

Horn, M.A., Moore, R.B., Hayes, L., & Flanagan, S.M. (2008). *Methods for and estimates of 2003 and projected water use in the Seacoast region, southeastern New Hampshire* (U.S. Geological Survey Scientific Investigations Report 2007–5157). Available at: http://pubs.usgs.gov/sir/2007/5157/pdfs/front_508.pdf.

Intergovernmental Panel on Climate Change. (2007). *Climate change 2007: The physical science basis. Contribution of Working Group I to the fourth assessment report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge, United Kingdom and New York, NY, USA, Cambridge University Press.

Jones, S.H. (2000). *A technical characterization of estuarine and coastal New Hampshire*. A final report to the New Hampshire Estuaries Project by the University of New Hampshire, Jackson Estuarine Laboratory, Durham, N.H.

Justice, D. & Rubin, F. (2006). *Impervious surface mapping in coastal New Hampshire (2005): A final report to the New Hampshire Estuaries Project*. Complex Systems Research Center, Institute for the Study of Earth, Oceans, and Space. University of New Hampshire, Durham, N.H. Available at: http://www.granit.unh.edu/Project/DownloadFile.pm?DOCUMENT_ID=127.

Kirshen, P., Watson, C., Douglas, E., Gontz, A., Lee, J., & Tian, Y. (2008). Coastal flooding in the northeastern United States due to climate change. Mitigation and Adaptation Strategies for Global Change, 13, 437-451. Available at: http://www.northeastclimateimpacts.org/pdf/miti/kirshen_et_al.pdf.

National Oceanic and Atmospheric Administration. (2007). The Patriot's Day Storm of 2007. National Weather Service Forecast Office: Gray/Portland. Retrieved July 8, 2008. Available at: http://www.erh.noaa.gov/gyx/patriots_day_storm_2007.htm.

New Hampshire Department of Environmental Services. (2008a). *Methodology and assessment results related to eelgrass and nitrogen in the Great Bay Estuary for compliance with water quality standards for the New Hampshire Section 303(d) list* (WD Doc R-WD-08-18). Prepared by P. Trowbridge, NH-DES.

New Hampshire Department of Environmental Services. (2008b). Shellfish Program. Unpublished data.

New Hampshire Estuaries Project. (2005). *Environmental indicator report: Shellfish.* University of New Hampshire, Durham, N.H: Philip Trowbridge, NHEP Coastal Scientist, New Hampshire Department of Environmental Services. Available at http://www.nhep.unh.edu/resources/pdf/env-ind-shellfish-nhep-05.pdf.

New Hampshire Estuaries Project. (2006a). Environmental indicator report: Water quality. University of New Hampshire, Durham, N.H. Prepared by P. Trowbridge, NHDES. Available at: http://www.nhep.unh.edu/resources/pdf/env_ind_water_quaity-nhep-06.pdf.

New Hampshire Estuaries Project. (2006b). *State of the estuaries*. University of New Hampshire, Durham, N.H. Available at: http://www.nhep.unh.edu/resources/pdf/2006_state_of_the-nhep-06.pdf.

New Hampshire Estuaries Project. (2007). *Hydrologic parameters for New Hampshire's estuaries*. Prepared by P. Trowbridge, NHDES. Available at: http://www.nhep.unh.edu/resources/pdf/hydrologic_parameters_for-nhep-07.pdf.

New Hampshire Office of Energy and Planning. (2006, November). *New Hampshire population projections for state and counties 2010 to 2030*. Available at: http://www.nh.gov/oep/programs/DataCenter/Population/documents/populationforcountiesbyageandsex.pdf.

Odell, J., Eberhardt, A., Burdick, D., & Ingraham, P. (2006). *Great Bay restoration compendium.* The Nature Conservancy and University of New Hampshire: New Hampshire Estuaries Project, Durham, N.H. Available at: http://www.nhep.unh.edu/resources/pdf/great_bay_restoration-tnc-06.pdf.

U.S. Environmental Protection Agency. (2007). *Future sea level changes: Sea level rise projections to 2100*. Retrieved July 8, 2008 from EPA Web site: Climate Change – Science. Available at: http://www.epa.gov/climatechange/science/futureslc_fig1.html.

U.S. Geological Survey. (2008). *Assessment of ground-water resources in the Piscataqua River and coastal watersheds, woutheastern New Hampshire*. Retrieved July 2, 2008 from USGS Web site. Available at: http://nh.water.usgs.gov/projects/seacoast/.

Ward, L.G. & Adams, J.R. (2001). *A preliminary assessment of tidal flooding along the New Hampshire coast: Past, present and future* (UNH CMB/JEL Report Series Number 54). New Hampshire Office of Emergency Management and the Office of State Planning Coastal Program.

Zankel, M., Copeland, C., Ingraham, P., Robinson, J., Sinnott, C., Sundquist, D., Walker, T., & Alford, J. (2006). *The land conservation plan for New Hampshire's coastal watersheds*. The Nature Conservancy, Society for the Protection of New Hampshire Forests, Rockingham Planning Commission, and Strafford Region Planning Commission. Prepared for the New Hampshire Coastal Program and the New Hampshire Estuaries Project. Available at: http://www.rpc-nh.org/PDFs/docs/coastal-conservation/Coastal_Plan_Complete.pdf.

Chapter 7
Water Use and Conservation

NEW HAMPSHIRE
DEPARTMENT OF
Environmental
Services

Overview

New Hampshire is relatively water rich, yet using water efficiently is an important element of ensuring the sustainability of our water resources. Water use in New Hampshire continues to grow to support a growing population and economy. The per capita residential consumption of water has increased due to discretionary uses such as lawn watering. At the same time, climate change and an aging, leaking infrastructure put pressure on water availability.

7.1 Description and Significance

7.1.1 Water Use

Water use includes elements such as water withdrawals by public water systems and private water users, consumptive use, wastewater discharge, the reuse or reclaiming of wastewater, return flows, and in-stream uses such as hydropower, recreation and aquatic habitat. In a narrow sense, water use refers to water that is actually used for a specific purpose, such as for domestic use, irrigation, or industrial processing. Water use is generally divided into two types: consumptive and non-consumptive uses.

Consumptive use represents water that evaporates, transpires, is incorporated into products or crops, is consumed by humans or livestock, or otherwise removed from the immediate water environment thereby making that amount of water unavailable for other potential users. Consumptive water use occurs when water is withdrawn or diverted from a ground- or surface-water source for public water supply, industry, irrigation, livestock, cooling for thermoelectric power generation, mining, and domestic purposes. Non-consumptive water use occurs when the water remains in or is immediately returned to the location in a stream or aquifer from which it was extracted. For example, hydroelectric power generation is considered to be a non-consumptive use of water.

How New Hampshire Uses Water

The ways in which water is used in New Hampshire have expanded since the native Americans and then colonists used waterways for transportation, fishing and hunting. In the late 1700s grist mills and sawmills began utilizing hydropower, which was harnessed on a much larger scale in the 1800s. The 1900s saw the increasing importance of domestic water use, drinking water, landscaping, industry, beverage manufacturing, recreation, and environmental protection. While studies have projected future water demands for New Hampshire based on current development trends, additional potential uses of water associated with new activities have not been assessed.

Based on an estimate made by U.S. Geological Survey (USGS) for water use in New Hampshire for the year 2000, New Hampshire uses approximately 211 million gallons per day (Hutson et al., 2004). This figure excludes approximately 236 million gallons per day of freshwater that is used at thermoelectric plants where water is generally not consumed and is returned to the location from which it was extracted. Of the 211 million gallons of water that is used, 127 million gallons

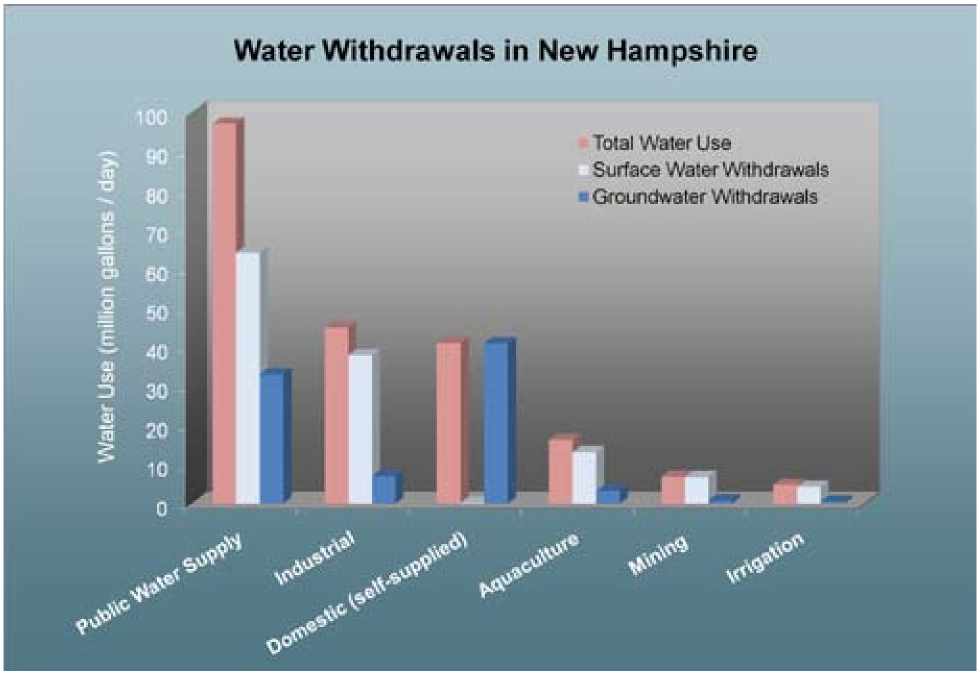


Figure 7-1. Water withdrawals in New Hampshire. ***Source: Hutson et al., 2004; NHDES, 2008a.***

per day (60 percent) is extracted from surface water and 84 million gallons per day (40 percent) is extracted from groundwater. Public water suppliers that provide water to homes, businesses and institutions are the largest users of all water and of surface water in the state. Cumulatively, domestic water users self-supplied with water obtained from private wells represent the largest use of groundwater in New Hampshire (Figure 7-1).

A detailed assessment of state-wide water use is currently being conducted. As part of a cooperative project with the New Hampshire Department of Environmental Services, the USGS is estimating all withdrawals, transfers, discharges, and consumptive uses of water throughout the state for each census block. These data will be coupled with work the New Hampshire Geological Survey (NHGS) is completing to estimate water availability at the sub-watershed (areas of about one-half of a square mile) level.

7.1.2 Water Conservation

Water conservation is any beneficial reduction in water loss, waste or use. Conservation measures include education that results in modified behavior, installation of water efficient hardware, infrastructure improvements and maintenance, and improvements in water use management and accounting. Efforts to conserve water are spurred by a number of factors including the following:

- Growing competition for limited water supplies.
- Increasing concerns regarding impacts of water withdrawals on other water users and on resources such as stream flows and wetlands.
- Cost and difficulty of developing new supplies.
- Costs associated with pumping and treating water.

- Costs associated with conveying, treating and discharging wastewater.
- Desire to delay or reduce capital investments for expanding the capacity of a water system.
- Desire to avoid developing less desirable sources of water that will require expensive treatment.
- Growing public support for the conservation of limited natural resources and overall environmental protection.

DES has summarized water conservation techniques for the largest users of water in the state through a series of fact sheets (New Hampshire Department of Environmental Services [NHDES], 2008b). Some of these techniques are highlighted below.

Water Conservation in the Home

A report studying water use in 44 New Hampshire Seacoast communities found that 72 percent of all water use was for household purposes (Horn et al., 2008). The study estimated the average per capita domestic water use to be 63 gallons per day during the winter months, representing indoor water use.

Domestic plumbing fixtures and appliances affect the amount of water utilized in a home. The 1992 U.S. Energy Policy Act (EPAct) established efficiency standards for water fixtures beginning in 1994. Fixtures manufactured before the effective date of the EPAct generally use 20-50 percent more water than new fixtures. Additionally, advances in technology have made available more water-efficient dishwashers and clothes washers, although lack of federal standards for these allowed water-inefficient appliances to remain on the market. The federal Energy Bill that passed in 2007 establishes water efficiency standards for dishwashers and clothes washers effective in 2010 and 2011 respectively.

A national residential indoor water use study completed in 2000 compared water use in non-conserving and conserving homes (U.S. General Accounting Office, 2000; Vickers, 2001). The national study revealed that indoor water use in a conserving home averaged 45.2 gallons per capita per day, while use in a non-conserving home is 69.3 gallons per capita per day. The distribution of and differences in water uses in a conserving versus non-conserving home are shown in Figure 7-2.

Water Conservation Outside the Home

As discussed in Chapter 1 – Introduction and Overview, domestic water use increases dramatically during summer months, primarily to water lawns. The most efficient way to reduce the need for irrigation is to transition from expansive lawn areas to natural landscaping with native or other low water-demand shrubs, trees and other plants. Natural landscaping is also beneficial in maintaining water quality. Clearing less forest and maintaining mature trees around houses provide shade, reduce drying winds, and help minimize energy and water use. By minimizing the area of land requiring irrigation and by landscaping with plants and grass that can resist drought more easily, both maintenance and water demands decrease. Where lawns are to be established, water use can

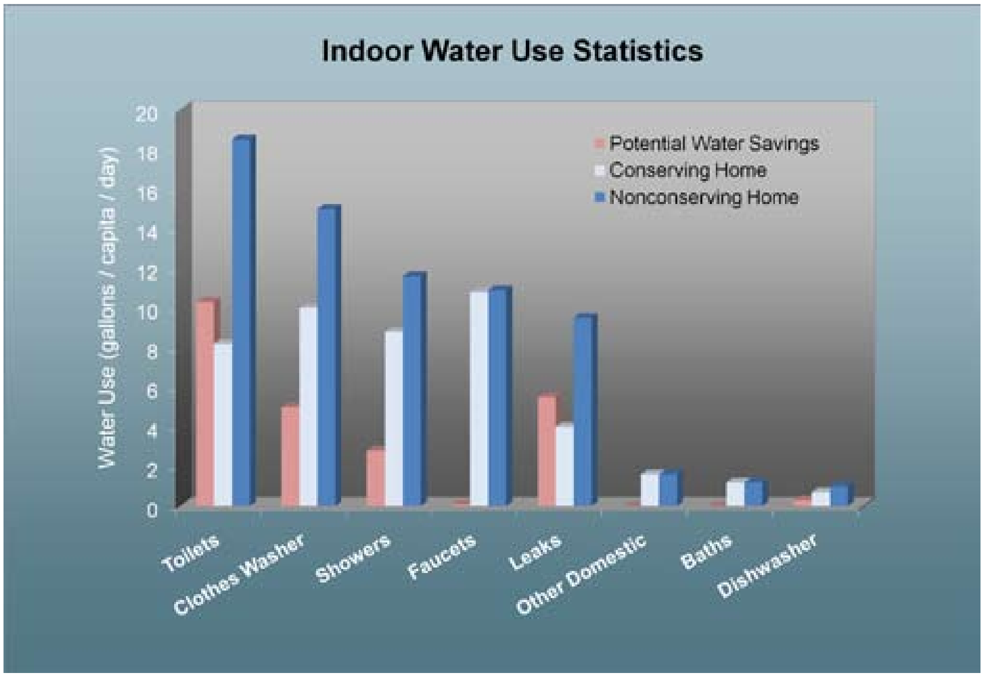


Figure 7-2. Indoor water use statistics. ***Source : U.S. General Accounting Office, 2000; Vickers, 2001.***

be minimized by reducing lawn area, ensuring lawns are established only where there are several inches of top soil, planting conservation ground cover mix, and optimizing watering schedules by utilizing sensors that ensure watering occurs only when necessary.

Public Water System Conservation Measures

In New Hampshire the largest customer of many public water systems is the water system itself via the water it loses through leaks in the distribution system, undocumented uses of water it does not bill for, or by not accounting for all of the water it pumps from sources.

The first step for a public water system owner to take when implementing a water conservation program is to conduct an audit of the system to assess the volume of water pumped from sources compared with the volume delivered to customers. The system owner can then determine the quantity of water pumped into the system that cannot be accounted for due to unauthorized water uses, leaks in the distribution system, or metering errors. The owner may then take measures to reduce unaccounted for water by conducting a system-wide leak detection and repair program, calibrating meters, and identifying and calculating uses of water that are not currently being accounted for. Another important conservation measure that public water system owners can implement is to ensure water customers are billed based on the volume of water that is used. Water use rate structures may encourage water use efficiency through surcharges applied to landscape watering as measured by an additional water meter (if allowed by the local sewer department), or through unit prices that increase as residential use exceeds certain water use thresholds.

An essential water conservation measure for public water systems is establishing an education and outreach program to promote how and why its customers should conserve water. Water systems can offer water audits to residential, industrial, commercial and institutional customers to identify cost-effective water conservation measures. Water systems can also establish financial incentives such as rebates for customers that invest in conservation measures, for example replacing older high volume toilets with more efficient models.

Water use restrictions are often used during summer months when outdoor water use for lawn irrigation places a high demand on water systems. Enforcing restrictions on outdoor watering can help to alleviate high demand in periods of reduced supply. Encouraging changes in the ways customers use water can help especially in the long term to create a sense of value and efficiency regarding water resources.

Industrial, Commercial, Institutional and Agricultural Water Conservation Measures

Industrial, commercial and institutional water users can perform audits similar to those used to assess households and public water systems. The most common conservation measures in the industrial sector are site-specific engineering modifications to water-using equipment and processes. These modifications may include optimization and recycling of cooling and process water, sequential reuse, improved control systems, and process adjustments. At most commercial and institutional sites, the greatest water savings is generally achieved by reducing irrigation of lawns and landscaping and replacing plumbing fixtures with low-volume toilets, urinals, showerheads and faucets. For agricultural water users, the greatest water savings may be achieved through the choice of crops, optimizing irrigation practices for crop production, and ensuring water is efficiently used for sanitation practices associated with food preparation.

Water Use and Energy Use Are Intrinsically Connected

Although many people today associate energy use with climate change, the relationship between water use and climate change is often overlooked. The pumping, treatment, distribution, heating and cooling of water require considerable inputs of energy. A national expert on water conservation at the EPA has estimated that approximately 3-10 percent of energy use in the United States can be related to pumping, treating, conveying and using water (U.S. Environmental Protection Agency [USEPA], 2008a).

7.2 Issues

7.2.1 Residential Development Patterns and Lawn Watering Lead to Water Supply Restrictions in Many Areas of the State

Outside of New Hampshire's cities, homes and businesses are built on lots that are usually at least an acre and are typically developed with lawns and other landscaping features. Extensive clearing and grading of new lots is now the norm. The maintenance of these manufactured landscapes creates a pronounced increase in water demand during the summer (Figure 7-3). Water use more than doubles in some New Hampshire municipalities that have undergone significant growth in the last few decades.

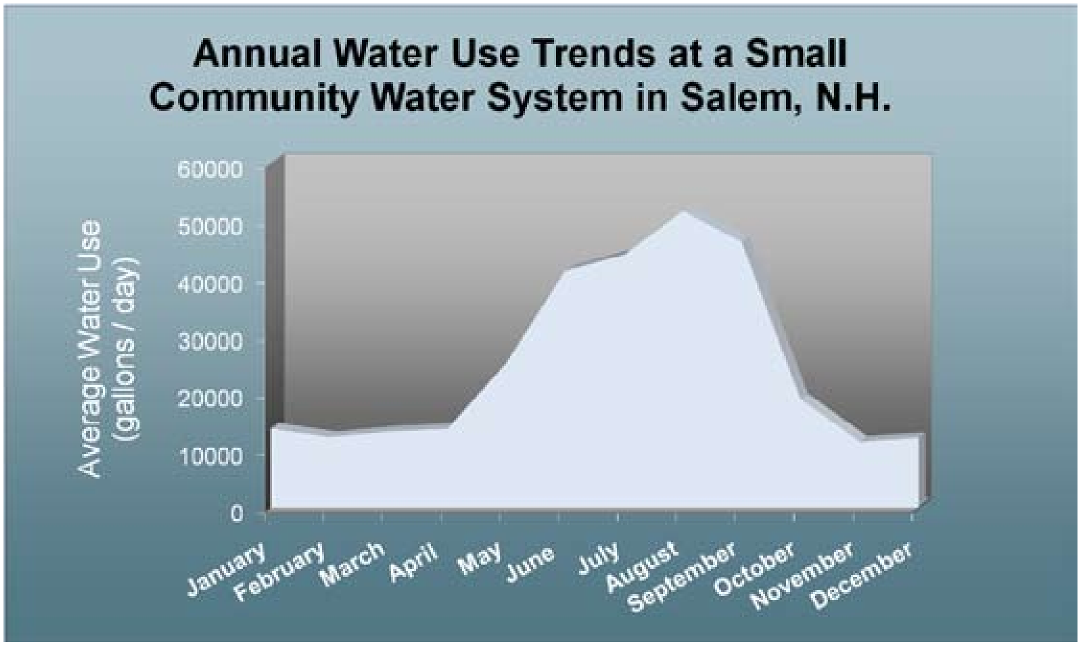


Figure 7-3. Annual water use trends at a small community water system in Salem, N.H. *Source: NHDES, 2008a.*

In addition to the irrigation issue, today's new homes are typically much larger than in the past, with more bathrooms, hot tubs, dishwashers and garbage grinders that increase water demands. As previously described in section 7.1.2, newer homes have more efficient fixtures than older homes, but the large size of the homes and irrigated grounds more than offset the savings. As land is cleared for home construction, trees are removed and topsoil is often carried away from the lot to be sold. Removing this organically rich soil reduces the lawn's ability to retain moisture and nutrients, creating excess needs for both water and fertilizer. The removal of mature trees increases the lawn's exposure to drying winds and sunlight. All of these factors lead to the increased water demand during the summer months, primarily created by irrigation.

7.2.2 Climate Change

The amount of water used in the summer and fall for irrigation of lawns, crops or golf courses is significantly affected by temperature and precipitation trends. As temperatures increase, so will water use for these activities to offset increased evapotranspiration. Longer growing seasons will affect water use habits, and the increase in intense rainfall events could reduce the potential for rain to infiltrate into the ground, reducing water availability.

7.2.3 Aging Water Systems Increase Water Losses

Leaks can be major sources of water loss in a distribution system, especially in old communities that still have some asbestos cement pipes. Some systems also have water lines at shallow depths due to bedrock. These shallower lines are more susceptible to freezing during colder months. Water systems can elect to "blow off" water by opening an extra valve in the line and discharge water onto the ground to prevent the lines from freezing. With some of the older community systems in New Hampshire, the continuous discharge through these blow-off valves provides a quick fix for a persistent problem. The costs of losing large volumes of water through leaks or blow-off valves may be alleviated by investing in repair or reconstruction of water lines to current design standards.

7.2.4 Lack of Public Understanding of Finite Water Resources

Public support for water conservation is essential in order to reduce household use. Given the plethora of lakes and ponds and the extensive networks of rivers and streams in New Hampshire, it is difficult for the public to see the finite nature of water resources. Nevertheless, the availability of new water sources is diminishing, the cost of treating water from existing sources is climbing, and some water sources are unavailable due to contamination. These facts need to be brought to the attention of the public if they are going to be expected to support water conservation efforts.

7.2.5 Conservation Investments: Lack of Long-Term Thinking

The goal of conserving water in order to save money requires a vision beyond the up-front costs associated with the initial investment in water efficient fixtures and equipment. Because of the initial costs, many businesses and residents are reluctant to undergo retrofits, especially when water is so inexpensive. Water systems may also be concerned about losing revenue if they are unsure about how to implement conservation programs in a revenue-neutral manner.

7.2.6 Conservation Rates: A Difficult Sell

Compared to many other products that people regularly purchase, water is relatively inexpensive. A typical consumer in New Hampshire pays less than a few hundred dollars per year – not even enough to buy groceries for a family for more than a week or two. Yet many residents feel that water should be free. Conservation rate structures, which charge increasing rates for greater water use, can be effective tools in encouraging residential water conservation. However, asking customers to choose between paying more and using less of a product is a difficult case to make. Resistance from customers may present an obstacle to implementing conservation rate structures.

7.3 Current Management and Protection

7.3.1 Water Use Registration and Reporting

The Water Use Registration and Reporting program is a key component of the state's efforts to comprehensively manage water resources. The objective of the program is to gather data on the major uses of the state's water and the demands placed upon individual aquifers, streams and rivers. All facilities that use more than 20,000 gallons of water per day, averaged over a seven-day period, must register with DES. Under the program "use" of water means the withdrawal of water from a source, transfer of water from one location to another, or return of water to the environment. Each withdrawal, discharge or transfer must be accurately measured and monthly water usage for each registered source, destination and transfer is reported quarterly to the NHGS.

Affected uses include, but are not limited to, the following examples.

- Water supply for domestic, commercial, industrial or institutional use.
- Treated or untreated municipal or industrial discharges.
- Contact and non-contact cooling water.
- Water for irrigation and snow making.
- Water used in the production of either electrical or mechanical power.
- Water transferred into and transported in bulk tanker trucks.

The collected baseline information regarding major water uses in New Hampshire is critical for managing water resources in an integrated manner. The information helps provide policy makers, regulators and stakeholders with an understanding of how cumulative water use affects overall demands and water budgets of aquifers and watersheds, which in turn supports the environmentally sound management of industrial, energy and overall development. The program also provides a tool for ensuring compliance with laws, regulations and water rights. Understanding the location, quantity and timing of water used enables DES to determine which water users are subject to laws passed by the Legislature in addition to understanding the many stresses on groundwater and surface waters.

7.3.2 Water Conservation

State Water Conservation Regulations

In 2003 the Legislature enacted RSA 485:61 to establish water conservation standards that apply to:

- New sources of groundwater for community systems.
- New sources of water for bulk and bottled water operations.
- New large groundwater withdrawals.
- New surface water withdrawals that require a water quality certification.

The rules (Env-Ws 390) adopted pursuant to RSA 485:61 require community water systems to develop and implement plans that address items such as metering, water audits and leak detection, estimating unaccounted for water, pressure reduction, rate structures, and outreach to consumers.

Industrial, commercial and institutional (ICI) water users need to replace single-pass cooling (if applicable), modify processes that result in the waste discharge of unused water, and implement appropriate best management practices (BMPs) for the facility. The initiatives and BMPs relevant to ICI facilities must be implemented when an economic analysis yields a payback period of less than four years.

Restriction of Residential Lawn Watering During a Drought

During a state- or federally-declared time of drought for the region, House Bill 457 gives authority to a local governing body of a municipality to limit lawn watering. The bill, passed in 2007, allows municipalities to develop regulations that restrict the use of water from private wells or connections to public water systems for outdoor lawn watering purposes with an obligatory three-day public notice prior to implementation.

Water Efficiency Standards for Appliances and Plumbing Fixtures

The Federal Energy Policy Act of 1992 addressed water conservation by mandating water efficiency standards for indoor water fixtures. In December 2007 federal legislation was signed into law establishing new water efficiency standards for residential dishwashers and clothes washing machines effective in 2010 and 2011, respectively.

The EPA has also developed a program called WaterSense that enables consumers to easily identify water-efficient products that do not sacrifice performance or quality. The program website provides directories of service providers and partnered manufacturers, retailers and distributors of water-efficient products. Similar to the Energy Star program for energy-efficient products, WaterSense endorses water-efficient products using a unique logo (Figure 7-4) (USEPA, 2008b). DES has joined the WaterSense program as a partner and promotes the program within New Hampshire. Water utilities are encouraged to become partners to receive valuable outreach materials that may supplement existing demand management efforts.

Figure 7-4. When using products bearing the WaterSense label, consumers can expect exceptional performance, savings on water bills, and assurance water is being conserved for future generations.

Innovative Water Management Projects

Innovative water use and reuse projects are already being implemented throughout the state. Treated wastewater is currently being used to recharge upper watersheds and to irrigate golf courses. Other projects have evaluated the feasibility of using highly treated wastewater for industrial processes. Lastly, communities are skimming high river flows to artificially recharge and store water in aquifers. DES promotes and has developed technical and regulatory guidance documents for these types of innovative projects (NHDES, 2007). However, these projects are only being pursued where existing water resources are inadequate to supply additional water or provide an appropriate assimilative capacity for additional wastewater discharges.

In early 2006 the Groundwater Discharge Permit Program developed comprehensive guidance for wastewater projects designed to recharge groundwater (NHDES, 2006). The guidance focuses on establishing baseline information needed to determine whether a given site is adequate for groundwater recharge. The guidance also addresses the design and implementation criteria needed to successfully operate and monitor the performance of a wastewater recharge-disposal method.

7.4 Stakeholder Recommendations

This section contains key recommendations that have been developed in concert with a group of volunteer stakeholders that have reviewed and contributed to this chapter.

7.4.1 Improve Per Capita Water Efficiency

New developments need to be designed to reduce outdoor discretionary water uses. Incentives should be created that encourage landowners to convert high water demand landscapes to natural or other types of low water demand landscapes. Additionally, the public should be educated and encouraged to reduce discretionary outdoor watering.

While federal regulations will ensure that new plumbing fixtures and appliances meet existing or new water efficiency standards, over half of the population of the state will reside in homes that predate these federal regulations. Programs should be developed that encourage the replacement of inefficient water fixtures and appliances.

Municipalities should adopt local ordinances to address landscape water efficiency measures. The ordinances may address limits on the amount of turf grass area, utilization of xeriscaping (landscaping that requires little or no irrigation) principles, retaining mature trees, ensuring adequate loam, water conservation controls on in-ground irrigation systems, proper irrigation design, establishment of water budget goals, and limitations on the times during which irrigation can occur. DES is currently developing model water conservation landscaping ordinances to curb the effects of landscaping techniques that result in inefficient uses of water.

7.4.2 Provide Incentives for Community Water Systems

Water systems face the difficult task of promoting something that they fear will reduce revenue. Additionally, investing in water conservation initiatives is generally secondary to investments in capital improvement projects. Water system managers more readily see the benefit of purchasing equipment or developing a water source versus spending funds to reduce water demand. Those water systems that are not required to implement efficiency measures because they are not developing new sources should be encouraged to perform comprehensive water audits to minimize and more accurately account for water use.

Upgrades to systems and hardware for more efficient water use have surprisingly short payback periods and can reduce energy costs for pumping and treatment if less water is lost following system rehabilitation. Making a case for the value of water conservation investments is necessary to reduce excess water use.

The value of saving water goes far beyond the smaller water bills and the extra supply created by conservation. Decreasing excess water use can also provide payback in the form of less stress on the water system and, consequently, less need for repair in the future. Relieving strain on water resources also helps to preserve existing water resources at the current quality and quantity so that an additional source, one in a finite supply set aside for future needs, does not need to be utilized. It is critical that water systems focus on selling less water more efficiently and charging rates that reflect the entire cost and value of water.

7.4.3 Continue Water Use Registration and Reporting Requirements, Fully Enforced and Implemented

Maintaining a database of withdrawal and use statistics for water systems is critical to the state's effective management of water resources. Non-reporting facilities and inaccurately measured uses may require enforcement. It is crucial that the Water Use Registration and Reporting Program be fully implemented over time.

7.4.4 Develop Innovative Water Resource Projects

Water resource projects should be promoted to: 1) skim high river flows to artificially recharge aquifers; 2) reuse highly treated wastewater in industrial settings to recharge upper watersheds; and 3) re-use treated graywater to irrigate landscaping. Although these projects are technically feasible and reasonable in cost, they are often not the least-cost alternative. However, in the long-term, these types of projects maximize the beneficial uses of water and will improve New Hampshire's quality of life, environment and economy as resources will be preserved.

References

Horn, M.A., Moore R.B., Hayes L., & Flanagan, S.M. (2008). *Methods for and estimates of 2003 and projected water use in the Seacoast region, southeastern New Hampshire* (U.S. Geological Survey Scientific Investigations Report 2007–5157, 87 p). Available at: http://pubs.usgs.gov/sir/2007/5157/.

Hutson, S.S., Barber, N.L., Kenny, J.F., Linsey, K.S., Lumia, D.S., & Maupin, M.A. (2004). *Estimated use of water in the United States in 2000* (U.S. Geological Survey Circular 1268. Released March 2004, revised April 2004, May 2004, February 2005). Available at: http://pubs.usgs.gov/circ/2004/circ1268/.

New Hampshire Department of Environmental Services. (2006). Groundwater discharge permitting guidance document for recharging aquifers with reclaimed wastewater (WD-05-31). Drinking Water and Groundwater Bureau, NHDES. Available at: http://des.nh.gov/organization/commissioner/pip/publications/wd/documents/wd-05-31.pdf.

New Hampshire Department of Environmental Services. (2007). Guidelines for developing an artificial recharge project. Drinking Water and Groundwater Bureau, NHDES.

New Hampshire Department of Environmental Services. (2008a). New Hampshire Geological Survey, Water Use Registration and Reporting Database. Unpublished Data.

New Hampshire Department of Environmental Services. (2008b). *Water efficiency practices, drinking water/groundwater fact sheets* (WD-GWGB-26-1 through WD-GWGB-26-17). Available at: http://des.nh.gov/organization/commissioner/pip/factsheets/dwgb/index.htm.

U.S. Environmental Protection Agency (2008a). *Energy and water, sustainable infrastructure for water & wastewater*. Available at: http://www.epa.gov/waterinfrastructure/bettermanagement_energy.html.

U.S. Environmental Protection Agency. (2008b). *WaterSense.* Retrieved July 15, 2008. Available at: http://epa.gov/watersense/.

U.S. General Accounting Office. (2000). Water infrastructure: Water-efficient plumbing fixtures reduce water consumption and wastewater flows (GAO/CED-00-232). Washington, D.C.

Vickers, A. (2001). Residential and domestic water use and efficiency measures. In *Handbook of water use and conservation: Homes, landscapes, businesses, industries, farms*. Amherst, MA: WaterPlow Press, pp. 15-19.

Chapter 8
Drinking Water

NEW HAMPSHIRE
DEPARTMENT OF
Environmental
Services

Overview

New Hampshire has an abundant supply of clean drinking water. There are challenges, however, for the public water systems that serve 64 percent of New Hampshire's population and for the remaining 36 percent of residents that rely on private, household drilled or dug wells (NHDES, 2008a). Drinking water from public water supplies is highly regulated to protect public health, but aging infrastructure and the cost of treating drinking water and otherwise meeting ever increasing regulatory requirements are significant issues for public water suppliers. Few public water systems in New Hampshire charge the true cost of providing water or have adequately planned to maintain and replace infrastructure that is decades old. Also, as our ability to detect and evaluate contaminants in drinking water has increased, so has the need to address more contaminants to protect public health. A recent example of this phenomenon is the presence of trace amounts of personal care products and pharmaceuticals in some water supply sources. The wisdom of treating all water to drinking water standards, water which is then used for non-drinking water purposes, is being addressed elsewhere in the country and needs to be considered in New Hampshire as well. Because of New Hampshire's rural nature, there is a large proportion of very small community public water systems, many of which are hard-pressed to meet the same requirements as larger systems, but with far fewer resources.

For both private well owners and public water systems that use wells, naturally occurring contaminants such as radon and arsenic are significant health concerns. Unlike public water systems, there is no requirement for private well water to be tested or treated, and many people in New Hampshire are unknowingly drinking water that exceeds health-based contaminant limits.

Finally, New Hampshire is a nationally recognized leader in protecting the groundwater and surface water that are the sources of drinking water. Still, landscape change has the potential to degrade our sources of drinking water by contributing contaminants and changing hydrology as described in Chapter 1 – Introduction and Overview.

8.1 Description and Significance

8.1.1 Drinking Water Is Critical to Health and Quality of Life

Human life depends on water. The average human can live 40 days or more without food, but only three to five days without water (Kendall, 1991). Drinking water is also used for food production and preparation, sanitation, outdoor irrigation, industrial processes and for many other activities.

The importance of drinking water and its protection was recognized 400 years ago at colonial Jamestown, Va., (see sidebar) and has been an acknowledged public health priority for centuries in the U.S. Unlike in developing countries, fewer than 1 percent of U.S. residents lived without complete indoor plumbing by the year 2000 (Rural Community Assistance Partnership, n.d.). As a result, diseases caused by unclean water supplies are much rarer in the U.S. Waterborne disease outbreaks, however, continue to occur in the U.S. and the endemic waterborne disease burden is significant. Recently, an expert panel of scientists from the Centers for Disease Control and Prevention and the U.S. Environmental Protection Agency estimated that 5.5 million to 32.8 million cases of acute gastrointestinal illness per year are attributable to community drinking water systems in the U.S. (Messner et al., 2006).

"There shall be no man or woman dare to wash any unclean linen, wash clothes, ...nor rinse or make clean any kettle, pot or pan, or any suchlike vessel within twenty feet of the old well or new pump. Nor shall anyone aforesaid within less than a quarter mile of the fort, dare to do the necessities of nature, since by these unmanly, slothful, and loathsome immodesties, the whole fort may be choked and poisoned."

- Governor Gage of Virginia, 1610

(Source: Virginia Dept. of Health, 2007)

8.1.2 New Hampshire Water Supply: Where Do We Get Our Drinking Water and How Is It Tested?

Private Wells

An estimated 36 percent of New Hampshire residents obtain their drinking water from private wells with roughly 4,700 new wells constructed each year. There are two main types of private wells in New Hampshire: bedrock wells and shallow dug wells. The type of well used is largely dependent on local soil types and water availability on the property. An estimated 90 percent of all new wells are bedrock wells, which can be from 100 to 700 feet deep, depending on where an adequate supply or yield is reached (NHDES, 2008c).

Since 2000, private wells have had to meet statewide design criteria for construction and placement (We 100-1000), but there are no clear state requirements for minimum well water quality or quantity. The State Plumbing Code requires that only potable water sources be connected to domestic plumbing systems, but this requirement is not uniformly applied, in part due to confusion about the meaning of "potable" and the absence of specific water quality standards. When homes are sold, the owner must disclose information about both the water supply system and the wastewater disposal system, including the date of the most recent water test and whether the seller has experienced a problem such as an unsatisfactory water test (RSA 477:4-c), but there is no requirement to do a test. As a result, private wells are usually only tested when the buyer chooses to do so, when a lender requires it at the time of sale, when a homeowner has a new well drilled by a contractor who recommends a test, when problems with water quality are noticeable, or in those few towns where a private well water test is required for a certificate of occupancy or for property transfer. There are also no state standards in regards to treatment of water from private wells.

Public Water Systems

A public water system is defined as "a piped water system having its own source of supply, serving 15 or more services or 25 or more people, for 60 or more days per year" (RSA 485:1-a). Public water systems must meet all the requirements of the federal and state Safe Drinking Water Acts. These requirements have increased over time.

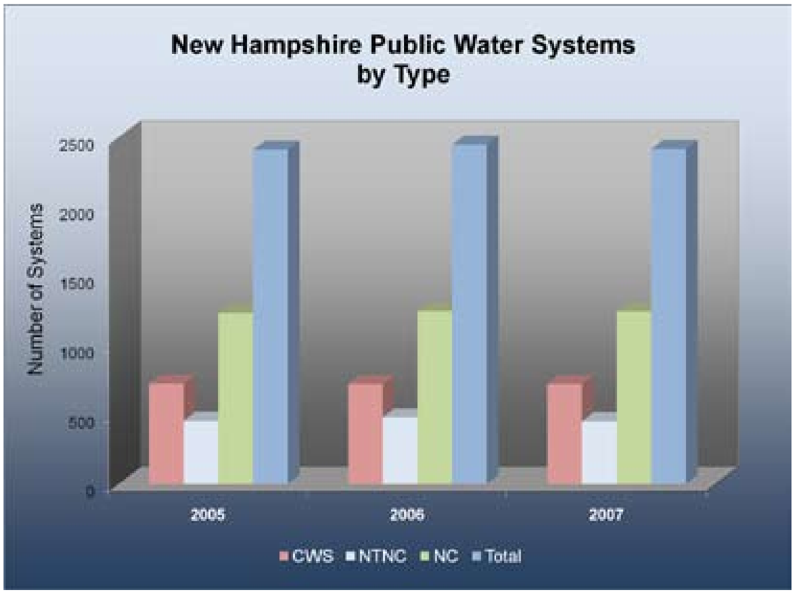


Figure 8-1. New Hampshire pubic water system profile: Community water system (CWS); non-transient/non-community (NTNC); transient/non-community (NC). ***Source: NHDES, 2008a.***

There are three types of public water systems: community water systems; non-transient/non-community systems; and transient systems. Depending on the type of system, the requirements vary, with more stringent requirements for larger systems and for those serving residential populations. Figure 8-1 shows the number of New Hampshire's public water systems among these categories. Each is described briefly below.

In 2007 there were 721 community water systems (CWSs) serving a combined resident population of approximately 849,905 (average size: 1,179) (NHDES, 2008a). These include municipalities, apartments and condominiums, mobile home parks, and single family home developments. Ninety-five percent of the CWSs in New Hampshire are small systems serving fewer than 3,300 residents. There are also 36 medium CWSs that each serve between 3,300 and 50,000 people, and two that are classified as large systems serving more than 50,000 each – Manchester Water Works and Pennichuck Water Works in the Nashua area (Figure 8-2) (NHDES, 2008a). The largest systems primarily use surface water for their source of supply, while the majority of small systems use groundwater.

The largest community systems are required to do the most comprehensive monitoring and treatment. Currently community systems must monitor for over 100 contaminants on a relatively frequent basis.

In 2007 there were 451 non-transient/non-community water systems (NTNCs) in New Hampshire (NHDES, 2008a). Typical NTNCs include non-residential schools, day cares, office buildings, commercial and industrial buildings, and

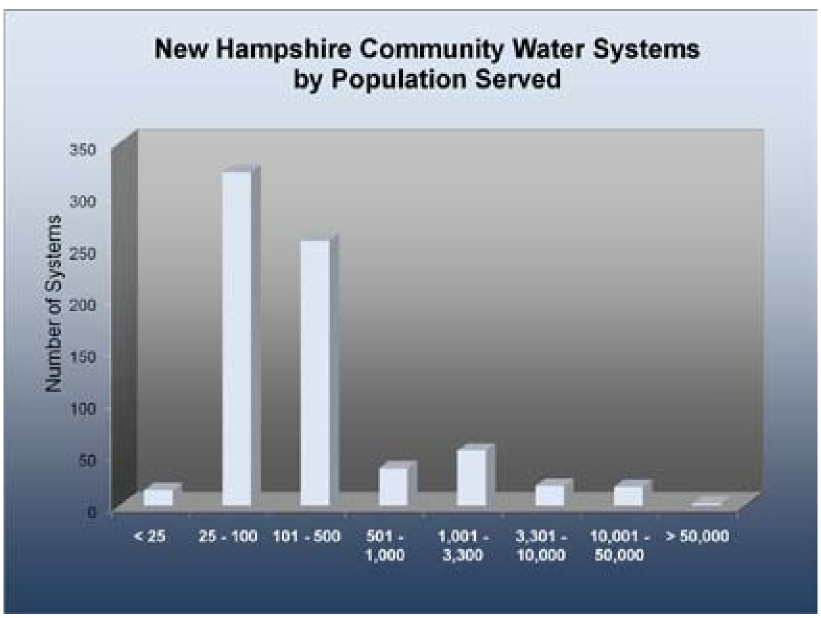


Figure 8-2. Of community water systems, the majority (82%) serve relatively small populations that have fewer than 500 customers. ***Source: NHDES, 2008a.***

businesses with permanent employees. Nineteen percent of New Hampshire's public water systems are NTNCs. This is larger than any of the other New England states and is a reflection of New Hampshire's rural nature. On average, these systems only serve about 200 people each, so there is often little economy of scale compared to community water systems.

All of New Hampshire's NTNC systems use groundwater for their source of water. The system operator is required to monitor for bacteria, lead and copper, nitrate, nitrite, inorganic contaminants (metals), volatile organic compounds or VOCs (solvents and hydrocarbons), and synthetic organic compounds or SOCs (pesticides). However, the sampling frequencies are less than for community systems and the compliance schedules for various treatment needs and monitoring are usually delayed until after community systems have complied.

In 2007 New Hampshire reported that there were 1,244 Transient/Non-Community Water Systems. Typical transient systems include restaurants, motels, hotels, ski areas, beaches and camp-grounds (NHDES, 2008a). All but one of these transient systems rely on groundwater for their source of water. Transient systems are only required to monitor for bacteria, nitrate and nitrite.

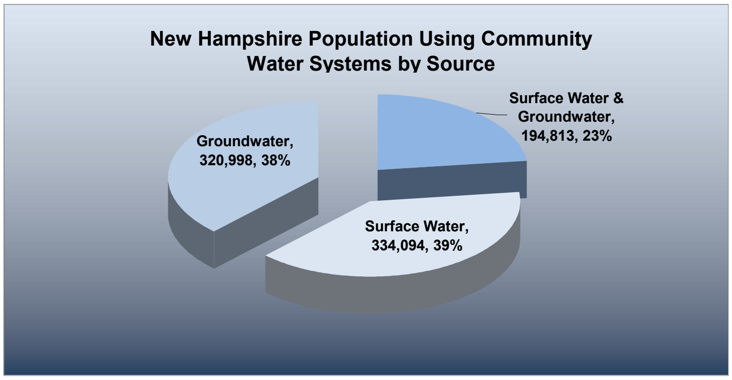


Figure 8-3. Population served by New Hampshire's community water systems. ***Source: NHDES Drinking Water and Groundwater Bureau.***

As indicated in Figure 8-3, 38 percent of the population served by CWSs is served by systems using only groundwater, 39 percent by systems using only surface water, and 23 percent by systems using both groundwater and surface water sources.

8.1.3 Drinking Water Uses and Statistics

Between 1950 and 2000 the U.S. population nearly doubled, but during the same period public demand for water more than tripled. Americans now use an average of 100 gallons of water each day, even though only two or three gallons might actually be consumed or used in cooking (U.S. Environmental Protection Agency [USEPA], 2008b). Indoor use varies but is typically around 70 gallons, nearly half of this for toilet flushing and clothes washers. That leaves nearly 30 gallons as outside water use for lawns, gardens and car washing (American Water Works Association, 2008). A recent study of the New Hampshire Seacoast estimated that each person uses an average of 75 gallons per day, although usage varied greatly among communities (Horn et al., 2008). A number of public water systems in New Hampshire report a doubling of customers' water use in the summer months due to irrigation. (See also Chapter 7 – Water Use and Conservation.)

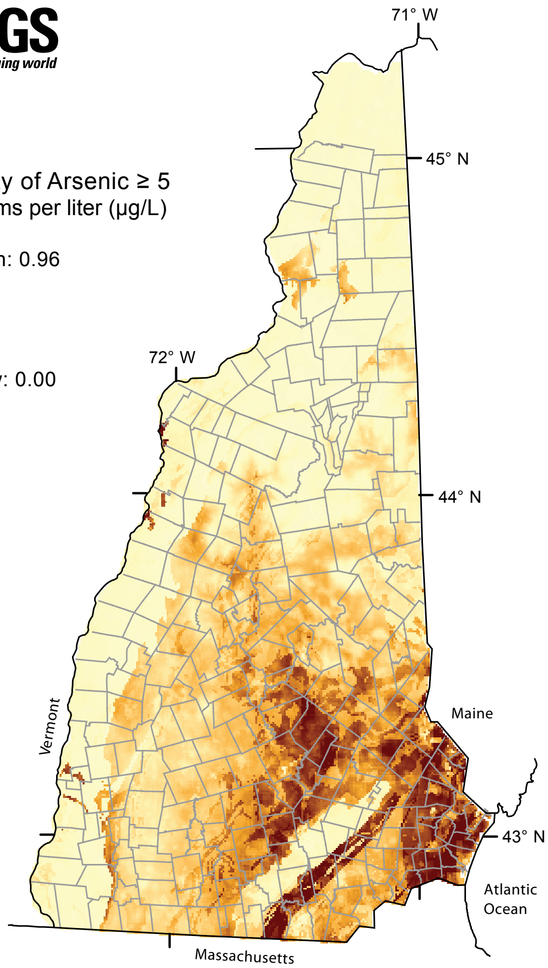


Figure 8-4. Probability that wells in each area of New Hampshire are likely to have water with arsenic concentrations exceeding 5 micrograms per liter (µg/L). ***Source: Ayotte et al., 2006b.***

8.1.4 Estimates of Naturally Occurring Contaminants in New Hampshire Well Water

New Hampshire's geology lends itself to certain common, naturally occurring contaminants, the most predominant being arsenic and radon. There are also iron and manganese deposits that can create common aesthetic concerns such as unpleasant taste and odor and unwanted staining. Our understanding of naturally occurring contaminants in well water is largely derived from the testing required at public water systems, the voluntary testing of private wells, and a number of scientific studies by USGS and others. It should be noted that many private wells are never tested.

Arsenic in well water is fairly widespread in New Hampshire (Figure 8-4). It is estimated that 20 percent of the state's private wells exceed the recently revised standard of 10 parts per billion of arsenic, which public systems must not exceed (Moore, 2004; Ayotte et al., 2006a). Although most of the arsenic in groundwater is likely of geologic origin, some of it may also be from historic pesticide use on apple orchards and other crops or from ash disposal (Robinson & Ayotte, 2006). Arsenic is a known carcinogen.

Radon gas is a byproduct of the radioactive decay of radium in certain rocks such as granite, so it is naturally common in the Granite State (Figure 8-5). Radon is a carcinogen. The major pathways to people are via migration of the gas through the soil and into homes where it may be inhaled, through groundwater entering the home as drinking water and then released as a gas, such as when showering or running water, and through ingestion of drinking water. The greatest exposure is through the first pathway.

Drinking water standards for radon have been quite controversial, with an initial proposal from U.S. Environmental Protection Agency of 300 picocuries per liter (pci/L), a limit that would have been exceeded by an estimated 95 percent of all New Hampshire wells. That standard was never finalized and it is unclear when a federal standard will emerge. Some New England states have set standards ranging from 4,000 – 10,000 pci/L and DES recommends that treatment be considered if the levels in well water exceed 2,000 pci/L. Nearly 40 percent of New Hampshire's wells are estimated to exceed 4,000 pci/L (NHDES, 2005). Other, less predominant naturally occurring contaminants found in some areas of the state include other radionuclides, fluoride and beryllium. Manganese at very high levels has also emerged as a health concern.

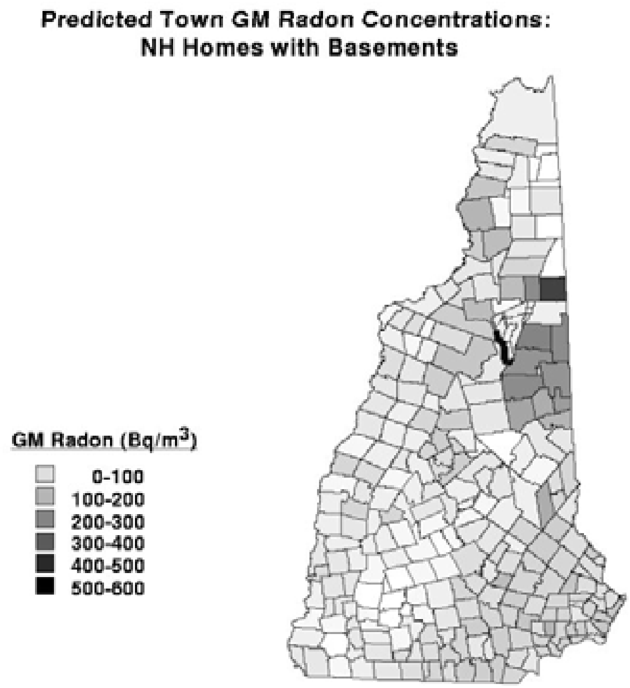


Figure 8-5. Predicted geometric mean (GM) concentrations of radon in homes with basements, by Town. ***Source: Apte et al., 1999.***

8.1.5 Water Supply System Components and Costs

Infrastructure in private water supply systems is minimal, consisting typically of a well, a pump, piping to the home, and a pressure tank. If there are water quality problems, the homeowner may have a point-of-entry device that treats all of the water entering the home, such as for radon. Alternatively, some homeowners are able to use point-of-use devices under the sink that treat only the drinking water coming from the tap, such as for arsenic. Older plumbing within the home may contain lead solder and fixtures that can leach lead and copper into the water. As previously noted, there is no uniform set of private well testing requirements or standards for treatment in New Hampshire, leaving it up to the homeowner to test their water and deal with the quality issues.

Almost all private and small community water sources are wells, either dug or bedrock as previously described. As the number of customers increases, it can become difficult to meet demands through wells. As a result, larger systems most often rely on surface water sources or a combination of surface and groundwater.

The infrastructure for public water systems includes additional components such as treatment, storage, pumping and distribution. Typically, the larger the system, the more complex the system components, with surface water systems generally requiring significantly more treatment than groundwater based systems. For many of New Hampshire's municipal systems, the infrastructure is decades if not centuries old. Therefore, routine and long-term maintenance of treatment and water distribution systems are important.

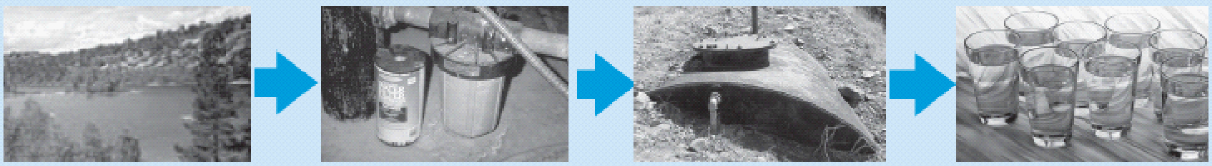
The sophistication of system monitoring and management also varies greatly. Generally, the larger systems can afford to have computerized monitoring and control systems and multi-level staffing, while smaller systems often struggle to cover the costs of basic treatment, monitoring and maintenance.

8.1.6 Multiple Barrier Approach to Safe Drinking Water

As regulations under the Safe Drinking Water Act have become more and more inclusive and stringent in response to new information about contaminants and their health impacts, water systems that once needed only basic treatment have had to implement more complex processes. Treatment,

The Multiple Barrier Approach to Protecting Public Health

The multiple barrier approach provides "defense in depth" against waterborne pathogens and chemical contaminants that can cause a variety of illnesses and conditions, some of them potentially fatal. By erecting barriers against these contaminants at each step in the process from raw, untreated source water to the delivery of treated finished water, system owners and operators can protect the health and well being of the people who rely on them for potable water.



Source Water

Barriers: Selecting and protecting the best source of supply.

Treatment

Barriers: Installing treatment methods, implemented by a certified operator, that will improve the quality of the source water.

Storage and Distribution

Barriers: Constructing, operating, and maintaining well-engineered storage facilities and distribution systems.

Monitoring and Public Information

Barriers: Providing consumers with information on water quality and health effects.

Figure 8-6. Multiple-barrier approach to safe drinking water. ***Source: USEPA, 2003.***

however, is only one element of an overall approach to ensuring safe drinking water that has been adopted over time by both the EPA and the water supply industry. The multiple barrier approach is now firmly established as the preferred way to ensure safe drinking water, although many water systems have employed the elements of this approach for many decades.

The multiple barrier approach may be slightly different for each type of system, but in general it includes steps that go all the way from the source of the drinking water to the tap. For example, a typical surface water multiple barrier approach includes watershed protection focusing on managing land uses and water-based activities, possibly optimization of the intake(s) to draw water from the location where water quality is optimal, a series of chemical and physical treatment steps including filtration and disinfection, protected storage of the treated water, monitoring steps, distribution system operations and maintenance, ongoing operator training, and additional tap water monitoring. Each of these provides a partial barrier to pathogens and chemical contamination, and together, public health is well-protected. Figure 8-6 shows the multiple-barrier approach graphically.

The multiple barrier approach can also be used for private wells. The steps are simpler but no less important, and may include using a reputable contractor to construct the well, locating it properly to avoid exposure to sanitary waste or other contaminants, keeping harmful materials away from the well, avoiding the use of nitrate fertilizers and pesticides nearby, disinfection of the piping to the house, testing of the well before use and every three years thereafter, installation and maintenance of appropriate treatment if indicated, and the use of backflow prevention devices wherever irrigation connections occur.

New Hampshire has embraced this approach and has promoted protection of the sources of our drinking water as an important tool in ensuring safe drinking water. The state supports local land use planning consistent with protecting both the quantity and quality of drinking water and many municipalities have adopted ordinances to protect their drinking water.

8.2 Issues

8.2.1 Private Well Users at Risk

Although about 36 percent of New Hampshire residents use private wells for their drinking water supply, the water quality of many of these wells is unknown. Currently there are no statewide monitoring or treatment requirements for private wells. Private wells are not covered by the Safe Drinking Water Act and are rarely regulated in towns or other states. New Hampshire has required a well construction report for private wells since the year 2000; however, there may be no records for wells constructed before then. Further, while New Hampshire encourages private well testing, it is unclear how effective the educational efforts have been.

As previously described, estimates suggest that a significant proportion of New Hampshire's private bedrock wells are contaminated with arsenic and/or radon, two naturally occurring contaminants. Recent studies have also increased concern about the health risks of elevated manganese and fluoride in some areas (Rocha-Amador et al., 2007). Dug wells are often at risk for pathogen entry if they are improperly maintained or constructed, or if wells are located where contaminants might enter due to flooding, nearby animal pens, manure piles, etc. In addition, there are other less common contaminants such as radionuclides other than radon, fluoride or beryllium, which can occur at unsafe levels in particular geographic areas. Salt from roads or salt piles is also a common problem in many areas of the state.

8.2.2 New Hampshire Has a High Proportion of Struggling Small Community Systems

Even large community water systems find the Safe Drinking Water Act regulations difficult and costly to meet, so it is no surprise that it is much more difficult for small water systems. Figure 8-7 depicts the many challenges that small water systems may encounter as they provide safe drinking water. New Hampshire has a large proportion of small systems which are widely distributed and often impossible to interconnect. Per customer costs may be dramatically different than those associated with large systems. These small stand-alone systems require fairly sophisticated operations, yet they cannot afford to hire full-time staff that specialize in drinking water. Some small municipal water systems may have to share one part-time staff member with the highway department, the fire department and others.

Conversely, larger systems benefit from economies of scale and can afford to hire highly educated, specialized staff teams with in-depth knowledge of treatment, distribution, and other aspects of drinking water provisions. As a result, customers of the smallest systems often pay the most for

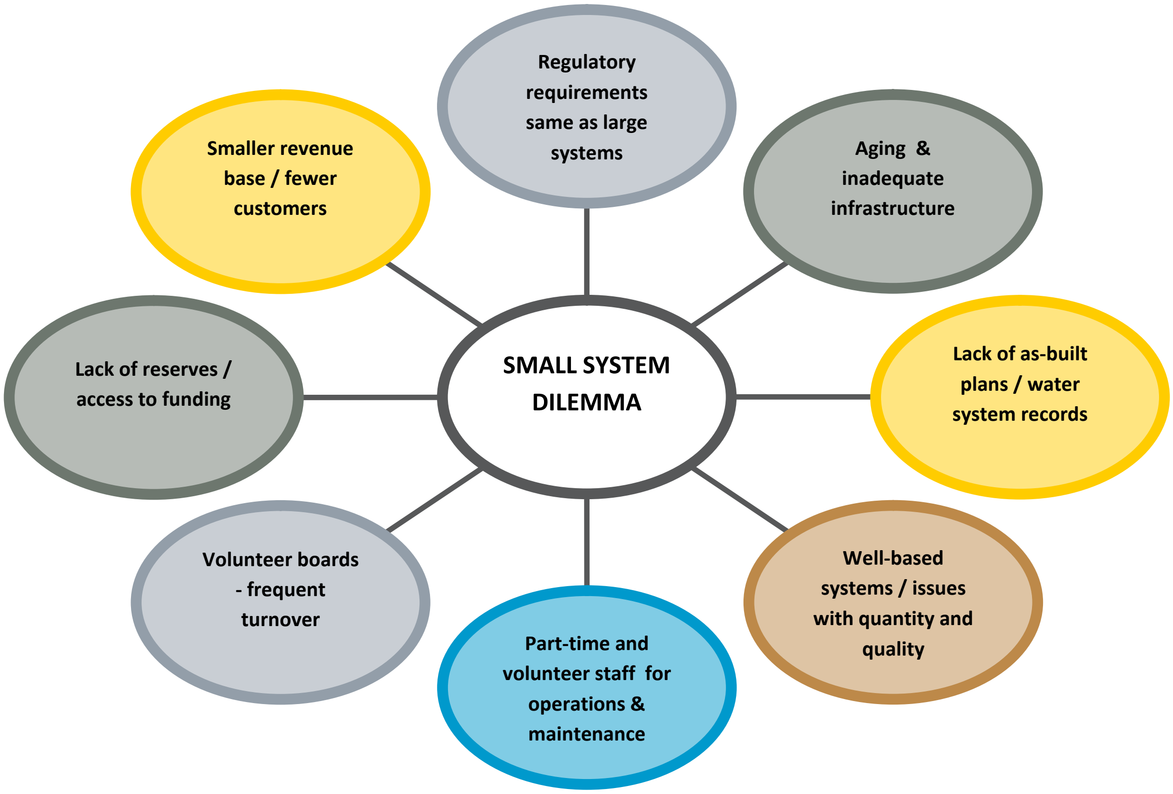


Figure 8-7. Challenges for small community water systems in New Hampshire.

the least in services. It is also important to note that providing water supply is a highly capital intensive mission where even the largest systems struggle to maintain and replace their aging infrastructure.

8.2.3 Aging Water Supply Infrastructure Is Widespread: Funding Insufficient

Much of the drinking water infrastructure in New Hampshire's cities and towns is 50 to100 years old. The infrastructure can include some or all of the following: dams for reservoirs, intakes, wells, pumps, transmission lines that take the water supply to treatment facilities, treatment facilities, water storage tanks, distribution networks, pump stations, meters, and electronic monitoring systems. Nearly all of these are costly to maintain or replace. Without regular capital improvements, more water leakage can occur and drinking water can become more difficult and costly to meet community needs.

A few of the largest systems are able to develop and implement long-term capital improvement plans, making infrastructure improvements over time. But for the most part, typical municipal systems are unable to keep up with the capital improvements that are needed to keep their systems up to date and operating efficiently, since they lack larger systems' economies of scale. Most water systems do not charge enough to cover all of the costs associated with providing water.

In 1996 a Drinking Water State Revolving Fund was established by Congress to, in part, help public water systems address aging infrastructure. New Hampshire receives approximately $8 million each year to loan out at reduced interest rates to our public water systems. In 2005 the 20-year projected demand for this funding in New Hampshire was $595.6 million (USEPA, 2005). Each year projects are prioritized based on severity of public health threat but demand consistently far exceeds supply. Because of the extensive process involved in receiving these loans, needy small public water systems rarely apply.

8.2.4 Population Pressures and the Purity Paradox

Treatment standards under the Safe Drinking Water Act are geared solely for the cost-effective protection of public health. Yet these stringent and costly standards are used to treat the entire water supply even though only a very small proportion of that water supply is actually used for drinking water. A considerable amount of water supply treated to drinking water standards is used to do laundry, flush toilets, irrigate lawns, put out fires, and clean streets.

Water systems expand to meet the peak demand of all uses, whether for drinking, lawn watering, or sanitary uses. Wells are drilled and re-drilled, surface water sources are expanded, and treatment capacity is increased to accommodate demand. Yet only a small portion of the total water used really needs to be of such high quality. There is a potential for both water and energy savings if non-drinking water uses could be satisfied by sources that are not treated to drinking water standards. Water from sinks and clothes washing (grey water) could be used for toilet flushing. Stormwater could be used to irrigate lawns with only minimal treatment in most cases. Until water costs much more, however, the savings associated with recycling grey water and stormwater will not outweigh the cost of separate conveyance systems.

This issue is likely to become more important in the future as population growth strains available supply and the cost of treatment continues to climb. As noted in Chapter 4 – Groundwater, continued growth and development also severely limits the ability to develop new municipal wells in many areas. Emerging contaminants that could drive the increase in treatment costs include pathogenic viruses, toxic algae, and pharmaceuticals and personal care products, e.g., prescription and over the counter therapeutic drugs, veterinary drugs, fragrances, cosmetics, sunscreen products, diagnostic agents and vitamins.

8.2.5 Climate Change May Have Implications for Public Health and Infrastructure

Some researchers are concerned that the rise of extreme precipitation events linked to climate change (see Chapter 1 – Introduction and Overview) will worsen U.S. waterborne disease outbreaks in the future. A 2001 article in the Journal of Public Health reported evidence that 68 percent of the waterborne disease outbreaks in the U.S. from 1948-1994 were preceded by the largest precipitation events (Curriero et al., 2001). It has not been determined whether this association holds true in New Hampshire. However, the predicted increase in frequency and intensity of storm events is a concern in terms of flooding at public water systems.

8.2.6 Water Supply Policies May Help or Hinder Smart Growth

Generally, land use patterns that concentrate growth in or near existing population centers and that involve compact development in newly developed areas are more protective of water resources and other aspects of environmental quality (air quality, energy use, consumption of other resources). There are several ways in which water supply policies on both the local and state levels may promote or hinder such "smart growth" land use patterns. First, as noted in section 8.2.4 and in Chapter 4 – Groundwater, attention should be given to the protection of future community well sites to enable growth of municipal systems in or near their existing service areas. Without this attention, these well sites will continue to be choked out by nearby development. Second, policies that address the expansion of service areas can either promote or hinder smart growth objectives, depending on the extent to which they encourage infill or compact development. Finally, the regulatory and financial demands on small community water systems may present an obstacle to compact development (as an alternative to large-lot development) outside existing service areas.

8.3 Current Management and Protection

8.3.1 Public Drinking Water Program

The New Hampshire Public Drinking Water Program implements the New Hampshire Safe Drinking Water Act (SDWA), which includes the requirements of the federal SDWA, which have expanded over the years (Figure 8-8). The federal SDWA was reauthorized in August 1996. New Hampshire has received "Primacy," the official designation by EPA for a state to implement the provisions of the federal SDWA. Approximately 90 percent of the funding for New Hampshire's Public Drinking Water Program comes from EPA, the remaining 10 percent comes from fees paid by water systems. Consequently, much of the work of DES's Drinking Water and Groundwater Bureau is dictated by the federal SDWA, including maximum contaminant levels (MCLs), monitoring schedules, and water system inspections. These requirements are designed to protect public health and were created at the national level in response to concerns expressed to the U.S. Congress regarding the need for

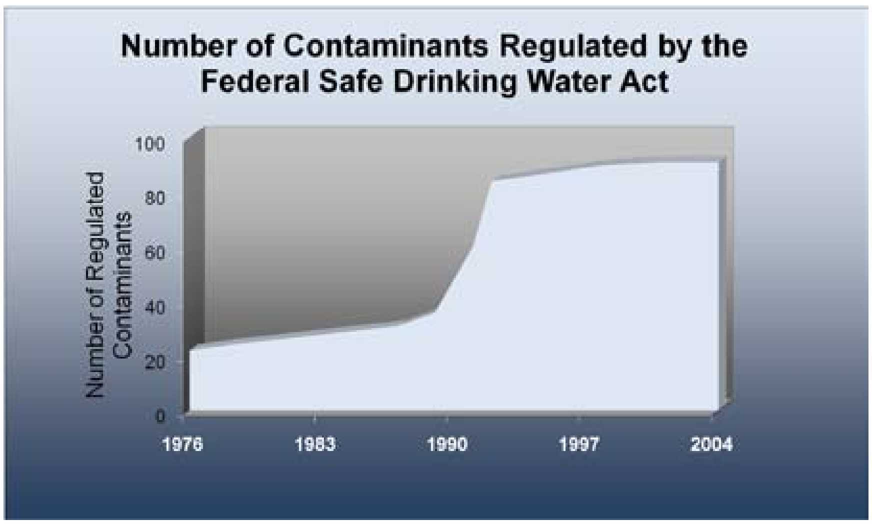


Figure 8-8. The number of contaminants regulated by the federal Safe Drinking Water Act has increased substantially over the past three decades. While compliance with the drinking water standards for so many contaminants proves to be difficult, this Figure does not account for regulatory standards that have changed to further limit a specific contaminant. *Source: USEPA, 2008a.*

strict standards in the drinking water industry. Overall, New Hampshire's drinking water program includes design, operation, and monitoring requirements for public water systems as well as protection of the sources of drinking water. In addition to DES, two public water system member groups have active roles in safe drinking water issues and provide significant training for public water system operators: New Hampshire Water Works Association and Granite State Rural Water Association. Finally, the Rural Community Assistance Program also provides assistance to public water systems in rural areas of the state.

8.3.2 Private Well Initiative

In 2000 DES and EPA launched a private well testing initiative, encouraging users of private wells to test their water more often and for a broader range of contaminants than before. DES enlisted the help of local health officers to blanket the state with posters and flyers urging homeowners to "Protect Your Family – Test Your Well's Water Quality Today." Health officers were asked to display the flyers in high-traffic locations in their municipalities. Public service announcements were produced and distributed to radio stations. A web site was developed containing pertinent fact sheets about contaminants of concern, lists of licensed well drillers and accredited laboratories, wellhead protection information, checklists, and other information for private well owners (NHDES, 2008e). Outreach to realtors and homeowners continue on a limited basis due to funding constraints.

8.3.3 Water Well Construction and Driller Licensing

Water well contractors and pump installers are licensed under RSA 482-B, which also establishes a Water Well Board to oversee licensing and the filing of well completion reports. The Water Well Board also adopts and enforces standards for the construction of wells and the installation of pumps. The board maintains records of over 112,000 wells constructed throughout the state since 1984 (NHDES, 2008d). The information is available for easy access through the internet, and is used frequently by homeowners, professionals such as hydrogeologists, and other interested parties.

8.3.4 Local Source Water Protection and Private Well Testing Ordinances

While a significant number of New Hampshire municipalities have taken steps to protect their important groundwater resources from contamination by human activities, very few have adopted regulations to protect private well users through mandatory testing. Seventy-five municipalities have adopted ordinances to protect aquifers, public wells, or other groundwater resources. Seventy of those ordinances rely on land use restrictions, while 27 incorporate a requirement for potential contamination sources to use best management practices. Twenty-one municipalities have adopted ordinances similar to the model groundwater protection ordinance developed by DES and the New Hampshire Office of Energy and Planning (NHDES, 2006), incorporating both land use restrictions and BMP requirements.

In contrast, only five municipalities have adopted ordinances that require testing of private wells for a prescribed list of contaminants, either in connection with real estate transfers or certificates of occupancy. An additional 44 municipalities report that they have a private well testing requirement, apparently in reference to the state plumbing code, which requires that water supplies connected to domestic plumbing systems supply potable water. However, the code does not define "potable" in terms of specific contaminants, so there is no assurance that the water is tested for common contaminants such as arsenic and radon.

8.4 Stakeholder Recommendations

8.4.1 Increase Private Well Protection

In spite of the major efforts towards protecting private wells by licensing contractors and drillers and requiring standards for well construction, there are no clear water quality or testing standards for private wells. There are also no mandatory state standards for vendors installing treatment for private wells. Since a large percentage of private wells produce water that exceeds health-based contaminant limits, additional steps are needed to improve the effectiveness of programs to inform and protect private well users.

8.4.2 Improve Capacity of Small Systems

New Hampshire has many small drinking water systems that are often unable to provide the same level of public health and safety protection as larger systems due to a lack of economy of scale and the difficulty in finding certified operators to assist them. Their capacity for financial management is critical, including training of water commissioners and understanding how to charge the true cost of water to customers. They also need technical assistance and managerial capacity to help deal with complex Safe Drinking Water Act regulations and critical drinking water operations. Where possible, regionalization is one option to assist small communities in meeting their obligations. Another option is to assist them through funding and technical assistance to develop better technical, financial, and management capabilities. Drinking Water State Revolving Funds should be made more accessible for small systems.

8.4.3 Maintain and Upgrade Drinking Water Infrastructure

As treatment facilities, water tanks, pumps, and water mains age, their tendency to fail increases, sometimes dramatically. However, few water systems, even the largest, can afford to pay for all of the capital improvements required to get their systems up-to-date. A significantly greater funding level is needed to protect public health and safety; the long-term economic and public health costs of not upgrading the infrastructure are too great.

8.4.4 Improve Local Protection Efforts

Although the state provides siting criteria for certain potential contamination sources, such as above ground and underground storage tanks and landfills, local planning and zoning boards have a much greater role in restricting the siting of activities that present a risk of contamination. Municipal governments need to improve their capacity to protect their own water supplies from the negative impacts that can result from development (see description of landscape change in Chapter 1 – Introduction and Overview). In addition to water wise local ordinances, more permanent protection of critical water supply lands through conservation is needed. Finally, in lieu of a statewide approach to ensure private wells are tested, municipalities should be encouraged to adopt ordinances to ensure that well testing and disclosure is occurring.

8.4.5 Track Emerging Contaminants

Although the provision of drinking water is already highly regulated, new contaminants and po-tential contaminants are identified every day. For example, using MTBE (Methyl tertiary-Butyl Ether) in gasoline to improve air quality turned out to be a mistake from the standpoint of groundwater protection, and this highly soluble contaminant has been found in many areas of New Hampshire (Ayotte et al., 2008). Although MTBE is no longer used in New Hampshire, other contaminants may threaten our drinking water quality in the future. For example, pharmaceuticals and personal care products are now being found at trace levels in groundwater and surface water in many parts of the country. Whether these will be found in New Hampshire, whether they will have human health effects, and the extent of their ecological effects, remain to be seen, but New Hampshire must continue to track research and health assessments to make sure that appropriate water quality health standards are developed when needed.

8.4.6 Water System Security and Interconnection

The water sector continues to be a concern as a target for terrorism. Preparedness for natural disasters is also necessary. DES and EPA have provided funding to help harden public water systems and to promote emergency interconnections between municipal systems. The state also encourages public water systems to join New Hampshire's Public Works Mutual Aid Program so that water systems can assist one another in the event of an emergency by enabling a prompt and effective response. Although emergency plans are required for community water systems, more emphasis in emergency preparedness is necessary including improved communications and coordination with local first responders and funding for backup power.

8.4.7 Prepare for Climate Change

Water systems need to understand climate change (see Chapter 1 – Introduction and Overview) and prepare adaptation strategies. The state should assist with identifying the anticipated impact of future climate change for the state's large, municipal water systems. The Drinking Water State Revolving Loan Fund program should take this information into consideration when making infrastructure investment decisions. It should also address drinking water impacts overall in future versions of the New Hampshire Climate Change Action Plan (NHDES, 2008b).

References

American Water Works Association. (2008). *Drinktap.org*. Retrieved March 14, 2008. Available at: www.drinktap.org.

Apte, M.G., Price, P.N., Nero, A.V., & Revzan, K.L. (1999). Predicting New Hampshire indoor radon concentrations from geologic information and other covariates. *Environmental Geology*, 37(3), 181-194.

Ayotte, J.D., Argue, D.M., McGarry, F.J., Degnan, J.R., Hayes, L., Flanagan, S.M., & Helsel, D.R. (2008). Methyl tert-Butyl Ether (MTBE) in public and private wells in New Hampshire: occurrence, factors, and possible implications. *Environmental Science and Technology, 42*(3), 677-684. Available at: http://pubs.acs.org/cgi-bin/sample.cgi/esthag/2008/42/i03/pdf/es071519z.pdf.

Ayotte, J.D., Baris, D., Cantor, K.P., Colt, J., Robinson, G.R., Jr., Lubin, J.H., Karagas, M., Hoover, R.N., Fraumeni, J.F., Jr., & Silverman, D.T. (2006a). Bladder cancer mortality and private well use in New England: An ecological study. *Journal of Epidemiology and Community Health, 60,* 168-172.

Ayotte, J.D., Nolan, B.T., Nuckols, J. R., Cantor, K.P., Robinson, G.R., Jr., Baris, D., Hayes, L., Karagas, M., Bress, W., Silverman, D.T., & Lubin, J.H. (2006b). Modeling the probability of arsenic in groundwater in New England as a tool for exposure assessment. *Environmental Science and Technology, 40*(11), 3578 – 3585.

Curriero, F.C., Patz, J.A., Rose, J.B., & Lele, S. (2001). The association between extreme precipitation and waterborne disease outbreaks in the United States, 1948-1994. *American Journal of Public Health, 91,* 1194-1199.

Horn, M.A., Moore, R.B., Hayes, L., & Flanagan, S.M. (2008). *Methods for and estimates of 2003 and projected water use in the Seacoast Region, southeastern New Hampshire* (U.S. Geological Survey Scientific Investigations Report 2007-5157.). Available at: http://pubs.usgs.gov/sir/2007/5157/.

Kendall, P. (1991). Drinking water quality and health. *Service in Action, 9.307.* Fort Collins, Colo.: Colorado State University Cooperative Extension. Available at: http://www.cdc.gov/nasd/docs/d0-00001-d000100/d000009/d000009.pdf.

Messner, M., Shaw, S., Regli, S., Rotert, K., & Blank, V. (2006). An approach for developing a national estimate of waterborne disease due to drinking water and a national estimate model application. *Journal of Water and Health, 4*(2), 201-240.

Moore, R.B. (2004). *Quality of water in the fractured-bedrock aquifer of New Hampshire* (U.S. Geologic Survey Scientific Investigations Report 2004-5093).

New Hampshire Department of Environmental Services. (2005). *Radon in air and water: An overview for the homeowner* (fact sheet WD-WSEB-3-12). Available at: http://des.nh.gov/organization/commissioner/pip/factsheets/dwgb/documents/dwgb-3-12.pdf.

New Hampshire Department of Environmental Services & New Hampshire Office of Energy and Planning. (2006). Model groundwater protection ordinance (WD-06-41). Available at: http://des.nh.gov/organization/commissioner/pip/publications/wd/documents/wd-06-41.pdf.

New Hampshire Department of Environmental Services. (2008a). *Annual compliance on public water system violations, January 1, 2007-December 31, 2007* (NHDES-R-WD-08-10). Available at: http://des.nh.gov/organization/divisions/water/dwgb/documents/2007_annual_complicance_report.pdf.

New Hampshire Department of Environmental Services. (2008b). Climate Change Policy Task Force. Retrieved December 8, 2008 from NHDES Web site. Available at: http://des.nh.gov/organization/divisions/air/tsb/tps/climate/action_plan/index.htm.

New Hampshire Department of Environmental Services. (2008c). New Hampshire Geological Survey and Drinking Water and Groundwater Bureau. Unpublished data.

New Hampshire Department of Environmental Services. (2008d). One Stop data and information. Retrieved December 8, 2008 from NHDES One Stop Web site. Available at: http://www2.des.state.nh.us/OneStop/.

New Hampshire Department of Environmental Services. (2008e). Private Well Testing Program. Retrieved December 8, 2008 from NHDES Web site. Available at: http://des.nh.gov/organization/divisions/water/dwgb/dwspp/index.htm.

Robinson, G.R., Jr., & Ayotte, J.D. (2006). The influence of geology and land use on arsenic in stream sediments and ground waters in New England, USA. *Applied Geochemistry, 21,* 1482-1497.

Rocha-Amador, D., Navarro, M.E., Carrizales, L., Morales, R., & Calderon, J. (2007). Decreased intelligence in children and exposure to fluoride and arsenic in drinking water. *Cadernos de Saude Publica* (Reports in Public Health), *23*(S4), S579-87.

Rural Community Assistance Partnership. (n.d.). *Still living without the basics in the 21st Century: Analyzing the availability of water and sanitation services in the United States.* http://rcap.org/assets/docs/basics/RCAP_full_final.pdf.

U.S. Environmental Protection Agency. (September 2003). *Small systems guide to Safe Drinking Water Act regulations* (EPA 816-R-03-017). Available at: http://www.epa.gov/ogwdw/smallsystems/pdfs/guide_smallsystems_sdwa.pdf.

U.S. Environmental Protection Agency. (2005). *Drinking water infrastructure needs survey and assessment, Third Report to Congress* (EPA 816-R-05-001). Available at: http://www.epa.gov/safewater/needssurvey/pdfs/2003/report_needssurvey_2003.pdf.

U.S. Environmental Protection Agency. (2008a). *Progress in providing safe drinking water.* Retrieved April 16, 2008 from EPA Web site. Available at: http://www.epa.gov/OGWDW/sdwa/30th/article_progress.html.

U.S. Environmental Protection Agency. (2008b). *Why water efficiency?* Retrieved March 28, 2008, from EPA Web site. Available at: http://www.epa.gov/WaterSense/water/why.htm.

Virginia Department of Health. (2007). *Source water protection in Virginia.* Retrieved July 15, 2008 from VDH Web site. Available at: http://www.vdh.virginia.gov/drinkingwater/source/importance.htm?mode=printable.

Chapter 9
Wastewater

NEW HAMPSHIRE
DEPARTMENT OF
Environmental
Services

Overview

About two-thirds of existing New Hampshire homes and the vast majority of new homes are served by individual onsite wastewater treatment systems (septic systems). The effectiveness of septic systems has improved over the years and the New Hampshire Department of Environmental Services has a comprehensive program to ensure the proper design, siting and construction of new septic systems. Older, sub-standard systems are gradually being replaced as properties change hands. Approximately one-third of the state's homes are served by centralized wastewater treatment facilities (WWTFs), many of which are small, old, and approaching their design capacities. Most WWTFs discharge treated wastewater to rivers or streams, although some discharge "onsite" to groundwater. Increased surface water monitoring and revisions of water quality standards will mean future requirements for advanced nutrient removal treatment at many WWTFs. The U.S. Environmental Protection Agency has estimated that it will take more than $570 million to address existing needs for wastewater collection and treatment upgrades and replacement, while New Hampshire estimates the need for treatment upgrades alone at $1 billion (USEPA, 2004a; Commission to Study the Publicly Owned Treatment Plants [Commission], 2007). It is not clear how that need will be met, since the federal grants that helped build the existing wastewater infrastructure are no longer available.

9.1 Description and Significance

Societies have managed and consolidated domestic wastewater to prevent disease for centuries, but the necessity for reducing wastewater pollutants in the environment was not realized until the 19th century. In 1892 only 27 American cities provided wastewater treatment (USEPA, 2004b). Since then, the number of WWTFs has grown to over 16,000 (USEPA, 2004b). The passage of the 1972 Clean Water Act fueled great improvements in wastewater treatment with the availability of grants to support sewer and WWTF construction and upgrades to meet new minimum wastewater treatment standards.

Currently, approximately two-thirds of all New Hampshire homes are served by individual onsite wastewater treatment systems, typically septic tanks and absorption fields that serve single-family residences (NHDES, 2008a). The remainder are served by larger cluster, community, or regional facilities that treat much larger quantities of wastewater.

Today's domestic wastewater contains many pollutants that can negatively affect the environment and public health and safety. In addition to human pathogens, wastewater also contains high levels of nutrients such as nitrogen and phosphorus that can trigger surface water algal blooms, low dissolved oxygen, and fish kills. Industrial wastes can also contribute toxic pollutants as byproducts of manufacturing.

Centralized treatment facilities involve major capital, operations, and maintenance costs, and the collection system of sewer lines and pump stations also requires regular maintenance and upgrades to prevent public health hazards caused by discharge of untreated or inadequately treated wastewater.

9.1.1 Onsite (Decentralized) Wastewater Management

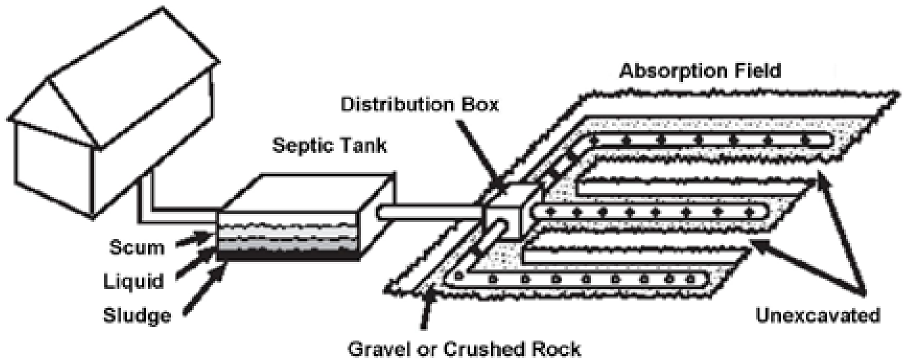


Figure 9-1. Basic components of an onsite septic system.
Source: USEPA, 2002.

Onsite individual wastewater treatment systems, usually referred to as septic systems, are the most common treatment systems for domestic wastewater in New Hampshire. These systems over time have evolved from the pit privies used widely throughout history to installations that are highly capable in suitable soils. Once viewed as a temporary wastewater solution for areas that had not yet been sewered, onsite systems are now a viable long-term solution for the vast majority of new homes in New Hampshire, with the added benefit of returning water to the local hydrologic system.

According to data submitted during the 2000 census, nearly 65 percent of the homes, full time and seasonal, in New Hampshire rely on septic systems for wastewater treatment[1] (NHDES, 2008a). Most individual onsite systems consist of a septic tank and a soil absorption field that removes settleable solids, floatable grease and scum, nutrients, and pathogens from wastewater discharges when sited and maintained correctly (Figure 9-1). The septic tank removes most floatable material and provides partial digestion of organic matter through an anaerobic process. The effluent that leaves the tank may still contain significant pathogens and nutrients that are further treated in local soils, sands, or other media absorption fields. For larger onsite commercial or cluster systems, or for individual systems in critical areas, higher levels of treatment can be achieved through more complex multiple treatment steps including recirculating sand filters and nitrification/denitrification steps. DES estimates that between 20 percent and 25 percent of new onsite systems provide wastewater treatment for commercial facilities or residential facilities with more than two families.

Innovative/Alternative Onsite Systems

Over the past several years, DES has approved many innovative technologies for the treatment and disposal of wastewater to subsurface systems. New technologies, such as large-diameter gravel-less pipe and anaerobic treatment systems, enable development to take place on more difficult sites, e.g., steep slopes or a high water table, with less required site disturbance than if conventional onsite technology were used.

[1] This does not differentiate between cluster and individual septic.

Sub-Standard and Failed Systems

A substantial, but unknown, number of existing onsite systems do not function properly because they were installed before current standards were in effect or because they were not properly designed, sited, constructed or maintained. Although sub-standard or failed systems are often suspected of impacting surface water or groundwater, their impact is not well understood. However, these systems are being gradually addressed as properties change hands and buyers require evaluations and subsequent repair or replacement and as complaints by neighbors or local health officers bring failed systems to DES's attention. DES estimates that between 8 percent and 10 percent of its current septic system approvals address repair or replacement of existing systems. In New Hampshire, evaluation of systems within 200 feet of a great pond is required before the property changes hands.

9.1.2 Centralized Wastewater Treatment Facilities

There is no single distinction between centralized WWTFs and large onsite systems, but in terms of the need for regulatory oversight, some onsite wastewater treatment facilities belong in the same category as centralized facilities. Characteristics that merit a greater level of oversight of the facility and different permitting requirements include the sophistication of the treatment processes, the complexity of the sewage collection system, and the potential environmental impact if the facility does not perform as intended. Among the centralized or complex onsite facilities, there are 91 publicly owned treatment works (POTWs) and 30 private WWTFs (Table 9-1). The capacities of these facilities range from 3,500 gallons per day to 34 million gallons per day (mgd). Thirty-two of these facilities have design flows of 1 mgd or more, 38 have flows of between 0.1 and 1.0 mgd, and 51 have design flows of less than 0.1 mgd. Of these 121 facilities, 74 require a National Pollutant Discharge Elimination System (NPDES) permit (NHDES, 2008b).

New Hampshire's WWTFs range in age from 10 to over 40 years, with the typical age being around 30 years. However, the age of a facility does not tell the whole story, since increasingly stringent limits imposed by discharge permits have driven the upgrading of many treatment plants over the years.

Table 9-1. Discharge destination and flow rate of POTWs and private WWTFs in New Hampshire. ***Source: NHDES, 2008b.***

	Groundwater	Surface Water	Groundwater and Surface Water	Total
POTWs	15	59	17	91
Private WWTFs	28	2	0	30
TOTAL	43	61	17	121

Flow Rates	Groundwater	Surface Water	Groundwater and Surface Water	Total
> 1.0 mgd	1	27	4	32
0.1 to 1.0 mgd	6	26	6	38
< 0.1 mgd	37	8	6	51
Total	44	61	16	121

Primary and Secondary Treatment

Wastewater may contain multiple classes of pollutants that demand various treatment methods. Primary treatment refers to the removal of larger particles and solids, using physical and chemical processes that coagulate and settle particles from the wastewater to eventually create a sludge that is disposed of separately. Secondary treatment, which is currently the minimum treatment required for all New Hampshire wastewater facilities, addresses oxygen-demanding pollutants and suspended solids (Figure 9-2). Secondary treatment relies mostly on natural biological processes in which microorganisms digest the organic matter in sewage to create less environmentally harmful byproducts. Wastewater treatment facilities contain and accelerate these processes to optimize the removal of "conventional" pollutants such as biochemical oxygen demand, total suspended solids, and pathogens. Some facilities in New Hampshire use aerated wastewater lagoons, allowing algae and bacteria to use sunlight and oxygen to break down these pollutants. These wastewater lagoons account for more than 25 percent of the secondary treatment methods used by WWTFs in the U.S. (USEPA, 2004b). This technology is also popular in New Hampshire, where there are 30 municipal wastewater treatment lagoons (Figure 9-3). Other facilities employ activated sludge treatment, which requires greater energy input, requires a smaller footprint, and suits larger facilities. In this type of treatment, aeration tanks mix and inject oxygen into wastewater to support a population of microorganisms that treat water.

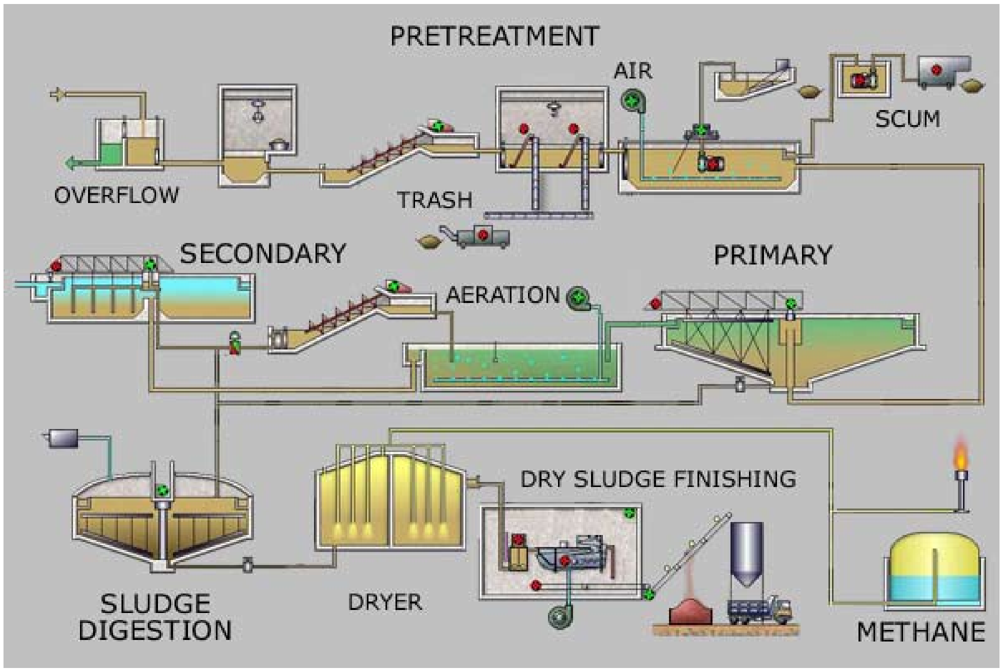


Figure 9-2. Steps of primary and secondary treatment. ***Source: Leonard, 2006.***

Disinfection

The disinfection process, which typically occurs after secondary treatment in municipal and regional WWTFs, eliminates or deactivates the microorganisms and pathogens that have the potential to cause human diseases. Products used for disinfecting wastewater include various forms of chlorine and ultraviolet radiation. Disinfection as part of wastewater treatment provides pro-

Figure 9-3. Lagoons in Pittsfield, N.H.. *Source: Town of Pittsfield, 2008.*

tection of public health where people engage in water-contact recreation or where shellfish are harvested.

Tertiary Treatment For Nutrient Removal

Although secondary treatment removes a measurable portion of the nutrient pollutants in wastewater, the discharge of a secondary-treated effluent may still affect aquatic life in receiving waters. Other advanced treatment methods can remove additional organic matter, nitrogen, phosphorus and toxins.

Land Application Methods

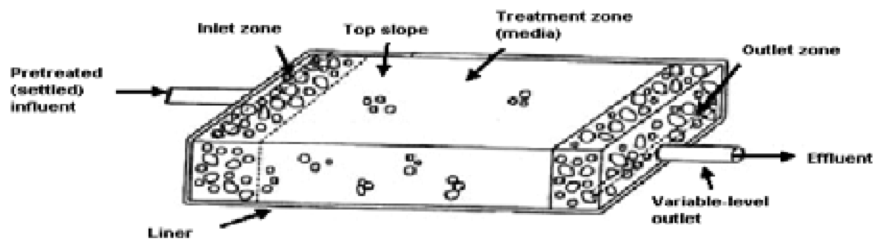
In addition to conventional WWTFs that discharge to surface waters, there are also several wastewater treatment methods that involve the application of wastewater to land or discharge into groundwater for further treatment or groundwater recharge. These methods include land treatment, wetlands treatment and wastewater infiltration.

Land treatment consists of the controlled application of wastewater to soil. As gravity pulls the wastewater downward through the soil, several physical, chemical, and biological processes help filter and treat excess nutrients. Wetlands also provide an opportunity for using the natural environment to enhance wastewater treatment. Constructed wetlands support vegetation that readily absorbs excess nutrients from wastewater-saturated soils. Wetlands also host a variety of microbial populations that can degrade pollutants in wastewater if application rates are controlled to allow healthy microbiological populations. Wastewater infiltration methods typically involve spraying, flooding, or irrigating land with partially-treated wastewater. Soil naturally filters wastewater as microbes and plants digest or take up nutrients from the soil (Figure 9-4).

Septage consists of material removed from septic tanks, cesspools, holding tanks, or other sewage treatment storage units such as septage lagoons, waste from portable toilets, and grease trap waste that has been co-mingled with wastewater. Land application, lagoons, septage treatment facilities, and several innovative and alternative waste treatment methods may process, treat, or dispose of septage. In New Hampshire more than 75 percent of septage generated in the state is transported to wastewater treatment plants for disposal (Gordon, 2006).

Residuals

Often the main focus of wastewater treatment is ensuring that the effluent, or the water discharged to the environment, meets permit requirements. The process of removing pollutants from wastewater inevitably creates an additional waste to address. Biosolids, which are solids left over from the treatment of wastewater, have a considerable capacity as fertilizer or fuel. Prior to applying biosolids to land area, biosolids are treated to reduce pathogens and vector attraction, and are analyzed for 177 constituents. If biosolids meet the standards required in Env-Wq 800, the biosolids receive state certification for beneficial reuse and may then be applied to land. Dewatered or dried biosolids also contain fuel potential and may be incinerated at waste-to-



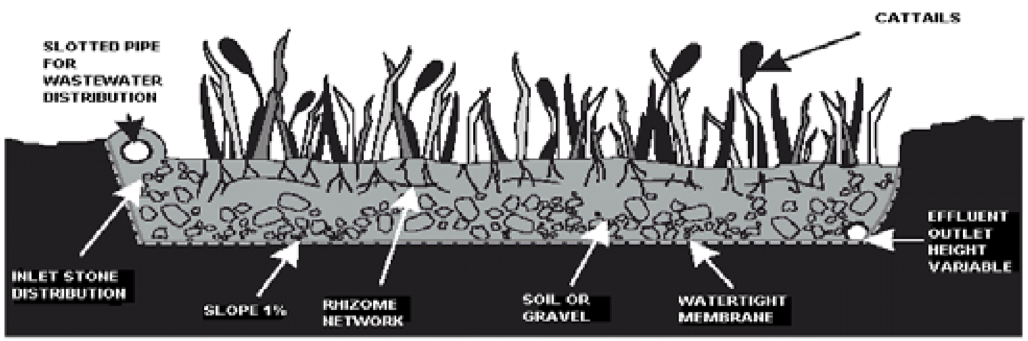


Figure 9-4. Elements of wetland wastewater treatment. ***Source: USEPA, 2002.***

energy facilities. There are also methods of anaerobically (without oxygen) digesting biosolids to generate methane gas. The methane can be captured to create heat and electricity, which may yield a significant source of power that does not require extra energy inputs from facilities.

Industrial Pretreatment

Wastewater from industrial processes often contains pollutants that disturb the effectiveness of wastewater treatment by harming helpful microorganisms. Depending on the nature of the wastewater, DES regulations (Env-Ws 904) may require pretreatment before it can be discharged into a collection system for a POTW. This industrial pretreatment also protects wastewater facilities and workers from harmful pollutants that could create hazards or interfere with operation or performance of the facility. Pretreatment reduces the likelihood that untreated contaminants enter receiving waters.

9.1.3 Combined Sewer Overflows

Combined sewers collect stormwater, industrial wastewater, and municipal wastewater or sewage. During storms, water enters storm drains (catch basins) installed in streets to minimize flooding. The stormwater combines with sewage already flowing in the pipes. With heavy rain, large amounts of stormwater can enter the combined sewer quickly and rapidly fill the pipes. If these flows exceed the capacity of the pipes then the combined sewer and wastewater will overflow, often to surface water. These wet weather discharges of untreated sewage, industrial wastewater, and stormwater are called combined sewer overflows (CSOs). These CSOs pose risks to public health, impact recreational water uses, and stress the aquatic environment (Figure 9-5).

Figure 9-5. Combined sewer overflow near a stream.
Source: USEPA, 2007.

Pollutants that are typically present in CSOs include the following: pathogens from human and animal fecal matter, which could cause illness; oxygen demanding pollutants that may deplete water column oxygen in the receiving water to levels that may be harmful to aquatic life; suspended solids that may increase turbidity or damage benthic communities; nutrients that may cause excessive algal and aquatic plant growth; toxics that may persist, bioaccumulate, or stress the aquatic environment; and floatable litter that may either harm aquatic wildlife or become a health and aesthetic nuisance to swimmers and boaters.

DES developed a CSO Control Strategy in 1990. Since then, six communities in the state addressed or developed plans to address their CSOs. The municipalities of Portsmouth, Manchester, Nashua, Lebanon, Berlin and Exeter identified a total of 47 CSOs (NHDES, 2003). In Manchester, for example, the Phase I of a CSO facility plan will reduce the average annual CSO volume from approximately 220 to 73 million gallons per year at a cost of $63.6 million (NHDES, 2003). The 220 million gallons are discharged into the Merrimack and Piscataquog Rivers from 26 CSOs. In 1997 the city of Nashua completed a CSO abatement program report that resulted in the EPA issuing an administrative order requiring the city to eliminate their nine CSOs by separating their combined sewer system by the year 2019. All nine of the CSOs will be eliminated by the year 2019 at an estimated cost of $100 million (NHDES, 2003). Although costly, the preservation of water quality, aquatic habitat, and the safety of recreational activities depend on the removal of CSOs from these aging systems.

A 2006 study conducted for the U.S. Army Corps of Engineers and five communities along the lower Merrimack River in New Hampshire and Massachusetts found that so-called Phase I CSO controls (elimination of most CSOs) combined with significant abatement of non-point sources of pollution would be more cost-effective at improving wet-weather water quality than more extensive CSO controls alone (CDM, 2006).

9.1.4 Illicit Discharges

An illicit discharge is a wastewater discharge to a municipal storm drainage system or a discharge of untreated sewage directly to a water body. Examples of illicit discharges commonly seen in New Hampshire include sanitary wastewater piping that is directly connected from a home into a storm drainage pipe or a cross-connection between the municipal sewer and the storm sewer systems. In the coastal watershed over 50 illicit discharges have been identified and removed since 1996, approximately 10 known illicit discharges are still being pursued, and another nine suspected illicit discharges are being investigated. In the Merrimack River watershed, since 2001, DES has investigated 200 miles of shoreline, documented 1,200 outfall pipes, identified and corrected five illicit discharges, and is still investigating 15 suspected illicit discharges in cooperation with local officials.

9.2 Issues

9.2.1 Facilities Approaching Design Capacity Due to Population Growth

Due to population growth, 25 percent of New Hampshire's municipal WWTFs are operating at or near 80 percent of their design capacity. These facilities will require upgrades in the near future to keep pace with projected increases in population (Commission, 2007). In the absence of adequate WWTF capacity, new development in urban fringes may instead rely on individual on-site systems and consequently shift to lower-density development, which tends to have greater impacts on water resources (USEPA, 2006).

9.2.2 Aging Infrastructure: Need for Upgrades Far Exceeds Funds

During the 1970s the federal government heavily subsidized the design and construction of the vast majority of WWTFs in New Hampshire to meet federally-mandated secondary treatment standards. Many of these facilities have surpassed their designed lifespan. Communities statewide are facing the need to build the next generation of treatment facilities to adequately meet both current and future demands for the protection of human health and the environment. The dilemma for many communities is both financial and technological since the next generation of treatment facilities must have the flexibility to remove more contaminants to achieve lower discharge levels. New Hampshire monetarily supports municipal wastewater infrastructure projects through state grants up to 30 percent of eligible costs and through State Revolving Loan Fund (SRF) loans up to 100 percent of eligible costs. Unlike the 1970s, no direct federal grants are available to fund design and construction of the next generation of wastewater facilities.

Sewer lines and, to a lesser extent, pump stations conveying sewage to treatment facilities vary in age. Because sewer lines run underground, they rarely receive consideration or draw concern unless a sewage leak becomes obvious. These leaks typically involve repairs that necessitate road closures and traffic re-routing. Aging sewer lines also carry less obvious risks, such as unwanted releases of sewage to the environment or the entry of "clean" water that can, and often does, overload treatment plants. In some cases in New Hampshire, this clean water leaking into the system, called infiltration and inflow or I/I, can account for as much as 25 percent of the treated flows, which may substantially increase the cost of treatment plant operations.

EPA Needs Assessments Identified Massive Shortfall

Through its Clean Watershed Needs Survey in 2004, the EPA collected a wealth of information to estimate funding needs for wastewater management on the state level (USEPA, 2004a). Estimated needs in New Hampshire totaled approximately $570 million including:

- $169 million for wastewater treatment facility improvements.
- $140 million for wastewater collection and conveyance system improvements.
- $261 million for the correction of combined sewer overflows.

The total was down from $900 million in the year 2000 mostly due to continuing correction of CSOs and the exclusion of some data from the 2004 survey due to a stricter protocol for documentation. It is also worth noting that since the 2004 survey was conducted, a number of NPDES permits have been calling for nutrient removal, which will substantially increase the need for facility improvements.

A more recent study conducted by a legislatively-mandated commission estimated that $1 billion will be needed for WWTF upgrades in New Hampshire over the next 10 years to meet the needs of continuing population growth and increasingly stringent treatment standards. Whichever estimate proves to be correct, the current federal and state funding of approximately $22 million per year is far short of the need (Commission, 2007).

By themselves, the statewide totals listed above do not reflect the greater struggles in smaller communities. These small community systems often need additional assistance to meet requirements set by the Clean Water Act due to a lack of adequate financing, training, and economies of scale to manage and maintain wastewater treatment systems at the same level of efficiency as larger facilities. According to the 2004 survey, small community wastewater facilities serve 39 percent of the state population and comprise $75 million, or roughly 13 percent of the total assessed wastewater treatment and collection needs (USEPA, 2004a). However, because the 2004 survey excluded information on some facilities, the reported need for small facilities is understated and is expected to be higher when the 2008 survey is completed.

9.2.3 New Requirements for Centralized Wastewater Treatment Facilities

As scientists more clearly define and quantify the effects of treated wastewater on aquatic life, treatment facilities are subject to increasingly stringent water quality limits. While part of the trend involves tighter restrictions on recognized contaminants such as nutrients, future limits will also address contaminants that may currently pass through WWTFs intact. These more recently recognized contaminants involve pharmaceuticals and personal care products, as well as certain metals such as lead, copper and aluminum. When WWTFs require expansion, state antidegradation rules require their discharges to meet a higher quality effluent standard. These rules preserve the existing quality of surface waters by restricting pollutant discharges that would further impair the water body.

The EPA is already moving toward including strict phosphorus limits for many New Hampshire discharge permits when they renew over the next five-year cycle. While some smaller facilities may avoid this requirement in the immediate future, it is likely that most, if not all, WWTFs will have to address this issue within the next five to 10 years (Commission, 2007).

The Great Bay estuary provides an example of the increasing concern surrounding nutrient pollution, which may be, in part, abated by more effective wastewater treatment. Although water quality in the Great Bay generally meets regulatory standards, monitoring has revealed a trend of increasing nutrient concentrations (New Hampshire Estuaries Project [NHEP], 2006). In addition, the potential for accidental pollution from several WWTFs in the seacoast region led to the closure of recreational shellfish beds in western Great Bay beginning in January 2005 (Metcalf & Eddy, Inc., 2005). Wastewater treatment facilities account for an estimated one-third of the nitrogen load to the Great Bay estuary (NHEP, 2006), so nitrogen removal upgrades could help alleviate the problem.

Pharmaceuticals and Personal Care Products

The latest research indicates that as people use increasing amounts of pharmaceuticals and personal care products (PPCPs), these products are being found in aquatic environments as a result of wastewater disposal. PPCPs include a wide variety of chemicals from prescription and over-the-counter therapeutic drugs including hormones, veterinary drugs, fragrances and cosmetics. They originate from human activities, residues from pharmaceutical manufacturing and hospitals, illicit drugs, veterinary use and agribusiness. While the human body breaks down some of these products, many others enter the wastewater stream intact and remain throughout the wastewater treatment process. As research furthers the knowledge related to ecological impacts of PPCPs, requirements for removing these complex substances from the wastewater stream may create a need for wastewater treatment process upgrades or supplements. The potential impacts of PPCP-containing wastewater when it is reused for recharging or supplementing drinking water sources is already being debated (American Water Works Association, 2008).

9.2.4 Landscape Change: Reliance on Single-Family Onsite Systems Promotes Sprawl

Local land use requirements such as minimum lot sizes and excessive setback distances tend to promote sprawling development, which has a number of negative impacts on water resources, as discussed in Chapter 7 – Water Use and Conservation and Chapter 10 – Stormwater. To some extent, many communities cite the need for sufficient areas of appropriate soils to accommodate single-family onsite systems as a justification for relatively large minimum lot sizes in non-sewered areas. Furthermore, local requirements, such as septic system setback requirements in excess of those required by DES, often have the effect of forcing systems onto less favorable sites without providing any additional benefits. At the same time, extending sewer service to developing areas does not necessarily discourage sprawl unless it is coupled with land use regulations that promote compact development.

An alternative to both single-family onsite systems and centralized wastewater treatment is the use of cluster systems, which consolidate the land required for individual septic leach fields into one area and effectively decrease the amount of open space consumed by each lot. Although New Hampshire's rules (Env-Wq 1005.05) specifically provide for cluster developments, the dimensional constraints, setbacks, developers' and municipal officials' lack of familiarity with these systems, and increased time needed for approval may create barriers to shifting the development paradigm at the local level.

9.2.5 Nutrient Loading Is a Concern with Onsite Systems

Of the many pollutants found in domestic wastewater that is processed by onsite systems, nutrients – nitrogen and phosphorus – are both found in concentrations of concern and are not substantially removed by onsite systems. While onsite systems facilitate the conversion of more harmful forms of nitrogen, e.g., ammonia, to less harmful compounds, e.g., nitrate, conventional systems do not remove the nitrogen, discharging it instead to the ground, where it is presumably diluted in groundwater to concentrations that are not harmful to humans or the environment. While required setbacks from property lines and water supply wells are designed to ensure adequate dilution to protect water supply wells, nitrate loading remains a concern where older systems have not been properly sited, designed, installed or maintained and where elevated levels of nitrogen reach freshwater or estuarine ecosystems. While nitrogen may contribute to over-enrichment of fresh water ecosystems, estuarine systems and coastal embayments are even more susceptible to the adverse effects of nitrogen enrichment (see section 6.2.3 in Chapter 6 – Coastal and Estuarine Waters).

Phosphorus is not removed by conventional onsite systems, but rather is adsorbed to varying degrees by the soil and plant roots through which the treated effluent passes on its way to surface waters. Phosphorus is not a generally human health concern, but it is usually the limiting nutrient in freshwater ecosystems. Consequently stream, rivers, and especially lakes and ponds are susceptible to the effects of phosphorus over-enrichment (see section 3.1.3 in Chapter 3 – Lakes and Ponds).

9.2.6 Septage Disposal

Since many New Hampshire residents rely on septic or onsite wastewater management systems, the disposal of residuals from the maintenance of septic tanks, commonly known as septage, must be done at local or regional WWTFs. New Hampshire, however, currently does not have enough capacity to treat all of the septage generated within the state. At present, out-of-state WWTFs dispose of approximately 19 percent of septage generated within the state (NHDES, 2008c). This out-of-state disposal subsidizes facilities outside the region with at least $1.5 million annually that could otherwise fund local facilities serving New Hampshire communities (Gordon, 2006). In 2007 approximately 58 million gallons, or 61 percent, of New Hampshire’s septage was disposed at in-state WWTFs, while 6 percent went to septage lagoons, 7 percent to land application, and another 7 percent to innovative or alternative “septage only” facilities (NHDES, 2008c).

This situation may worsen in the future since about 80 percent of new development in recent years has occurred in non-sewered areas (NHDES, 2008a). For example, The Seacoast Wastewater Management Study estimates that annual septage volume in that region will increase by about 33 percent by 2025, based on a population projection in non-sewered areas of the seacoast region (Metcalf & Eddy, Inc., 2005). Future increases in the volume of septage will present problematic situations for treatment plants that have reached or will soon reach their design capacity.

9.3 Current Management and Protection

9.3.1 Centralized Wastewater

State Aid Grant Program for Wastewater Treatment Facilities

The State Aid Grant (SAG) program provides financial assistance in the form of grants for 20 percent of eligible costs related to planning, design, and construction of certain sewage disposal facilities by municipalities. The enabling statute (RSA 486:1,III) sets minimum requirements for project eligibility. The SAG program has granted over $878 million ($442 million federal and $436 million state) to New Hampshire municipalities since the 1960s, when it was established, and continues to provide an average of $13.6 million annually to communities.

The SAG Plus program aims to develop regional septage capacity throughout New Hampshire. The program provides an additional 10 percent of eligible costs associated with expanding, upgrading, or developing new WWTFs to provide for septage disposal. The grant increases by 2 percent for each written agreement the host community holds with a municipality to provide for its septage disposal needs. With the additional capacity for in-state septage disposal driven by this new funding initiative, septage exports to out-of-state facilities dropped by 19 percent (or 18.3 million gallons) in 2007 (NHDES, 2008c).

State Revolving Loan Fund Program

The SRF Loan program provides low interest loans to assist communities with the design and construction of eligible wastewater projects. Requirements for obtaining SRF loans are generally similar to those for the SAG program; however, obtaining an SRF loan for construction also requires solicitation of minority- and women-owned business enterprises for project participation. The SRF Loan program also requires that DES prepare an environmental assessment to present to the municipality for public comment.

Design Standards

The rules contained in Env-Wq 700 outline state standards for the design of sewers, sewer pumping stations, sludge handling, treatment processes, and the structural design of wastewater treatment plants. Amendments to the regulations in 2005 addressed changes in technology that occurred since the rules were previously readopted in 1997.

Wastewater Treatment Facility Operator Training Requirements

DES requires licensing of all operators who are responsible for the operation of a WWTF. The operator in charge oversees the daily operation of the WWTF and is accountable for all plant operational duties, record keeping and reporting. Each facility must also designate and have a certified backup operator. To become a certified wastewater operator, individuals must apply for eligibility to sit for one of the four grades of examinations or apply for a reciprocal license. Continuing education is also a requirement for licensed wastewater operators.

Federal NPDES Permit Program

In 1972 the National Pollution Discharge Elimination System (NPDES) was established under the federal Clean Water Act. NPDES prohibits discharges of pollutants from any point source into water resources without a NPDES permit. NPDES permits include municipal and industrial categories, which include major (large dischargers) and minor (small dischargers) permits. In addition to meeting effluent limitations, WWTFs must conduct monitoring programs to document continued compliance.

Capacity, Management, Operation, and Maintenance Regulations

The EPA's recently proposed revisions for the federal NPDES permit regulations may require POTWs to develop and implement capacity, management, operation, and maintenance programs, which would affect wastewater collection system owners required to obtain a NPDES permit. The main goal of these revisions is to ensure that wastewater collection and treatment systems have the capacity to convey base flows and peak flows to prevent sanitary sewer overflows.

Prevention of Water Quality Degradation or Water Quality Standards Violations

Wastewater treatment facility discharges must not cause or contribute to water quality standards violations and NPDES permits must include effluent limitations that are protective of water quality. Where water quality is currently good, the New Hampshire antidegradation regulations aim to prevent the degradation of water quality. New WWTFs or facilities that propose to increase their design flow are subject to anti-degradation review. Where water quality is impaired and a Total Maximum Daily Load (TMDL) has been developed, NPDES must include permit limits that reflect specific waste load allocations required by the TMDL. For more information on water quality standards, antidegradation, and TMDLs, please see Chapter 2 – Rivers.

Clean Watershed Needs Survey (Infrastructure Needs)

Every four years, the EPA conducts a comprehensive assessment of the capital needs to meet water quality goals set in the Clean Water Act (USEPA, 2008). The assessment, called the Clean Watershed Needs Survey, includes information about:

- Publicly owned wastewater collection and treatment facilities.
- Stormwater and combined sewer overflows.
- Nonpoint source pollution control projects.
- Decentralized wastewater management.
- Estuary management projects.

The surveys contain information regarding the types of WWTFs and the associated population served by each. The reported needs include the estimated financial needs to improve wastewater treatment plants and collection system and wastewater management within the state.

9.3.2 Decentralized Systems

Subsurface Systems Program

The DES Subsurface Systems Bureau relies on licensed designers and installers, as well as system design reviews and installation inspections through the Subsurface Systems Bureau. While state rules require monitoring and maintenance of onsite systems by owners, there is no state program to ensure compliance with these rules. The Subsurface Program provides educational flyers regarding septic system use, maintenance and inspection with each approved system permit. With innovative or alternative systems, however, vendors may be required to provide monitoring and maintenance to ensure the proper operation of these systems.

New Hampshire rules for Subdivisions and Individual Sewage Disposal Systems (ISDS) set requirements for lot subdivisions as well as the design and placement of onsite wastewater management systems (Env-Wq 1000). The rules also include provisions for open space or conservation subdivisions and innovative or alternative onsite wastewater treatment technology.

The Subsurface Systems Bureau also reviews applications for repair and replacement of "failed" onsite wastewater systems. However, a vague definition of "failure" creates difficulty to consistently address failed systems. Legislation passed in 2008 (Senate Bill 384) defines failed systems in terms of hydraulic failure: when the system fails to contain sewage or causes discharge of sewage on the ground surface or into adjacent surface waters.

The Subsurface Systems Bureau works cooperatively with local health officers to respond to complaints regarding septic systems that are suspected of failing. In many cases, DES conducts dye tests where systems are suspected of discharging to surface waters. When hydraulic failure is evident, DES typically requires immediate and continued pumping of the septic tank and an evaluation to determine the necessary corrective action. Health officers play a vital role in protecting public health in these situations, since their statutory authority enables them to require immediate action under the threat of issuing a notice to vacate. Corrective action for failed systems may range from partial replacement to design and installation of a completely new system. DES is currently working with Granite State Designers and Installers Association to standardize the practice of evaluating systems suspected of failure.

Waterfront Property Site Assessment Studies

Before signing a purchase and sale agreement, property owners selling any developed waterfront property must have a site assessment completed as required by the Subdivision and ISDS rules (Part Env-Wq 1025) in order to determine whether the existing onsite system is DES-approved and whether the property can accommodate an onsite system meeting current standards. A permitted septic system designer must conduct the on-site assessment. The requirement applies to any property within 200 feet of tidal waters or a great pond (more than 10 acres in area), but not to property on rivers or stream shorelines. Legislation passed in 2008 (SB 384) will extend the requirement to rivers affected by the Comprehensive Shoreland Protection Act (fourth-order rivers).

Groundwater Discharge Permits

Any WWTF that discharges 20,000 gallons per day or greater to groundwater must have a groundwater discharge permit. Groundwater discharge typically applies to rapid infiltration of wastewater in shallow basins and slow rate irrigation (usually spray irrigation). The permit program requires applicants to show that discharged water remains within a designated groundwater discharge zone, and that this water meets quality standards applicable to various waters of the state. In addition, applicants must create detailed plans for a groundwater monitoring well network and outline all potential public health and environmental impacts of the system. The permit also requires that the groundwater discharge be located a sufficient distance from property lines, water resources, public water supplies and well intakes to meet applicable buffers and groundwater travel times.

Septage Management and Coordination Efforts

In 2005 DES modified the state's Septage Management Rules (Env-Wq 1600) in order to provide incentives for innovative and alternative septage disposal facilities. The incentives include decreased buffer distances to property lines and increased permit terms (10 years as opposed to five years) so that private entrepreneurs would have an easier time finding financing options.

DES also added a full time position to provide technical assistance to municipalities and raise awareness of the importance of septage management issues. The septage coordinator also helps to facilitate opportunities for public and private partnerships in order to create new facilities.

Innovative/Alternative Onsite Systems

All innovative/alternative systems for on-site treatment or disposal of wastewater below the ground need approval from DES under the provisions of New Hampshire Administrative Rule Env-Wq 1024, which allows general and provisional approvals. In 2006 DES's Water Division established an Innovative/Alternative Subsurface Technology Committee consisting of various technical and legal staff to oversee the evaluation and approval process.

DES Outreach

Wastewater infrastructure and wastewater, in general, do not typically draw the same passion at municipal meetings as a debate on building a new school or buying new fire vehicles. Communities tend to look upon wastewater as a necessary nuisance and wastewater infrastructure is taken for granted. DES outreach aims to increase awareness of the need for proactive measures to address local wastewater and septage needs. Fact sheets and seminars discuss the status of aging plants and pending permitting requirements for the WWTFs. The outreach also helps communities extend the useful life of their existing WWTFs and plan for the next generation of wastewater treatment.

9.3.3 Illicit Discharge Investigations

In 1996 DES initiated illicit discharge detection investigations in an effort to address pollution discharges to storm drainage systems. The coastal watershed communities were the first to undergo these investigations, followed by the Merrimack River watershed in 2001.

The typical procedure for conducting illicit discharge investigations includes the following steps.

1. Illicit discharge investigations begin with a meeting between DES staff and the local department of public works personnel in the municipality where the survey will take place. Storm drainage infrastructure maps are a good starting point for a discussion.
2. DES and/or Department of Public Works (DPW) staff identify hot spots and prioritize survey areas.
3. DES and/or local staff conduct dry-weather field screening to look for non-stormwater discharges in the storm drain outfalls.
4. Water quality tests are conducted to see if the non-stormwater discharges are illicit discharges.
5. DES and/or DPW staff track down the source(s) and remove the illicit discharge(s).
6. Where pollution sources are found, staff work with appropriate parties on remediation, which often requires technical and financial assistance. In some cases, regulatory compliance and enforcement is warranted.

In the coastal watershed DES's role has shifted from conducting initial investigations to assisting municipalities and other organizations in their efforts to find and eliminate illicit discharges. DES trains and assists local personnel and follows up on complaints and discharges of unknown origin that are not resolved by local programs. The New Hampshire Estuaries Project has been providing grant funds to coastal communities to eliminate illicit discharges since 2000.

As noted in Chapter 10 – Stormwater, 38 New Hampshire municipalities and non-municipal entities are required under the federal NPDES Stormwater Phase II program to develop and implement programs to eliminate illicit discharges.

9.4 Stakeholder Recommendations

This section contains key recommendations that have been developed in concert with a group of volunteer stakeholders that have reviewed and contributed to this chapter.

9.4.1 Take Action to Get the Most Out of the Existing Wastewater Infrastructure

DES should redouble its efforts to encourage the implementation of the following strategies to extend the life of existing wastewater infrastructure.

- Promote water conservation, together with control of infiltration and inflow, as the most effective means of reducing wastewater infrastructure operation and maintenance cost.
- Ensure that all wastewater utilities review capacity, management, operations, and maintenance programs to identify general areas of strength and weakness.
- Promote community on-site wastewater disposal systems.

9.4.2 Start Planning Early for the Next Generation of Wastewater Infrastructure

DES should pursue a holistic wastewater infrastructure planning strategy that encompasses a broad range of environmental considerations, employs the most appropriate technologies, and receives the necessary public support. Such a strategy would include the following components.

- Employ energy saving technologies, such as methane gas recovery, solar powered aeration equipment, etc.
- Consider how changing climate conditions may affect wastewater infrastructure.
- Consider the positive and negative impacts of wastewater treatment and discharge on groundwater and surface water. To minimize hydrologic impacts, strive to keep wastewater local to the extent practical. Where appropriate, direct some or all of the flow of treated wastewater to groundwater rather than surface waters.
- Consider the need to remove emerging contaminants from wastewater.
- Educate the public regarding the vital role of the wastewater infrastructure in protecting environmental quality and quality of life.
- Attract the next generation of wastewater treatment plant operators to the profession.

9.4.3 Promote the Use of Onsite Treatment Technology in Ways that Protect Environmental Quality

Encourage Continuing Innovation in Onsite Treatment Technology

Given that an estimated 80 percent of new development in New Hampshire is taking place in non-sewered areas, the acceptance of effective innovative technologies plays a critical role in enabling development to employ effective onsite technologies while minimizing site disturbance and returning wastewater flows to the local hydrologic system. In order to encourage continuing innovation, DES's Innovative/Alternative Subsurface Technology Committee should ensure that the approval process for innovative technologies is not overly onerous.

Create and Maintain a Uniform Regulatory Environment for Onsite Systems

DES's siting and design requirements for onsite systems are based on the latest technical information about the performance of these systems in the environment. Many municipalities impose greater setback distances with the objective of enhancing protection of water resources, but such setbacks often have unintended consequences, such as forcing septic systems onto less-than-ideal soils and slopes. To dissuade municipalities from adopting such restrictions, DES needs to do a more effective job of educating local officials about the technical soundness of DES's siting and design requirements, as well as its regulatory program. Encouraging municipalities to rely on the requirements of DES's Subsurface Systems Bureau rather than creating additional local setbacks or design requirements for onsite systems would promote a more uniform regulatory environment.

Consider Establishing a Certification Program to Evaluate Septic Systems

Practices among home inspectors and septic designers and installers vary in terms of how existing septic systems are evaluated to determine whether they are functioning as intended, either in the context of a pending property sale or a complaint regarding a system suspected of failure. While DES is working with Granite State Designers and Installers Association to voluntarily standardize such practices, it may be desirable to establish a formal training and certification program for professionals conducting septic system evaluations to ensure that appropriate standards and practices are employed.

9.4.4 Continue Efforts to Eliminate Discharges of Untreated Sewage Where Cost Effective

Both combined sewer overflows (CSOs) and illicit discharges result in the discharge of untreated sewage to the state's waters, a situation that stymies the state's goals of protecting human health and the environment. Elimination of these legacy discharges will require continued efforts by DES, communities with CSOs, and MS4s regulated under the federal NPDES program (see Chapter 10 – Stormwater). As noted in section 9.1.3, a combination of strategies to reduce pollutant loads may sometimes be more cost-effective in improving water quality than eliminating every last CSO.

References

American Water Works Association. (2008). Endocrine disruptors, pharmaceutical and personal care products: actions and communications (announcement of Web cast). Retrieved May 7, 2008 from AWWA Web site. Available at: http://www.awwa.org/publications/breakingnewsdetail.cfm?itemnumber=35166.

CDM. (2006). Merrimack River Watershed assessment study, final phase I report. Prepared for the New England District U.S. Army Corps of Engineers. Cambridge, Mass.: CDM. Available at: http://www.nae.usace.army.mil/projects/ma/merrimack/merrimackfinalreport.pdf.

Commission to Study the Publicly Owned Treatment Plants Needs of New Hampshire and State Laboratory Water Tests and Fees for Such Tests Collected by the Department of Environmental Services. (2007). Final report. State of New Hampshire.

Gordon, R. (2006, October). Septage disposal: Municipal responsibility is a key to clean water. New Hampshire Town and City. Retrieved March 24, 2008 from the New Hampshire Local Government Center Web site. Available at: http://www.nhmunicipal.org/LGCWebSite/InfoForOfficials/townandcityarticles.asp?TCArticleID=42.

Leonard, G. (2006). Image:ESQUEMPEQUE-EN.jpg. Retrieved June 30, 2008 from www.wikipedia.org. Available at: http://en.wikipedia.org/wiki/Image:ESQUEMPEQUE-EN.jpg#filehistory.

Metcalf & Eddy, Inc. (2005). Seacoast Region wastewater management study: Final preliminary findings. Wakefield, Mass.: Metcalf & Eddy, Inc.

New Hampshire Department of Environmental Services. (2003). Combined sewer overflows (CSOs), what are combined sewers and a combined sewer overflow? (fact sheet WD-WEB-9). Available at: http://des.nh.gov/organization/commissioner/pip/factsheets/wwt/index.htm.

New Hampshire Department of Environmental Services. (2008a). 2000 U.S. Census data received by NHDES through the New Hampshire Department of Energy and Planning. Data adjusted for estimated growth in 2004 and adjusted based on septic system construction permits issued by NHDES. Unpublished data.

New Hampshire Department of Environmental Services. (2008b). Data from the Groundwater Discharge Permitting and Registration Program, Drinking Water and Groundwater Bureau, and the Operations Section, Wastewater Engineer Bureau, NHDES. Unpublished data.

New Hampshire Department of Environmental Services. (2008c). Data from the Sludge and Septic Database, Residual Management Section, Wastewater Engineering Bureau, NHDES. Unpublished data.

New Hampshire Estuaries Project. (2006). State of the estuaries. University of New Hampshire, Durham, N.H. Available at: http://www.nhep.unh.edu/resources/pdf/2006_state_of_the-nhep-06.pdf.

Town of Pittsfield, New Hampshire. (2008). Waste water treatment facility. Photograph retrieved July 30, 2008 from Town of Pittsfield Web site. Available at: http://www.pittsfield-nh.com/departments/wastewater/index.htm.

U.S. Environmental Protection Agency. (2002). Chapter 4: Treatment processes and systems. In Onsite Wastewater Treatment Systems Manual (EPA 625/R-00/008). Washington, D.C.: EPA Office of Water, Office of Research and Development. Available at: http://www.epa.gov/nrmrl/pubs/625r00008/html/625R00008.htm.

U.S. Environmental Protection Agency. (2004a). New Hampshire clean watershed needs survey 2004. Washington, D.C.: Office of Water, Office of Wastewater Management. Available at: http://www.epa.gov/cwns/nh.pdf.

U.S. Environmental Protection Agency. (2004b). Primer for municipal wastewater treatment systems (EPA 832-R-04-001). Washington, D.C.: Office of Water, Office of Wastewater Management. Available at: www.epa.gov/npdes/pubs/primer.pdf.

U.S. Environmental Protection Agency. (2006). Protecting water resources with higher-density development (EPA 231-R-06-001). Washington, D.C.: National Service Center for Environmental Publications. Available at: http://www.epa.gov/smartgrowth/water_density.htm.

U.S. Environmental Protection Agency. (2007). Sanitary sewer overflows. Region 6 Compliance Assurance and Enforcement. Photo by J. L. Graham, Jr. Available at: http://www.epa.gov/earth1r6/6en/w/sso/sso.htm.

U.S. Environmental Protection Agency. (2008). Clean watersheds needs survey 2004: Report to Congress. Available at: http://www.epa.gov/owm/mtb/cwns/index.htm.

Chapter 10
Stormwater

New Hampshire Department of Environmental Services

Overview

Improving stormwater management as New Hampshire's landscape continues to be developed is necessary in order to avoid continuing deterioration in water quality, reductions in groundwater recharge, and costly damage to infrastructure. In the past stormwater has been managed with the goals of controlling erosion and flooding, but the conventional approach has not been successful in either protecting water quality or accommodating flood waters. Recent changes in state and federal programs – and to some extent in local programs – recognize the shortcomings of the conventional approach and lay a course for a more up-to-date approach that can preserve both water quality and pre-development hydrologic conditions. The new approach employs tools such as low impact development techniques and stormwater utilities. Using these tools, it is possible to maintain water quality, ecosystem health and groundwater resources.

10.1 Occurrence and Significance

Stormwater runoff begins as rainwater or snowmelt. When rain falls on a forested landscape, about half of it seeps into the ground and 40 percent evaporates or is taken up by vegetation and transpires from plants to the atmosphere. The remaining 10 percent moves slowly through the forest floor towards surface water, undergoing natural processes that filter and purify it. Landscape change significantly alters this part of the hydrologic system. Stormwater that falls on a developed landscape hits roofs, parking lots, roadways, and other impervious surfaces that prevent the infiltration of water. This reduces the amount of water that can seep into the ground and increases the speed and volume of stormwater running off a site (Figure 10-1).

In addition to affecting the hydrology of a site, landscape development also affects the quality of runoff. Aside from air pollutants picked up as it falls, rainwater is clean. As the resulting stormwater washes over developed or disturbed areas, it picks up a wide variety of pollutants such as nutrients, sediment, petroleum products, heavy metals and pathogens (Figure 10-2). In summer months the stormwater may also be warmed by its encounter with roofs and pavement.

Studies conducted on large numbers of watersheds in other regions of the country have demonstrated water quality deterioration where impervious surfaces cover greater than 10 percent of the watershed area.

While there are no statewide records regarding impervious surface coverage, a study by the University of New Hampshire found that the coverage of impervious area in New Hampshire's coastal watersheds increased from 4.7 percent in 1990 to 8.0 percent in 2005 (New Hampshire Estuaries Project, 2006). Statewide, an estimated 13,500 acres of open space is converted to developed area each year (Society for the Protection of New Hampshire Forests, 2006).

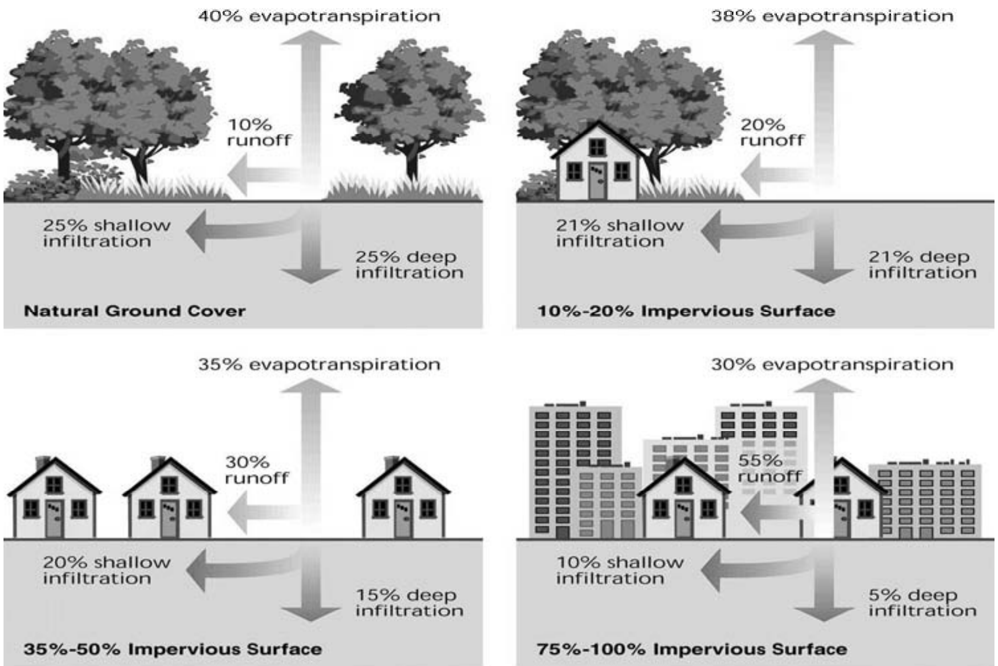


Figure 10-1. Effects of increasing impervious cover. ***Source: U.S. Environmental Protection Agency, 2006.***

10.2 Issues

10.2.1 Conventional Stormwater Management Practices Are Harmful to Water Resources

Historically, in order to prevent localized flooding and reduce erosion resulting from increased runoff at developed sites, storm drain networks were designed to collect and quickly carry stormwater runoff to the nearest surface water, such as a stream, river, lake or pond. Prior to 1960 there was little or no treatment to remove contaminants carried by the runoff (USEPA, 1983).

Over time it became clear that the conventional curb-and-gutter approach to stormwater management results in more frequent and more severe downstream flooding in urbanized watersheds due to the increased volume of runoff

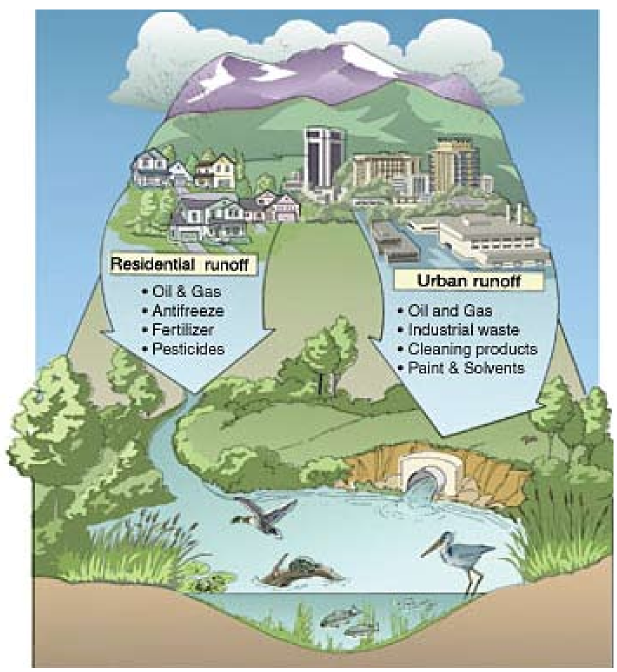


Figure 10-2. Both residential and urban areas of development contribute pollutants to stormwater runoff, many of which have everyday uses. ***Source: Clean Water Education Project, 2008.***

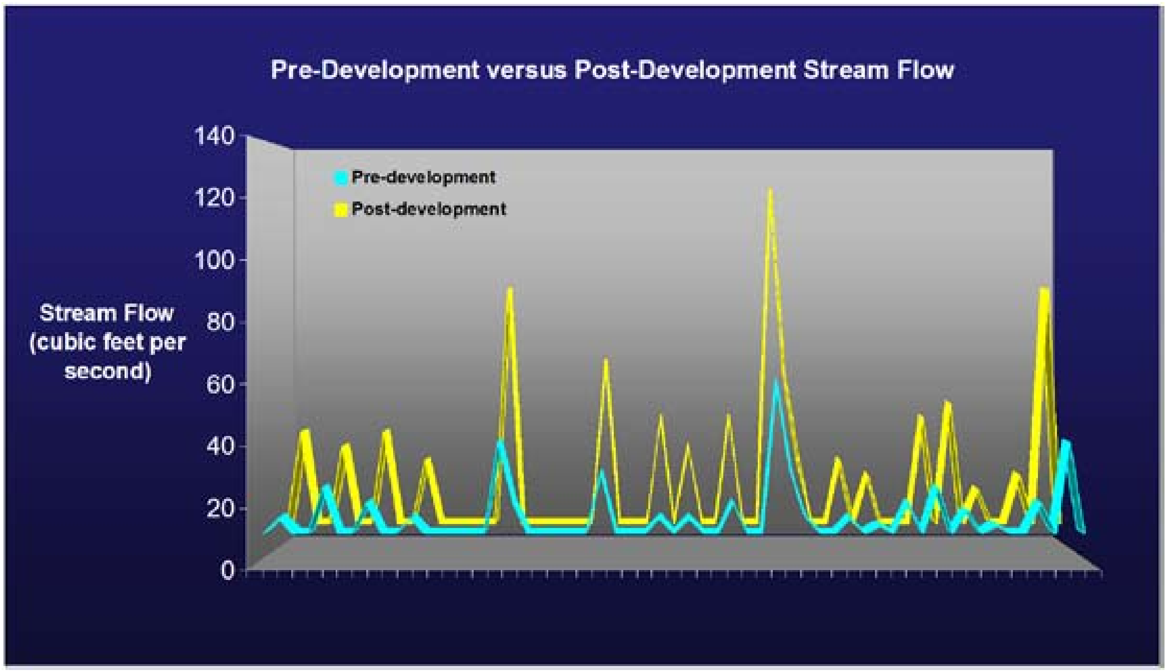


Figure 10-3. With impervious surfaces, the delivery of rainfall to streams is shortened immensely, as shown in the typical stream-flow effects of developed areas versus undeveloped areas. The sharp, accented peaks in post-development streamflow are a result of the greater volumes of water delivered to the stream in a shorter period of time. These conditions cause stream channel scouring and sediment pollution downstream. *Source: Adapted from Maryland Department of the Environment and Center for Watershed Protection, 2000.*

and the rapidity with which it reaches receiving water bodies (Figure 10-3). It also became quite clear that stormwater from developed areas contains high concentrations of a wide range of water pollutants (USEPA, 1983).

Consequently, conventional stormwater management evolved to include stormwater detention structures to slow the release of runoff from large developed sites and to provide an opportunity for settling of suspended sediment in runoff. However, as stated in a recent report from the National Research Council, "Stormwater cannot be adequately managed on a piecemeal basis due to the complexity of both the hydrologic and pollutant processes and their effect on habitat and stream quality. Past practices of designing detention basins on a site-by-site basis have been ineffective at protecting water quality in receiving waters and only partially effective in meeting flood control requirements." (National Research Council [NRC], 2008, p. 8)

Water Quality Effects

Studies conducted on large numbers of watersheds in other regions of the country have demonstrated water quality deterioration where impervious surfaces cover more than 10 percent of the watershed area (Center for Watershed Protection [CWP], 2003). A recent study in New Hampshire demonstrated that the percent of urban land use in stream buffer zones and the percent of impervious surface in a watershed can be used as indicators of stream quality (Figure 10-4) (Deacon et al., 2005).

Eighty-three percent (23,778 acres of lakes and 1,524 miles of rivers) of the water quality impairments (Figure 10-5) listed in DES's 2008 water quality assessment report were attributed wholly or in part to stormwater (New Hampshire Department of Environmental Services, 2008). The most common nonpoint source pollutants are nutrients and sediment. These wash into rivers, lakes and ponds from agricultural land, construction sites, and other developed or disturbed areas. Other common nonpoint source pollutants include pesticides, pathogens (bacteria and viruses), salts, oil, grease, toxic chemicals and heavy metals. Beach closures, degraded habitat, increased drinking water treatment costs, fish kills, and many other environmental and human health problems result from stormwater-related nonpoint source pollutants.

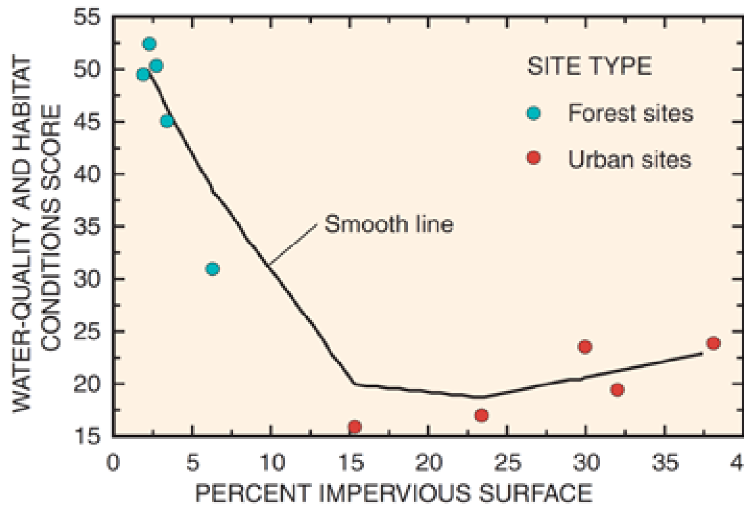


Figure 10-4. Water quality and aquatic habitat condition as a function of impervious coverage (percent) in small coastal watersheds in N.H. A lower score indicates poorer water quality and habitat conditions. *Source: Deacon et al., 2005.*

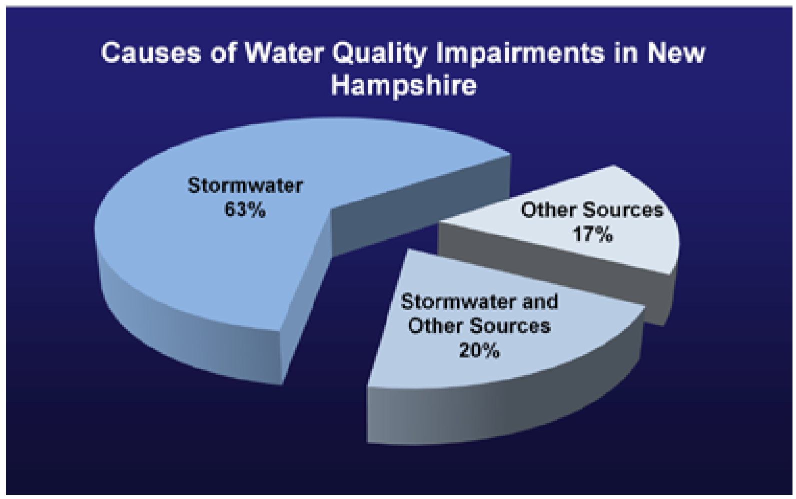


Figure 10-5. Causes of water quality impairments in New Hampshire. *Source: NHDES, 2008.*

Data from national studies and from the UNH Stormwater Center have shown that conventional approaches to stormwater management (detention basins, treatment swales) do not meet DES's current performance standard of 80 percent removal of total suspended solids (the most commonly used benchmark for such structures) and that they do not provide a viable means of meeting future water quality objectives (J. Houle, University of New Hampshire Stormwater Center, personal communication, October 10, 2008).

Effects on Groundwater Quantity

In an undeveloped landscape approximately half of the precipitation from a rain storm seeps into the ground. This water replenishes groundwater and provides water for vegetation. Chapter 4 – Groundwater provides information about the importance of groundwater for water supply and its role in supporting surface water flows and ecosystems. As Figure 10-1 demonstrates, as more impervious surfaces cover the landscape, less water is getting back into the ground. The current practice of routing stormwater to surface waters was developed in part because of concern for groundwater quality and because infiltration in the winter was thought to be infeasible. Federally funded studies in New Hampshire now indicate that stormwater can be properly treated and infiltrated on-site and year-round in areas where large quantities of regulated substances are not stored (University of New Hampshire Stormwater Center, 2008).

10.2.2 Existing Stormwater Infrastructure Is Inadequate

As Chapter 1 – Introduction and Overview and Appendix A explain, climate change is bringing higher temperatures and more frequent, intense storm events to the Northeast. Studies in New Hampshire have shown that the state's existing drainage infrastructure (culverts, etc.) is seriously under-sized to accommodate the increases in storm intensity and frequency expected in the coming decades. Specifically, a study of culverts in Keene found that 44 percent of culverts are likely undersized as a result of climate change and build-out of the watershed (Stack et al., 2006). Recent research examining impacts of climate change in the Northeast demonstrated that existing urban infrastructure, such as culverts, will be under-capacity by 35 percent (Ballestero et al., 2008). Nationwide research indicates that the frequency of heavy rainfall events is already increasing and that existing guidelines for the sizing of stormwater infrastructure are inadequate (Guo, 2006). Continuing to convert forests to impervious surfaces without implementing stormwater management designs that replicate pre-development hydrology will only exacerbate this situation, increasing the likelihood of costly damage to infrastructure during high runoff events.

10.2.3 Municipalities Have Inadequate Funding and Regulatory Mechanisms to Improve Stormwater Management

The National Pollutant Discharge Elimination System (NPDES) Phase II permit requirements, explained below in Section 10.3.1, increased municipalities' awareness of and responsibility for stormwater management. With these additional responsibilities come added costs. Maintaining catch basins and other stormwater infrastructure and cleaning streets is critical to protecting water quality downstream. Most municipalities are expected to manage stormwater with no increase in staff or budget. New funding mechanisms are needed for municipal management of stormwater if it is to be effective.

Another factor driving the need for expanded municipal stormwater programs is the evolution taking place in stormwater management. As noted above, conventional stormwater management, i.e., collect, detain, treat and release, does not fully address the negative impacts of increased impervious cover. Recognizing this problem, both state and local stormwater management programs – including DES's Alteration of Terrain program – are moving towards requiring management practices that infiltrate a prescribed volume of stormwater. However, these infiltration management practices require proper monitoring and maintenance in order to function as intended. Either individual property owners or municipalities must be responsible for ongoing monitoring and maintenance. DES's recent amendments to its Alteration of Terrain rules enable property owners to transfer their maintenance responsibilities to a willing municipality.

Since municipal budgets are supported by property taxes, property owners pay for municipal stormwater services based on the value of their property rather than the amount of stormwater generated on that property. In a typical community with a mix of residential and non-residential development, commercial and industrial entities generate most of the stormwater, but owners of residential property collectively pay more in taxes.

An alternative to general funding is the use of a stormwater utility, a special assessment district created to generate funding for stormwater management based on those who use or benefit from the system. Similar to rate-based Enterprise Funds used by water and sewer departments, stormwater utilities charge residents and businesses a fee specifically for storm drain system maintenance and upgrades, drainage plan development, flood control measures, water quality programs, administrative costs, and some capital improvements (Figure 10-6). Separate fees are typically established for residential properties and commercial/industrial properties, with commercial/industrial fees based on the amount of impervious area on the property. Monthly fees are typically quite small for single family residences, ranging from three to five dollars.

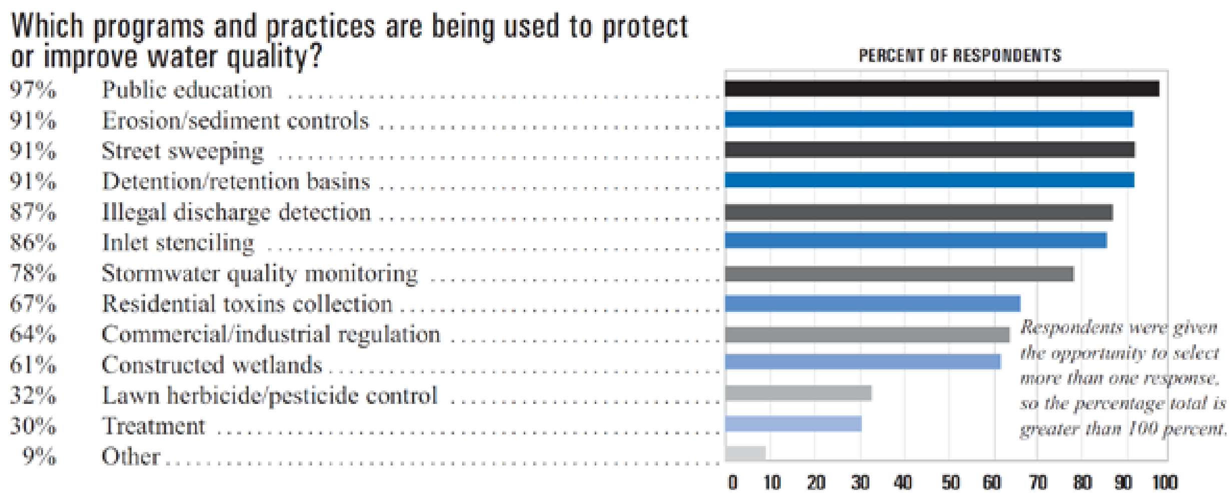


Figure 10-6. Stormwater utilities, responding to a national survey, conduct a variety of activities to protect water quality. ***Source: Black & Veatch, 2007.***

Recent years have seen increased interest in stormwater utilities in New Hampshire and other New England states, which so far have lagged behind other parts of the country in the formation of stormwater utilities. Although there are only a handful of these utilities in New England, there are over 600 nationwide (Hoskins, 2006). However, a combination of aging infrastructure, NPDES regulatory requirements, municipal budget constraints, and the positive experiences of communities in neighboring states that operate stormwater utilities are driving several New Hampshire municipalities toward the formation of their own utilities (M. Schramm, personal communication, October 14, 2008).

In 2008 the New Hampshire Legislature amended RSA 149-I to enable municipalities to form stormwater utilities.

10.3 Current Management and Protection

There are a number of federal, state, and local programs that address stormwater management. The key programs are explained below.

10.3.1 National Pollutant Discharge Elimination System

The Construction General Permit under the National Pollutant Discharge Elimination System (NPDES) stormwater program is the farthest-reaching regulatory program dealing with erosion and stormwater management in New Hampshire because it applies statewide to any construction activity that disturbs as little as one acre of land. The NPDES program includes several other important elements that address stormwater in New Hampshire.

In New Hampshire the NPDES under the federal Clean Water Act is administered by the U.S. Environmental Protection Agency. Since 1991, Phase I of the NPDES stormwater program has regulated stormwater discharges from large municipal separate storm sewer systems (large MS4s), stormwater associated with industrial activity, and construction sites disturbing five acres or more. Since March of 2003, Phase II of the NPDES stormwater program has regulated stormwater discharges from small MS4s, municipally owned industrial activities, and construction sites disturbing one acre or more. The EPA implemented the Phase I and II regulations by issuing three general permits:

- Municipal Separate Storm Sewer System (MS4) General Permit.
- Multi-Sector General Permit (MSGP).
- Construction General Permit (CGP).

The EPA's MS4 General Permit for New Hampshire covers certain small MS4s based on population or location near an "urbanized area." Forty-five towns (Table 10-1) are affected, although Brentwood, Chester, East Kingston, Hampton Falls, Lee, Madbury and Newington received waivers from the requirement to obtain a permit. An owner of an MS4, which may or may not be a municipality, in one of the affected towns must develop and

Table 10-1. New Hampshire towns that are fully or partially within an urbanized watershed.

Amherst	Durham	Hooksett	Milford	Portsmouth
Atkinson	East Kingston	Hudson	Milton	Rochester
Auburn	Exeter	Kingston	Nashua	Rollinsford
Bedford	Goffstown	Lee	New Castle	Rye
Brentwood	Greenland	Litchfield	Newington	Salem
Chester	Hampstead	Londonderry	Newton	Sandown
Danville	Hampton	Madbury	North Hampton	Seabrook
Derry	Hampton Falls	Manchester	Pelham	Somersworth
Dover	Hollis	Merrimack	Plaistow	Windham

implement a stormwater management program that addresses six minimum control measures (Table 10-2).

Table 10-2. Control measures required under MS4 general permit.

1. Public Education and Outreach
2. Public Participation/Involvement
3. Detection and Elimination of Illicit Discharges
4. Control of Runoff from Construction Sites
5. Control of Runoff from Sites After Construction
6. Pollution Prevention/Good Housekeeping

Consequently, 38 New Hampshire municipalities and four "Non-Traditional MS4s," e.g. University of New Hampshire and New Hampshire Department of Transportation, are now responsible for requiring erosion controls and post-construction stormwater best management practices for sites as small as one acre. Those municipalities and non-traditional MS4s must monitor these activities through reviewing applications, inspecting controls in the field, and ensuring long-term maintenance. Additionally, municipalities and non-traditional MS4s are required to educate and involve the public in stormwater management, investigate and remove illicit discharges, and maintain stormwater infrastructure to avoid contamination of surface waters (Table 10-2).

There are three regional coalitions in New Hampshire representing the 38 small municipal MS4 municipalities and four non-traditional MS4s. The coalitions include the Nashua, Manchester, and Seacoast areas. Members include department of public works stormwater representatives, town administrators, and consultants contracted to work on municipal stormwater programs. DES provides assistance to the coalition members through attending the monthly or quarterly meetings and any associated events or training, and providing technical and grant resources, grant project management, networking opportunities, meeting agendas and facilitation, presentations, permit updates, DES updates and communication, outreach planning and implementation, and coordination between the three coalitions.

The Multi-Sector General Permit (MSGP) covers industrial activities, including those conducted by municipalities, statewide.

The Construction General Permit (CGP), as noted above, applies to construction activity that disturbs one or more acres of land. Similar to the MSGP, the CGP applies statewide.

To be covered by the MSGP or the CGP, operators of industrial activities and construction sites must file a Notice of Intent with the EPA, and develop and implement a stormwater pollution prevention plan and (for the CGP) appropriate construction site runoff controls to meet the goal of reduced pollutant discharge to receiving waters.

10.3.2 Section 401 Water Quality Certification Program and Antidegradation

Under Section 401 of the federal Clean Water Act, if an activity that may result in a discharge requires a federal permit, that activity also requires state certification that it will not violate state water quality standards. Most stormwater related projects, including projects needing wetlands permits, alteration of terrain permits, and federal NPDES construction general permit notices of intent, already have a 401 certification because a general federal permit has been certified. Projects involving large landscape changes may require a separate certification. In New Hampshire, Section 401 Water Quality Certifications are issued by DES's Watershed Management Bureau under RSA 485-A:12.

The U.S. Army Corps of Engineers, EPA, and the Federal Energy Regulatory Commission are the primary federal agencies that issue permits requiring 401 certification. An applicant must contact these agencies to determine whether a federal permit or license is necessary for the project. If a federal permit is necessary, then the applicant must obtain a 401 certification from DES.

The antidegradation provisions of the Clean Water Act (see Chapter 2 – Rivers) are also implemented through the 401 certification process. Antidegradation places limits on water quality degradation for high quality waters.

10.3.3 Alteration of Terrain Program

DES's Alteration of Terrain permit program protects New Hampshire surface waters by requiring the prevention of soil erosion and management of stormwater runoff from large development projects. It requires a permit for any disturbance of 100,000 square feet or more, except in areas covered by the Shoreland Protection Act (within 250 feet from lakes, large ponds and large rivers), where the permitting threshold is 50,000 square feet. Until recently, the rules for major alteration of terrain reflected the conventional approach to stormwater treatment (collect, detain, treat, and release to surface water). However the rules have been extensively revised to improve treatment requirements, limit effective impervious cover, and require on-site infiltration where it is appropriate. The new rules will take effect on January 1, 2009.

10.3.4 Shoreland Protection Program

Created by the Comprehensive Shoreland Protection Act (RSA 483-B) in 1991, DES's Shoreland Protection Program enforces minimum standards for the subdivision, use, and development of land adjacent to the state's larger water bodies. Protection under the act extends to land within 250 feet of those water bodies, with various levels of restrictions for land within 50 feet, 150 feet, and 250 feet of the water body.

In 2005, Senate Bill 83 established a commission to study the effectiveness of the Comprehensive Shoreland Protection Act. Among other things, the commission was charged with assessing land-use impacts around the state's public waters; size, type, and location standards pertaining to structures as outlined in the CSPA; shoreland buffer and setback standards; and nonconforming use, lot, and structure standards. The final report of the commission (Commission, 2006) contained 17 recommendations for changes to the act. Sixteen of those recommendations for change were enacted into law and became effective April 1, 2008. The changes are broad in scope and include impervious surface limits, a provision for a waterfront buffer in which vegetation removal is restricted, shoreland protection along rivers designated under the Rivers Management and Protection Program (see section 2.3.3 in Chapter 2 – Rivers and Streams), and the establishment of a permit requirement for many construction, excavation or filling activities within the protected shoreland.

Although the 2008 legislation expanded the list of rivers and streams that are covered under the program, the program applies only to 14 percent of all rivers and streams in New Hampshire; lakes and ponds of at least 10 acres; and tidal waters.

10.3.5 Local Stormwater Programs

For most development projects that fall below the size threshold of DES's Alteration of Terrain Program and outside the jurisdiction of DES's Comprehensive Shoreland Protection Program, as well as outside the NPDES MS4 communities, the only project-specific review that these projects receive is on the local level. Although construction projects that disturb more than one acre need to file with the EPA under the NPDES Construction General Permit, the majority of these projects do not receive any formal review by the state or EPA. Consequently, municipalities play a crucial role in regulating the majority of development projects and averting the potentially significant cumulative impacts of these projects.

10.3.6 Technical Assistance Programs

Stormwater management is a component of much of the technical assistance provided by DES and others, such as the University of New Hampshire Stormwater Center.

Working with the regional planning commissions, the New Hampshire Office of Energy and Planning, and the New Hampshire Local Government Center, DES developed a model stormwater ordinance for municipalities. It addresses water quality concerns beyond traditional peak flow considerations and meets the requirements of the federal MS4 program (Regional Environmental Planning Program [REPP], 2008).

Currently, DES is finalizing a three-volume stormwater manual, which includes guidance on pollutant load reduction (volume 1), design specifications for stormwater BMPs (volume 2), and sediment and erosion control BMPs (volume 3). Volumes 2 and 3 were published in December 2008, soon to be followed by Volume 1.

The UNH Stormwater Center studies stormwater-related water quality and quantity issues. One unique feature is the field facility used to evaluate and verify the performance of stormwater management devices and technologies. Fifteen different management systems are currently undergoing side-by-side comparison testing under strictly controlled conditions. This on-campus evaluation facility enables the center to offer technology demonstrations and workshops, and also specialized training opportunities. In addition to the primary field facility, the center has other sites available to study stormwater management approaches that need more space or present unique conditions.

10.4 Stakeholder Recommendations

This section contains key recommendations that have been developed in concert with a group of volunteer stakeholders that have reviewed and contributed to this chapter.

10.4.1 Encourage and Facilitate the Local Adoption of State Stormwater Management Standards

Although DES has taken large strides to improve stormwater runoff management through revisions to the Alteration of Terrain and Shoreland Protection rules, these programs do not affect activities that fall outside the protected shoreland and below the square footage thresholds of the Alteration of Terrain program. Consequently, local land use regulations play an important role in ensuring the effective management of stormwater. Unfortunately, in many towns local regulations focus on the management of peak runoff from only the largest storms, missing the opportunity to minimize the generation of stormwater, to infiltrate it into the ground, and to adequately treat what is discharged to surface waters.

With the adoption of the revised Alteration of Terrain rules and the publication of the Stormwater Guidance Manuals, communities should be encouraged to adopt them for smaller-sized developments and redevelopments. This will require outreach and assistance at the state, regional and local levels.

Low Impact Development Techniques

Design with the Landscape
- Cluster development
- Open space preservation
- Site fingerprinting

Reduce and Disconnect Impervious Areas
- Reduced pavement widths
- Shared driveways
- Reduced setbacks
- Green roofs
- Porous pavement
- Disconnected downspouts
- Eliminating curbs and gutters
- Creating grassed swales and grass-lined channels

Intercept Runoff
- Parking lot, street, and sidewalk storage
- Rain barrels and cisterns (rainwater harvesting)
- Depressional storage in landscaped areas

Infiltration Practices
- Infiltration basins and trenches
- Infiltration swales
- Rain gardens and other vegetated treatment

Runoff Conveyance Practices
- Roughened surfaces
- Long flow paths over landscaped areas
- Smaller enclosed drainage systems
- Terraces and check dams

Filtration Practices
- Bioretention/rain gardens
- Vegetated buffers/conservation

Low Impact Landscaping
- Native, drought-tolerant plants
- Converting turf areas to shrubs and trees
- Reforestation
- Encouraging longer grass length
- Wildflower meadows rather than turf along medians and in open space
- Amending soil to improve infiltration
- Using locally captured runoff for irrigation

10.4.2 Encourage Low Impact Development and Compact Development

Preserve Natural Hydrology with Low Impact Development

Going hand-in-hand with an effort to coordinate local stormwater management regulations with state standards, low impact development (LID) site design techniques, which replicate natural hydrologic conditions, should also be encouraged to lessen the negative effects of development on hydrology and water quality. The National Research Council's stormwater report emphasizes the importance of this approach: "Nonstructural SCMs [stormwater control measures] such as product substitution, better site design, downspout disconnection, conservation of natural areas, and watershed and land-use planning can dramatically reduce the volume of runoff and pollutant load from a new development. Such SCMs should be considered first before structural practices." (National Research Council, 2008, p. 8)

LID techniques go beyond the selection of stormwater infiltration practices, as required in DES's new Alteration of Terrain rules, to encompass the entire site design process. LID site design aims to reduce and separate impervious surfaces, rely on natural treatment processes, decentralize the treatment of stormwater, and infiltrate stormwater where appropriate. Although LID techniques manage stormwater more effectively than traditional management practices and typically do not cost any more (Table 10-3), many municipalities and developers are hesitant to adopt, require and use these techniques. A concerted effort is needed to accelerate the adoption of LID site design techniques.

Table 10-3. Summary of cost comparisons between conventional and low impact development approaches. ***Source: USEPA, 2007.***

Project	Conventional Development Cost	LID Cost	Cost Difference[b]	Percent Difference[b]
2nd Avenue SEA Street	$868,803	$651,548	$217,255	25%
Auburn Hills	$2,360,385	$1,598,989	$761,396	32%
Bellingham City Hall	$27,600	$5,600	$22,000	80%
Bellingham Bloedel Donovan Park	$52,800	$12,800	$40,000	76%
Gap Creek	$4,620,600	$3,942,100	$678,500	15%
Garden Valley	$324,400	$260,700	$63,700	20%
Kensington Estates	$765,700	$1,502,900	–$737,200	-96%
Laurel Springs	$1,654,021	$1,149,552	$504,469	30%
Mill Creek[c]	$12,510	$9,099	$3,411	27%
Prairie Glen	$1,004,848	$599,536	$405,312	40%
Somerset	$2,456,843	$1,671,461	$785,382	32%
Tellabs Corporate Campus	$3,162,160	$2,700,650	$461,510	15%

[a] The Central Park Commercial Redesigns, Crown Street, Poplar Street Apartments, Prairie Crossing, Portland Downspout Disconnection, and Toronto Green Roofs study results do not lend themselves to display in the format of this table.
[b] Negative values denote increased cost for the LID design over conventional development costs.
[c] Mill Creek costs are reported on a per-lot basis.

Preserve More Natural Areas with Compact Development Strategies

A key provision of low impact development is to retain as much natural and undisturbed land as possible. This can be done through land purchases, conservation easements, or compact development methods that reduce the area disturbed for new construction.

The current, conventional method to zoning involves a minimum lot size to guide development, which often translates to dispersed development on large, equal-sized lots. Although some natural ground cover is preserved on each lot, the former natural area becomes fragmented, and large areas are converted to lawns, which are less pervious and often a source of nonpoint source pollution, e.g., nutrients and pesticides. The use of innovative zoning techniques to guide development, instead of relying on a minimum lot size, can reduce the amount of disturbed area per dwelling unit and conserve large, contiguous natural areas, which can be especially valuable for groundwater recharge and in areas near sensitive resources, such as near streams (USEPA, 2006) (Figure 10-7). Less fragmentation also allows the working landscape to stay intact which improves New Hampshire's ability to achieve sustainable agriculture and forestry goals.

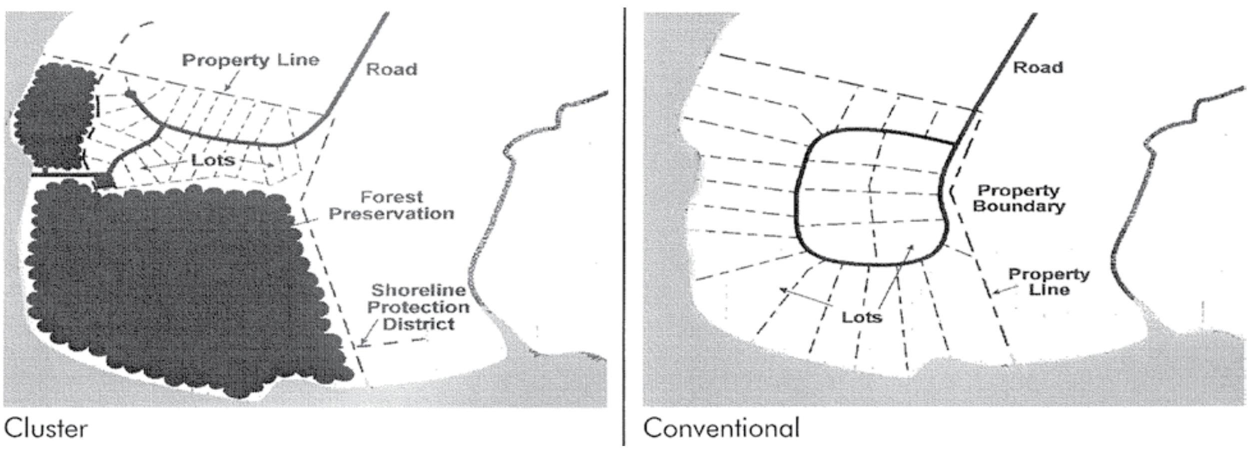


Figure 10-7. Cluster or conservation subdivision versus conventional subdivision. ***Source: CWP, 1998.***

Municipalities can use a number of techniques, including conservation subdivision, lot size averaging, transfer of density credits, and feature-based zoning, to provide for a diversity of development densities that can preserve working landscapes and reduce stormwater impacts. Model ordinances for these and several other innovative land use controls are included in the Innovative Land Use Planning Techniques Guide (REPP, 2008). These approaches, coupled with LID techniques, can be highly effective at minimizing the hydrologic and water quality impacts of development (USEPA, 2006).

Local zoning ordinances may also use density bonuses as an incentive for land preservation. In exchange for the permanent protection of natural area, developers may exceed the conventional density to a defined extent.

One of the barriers to overcome in advocating for a diversity of development densities is the perception that concentrating development in some areas negatively impacts rural character. Attention to site design can address this concern by ensuring that new development and redevelopment fit in with the character of the surrounding community (REPP, 2008). In general, municipalities need more tools and assistance to make LID and innovative zoning a reality.

10.4.3 Upgrade Stormwater Infrastructure

As indicated in section 10.2.2, existing stormwater infrastructure, culverts in particular, is undersized for both the current climate and expected climate change. In order to avoid costly road washouts and damaging localized floods such as the Cold River flood of October 2005, existing infrastructure needs to be upgraded to accommodate the anticipated flows.

10.4.4 Implement Stormwater Utilities

As noted above, stormwater utilities are a viable way for municipalities to raise the funds needed to maintain and upgrade their stormwater infrastructure. Until recently, stormwater utilities have been relatively rare in New England, but this is changing. This lack of familiarity on the part of municipal and regional planners and public works administrators has slowed their acceptance in New Hampshire. Technical assistance is needed to assist municipalities in establishing and operating stormwater utilities in order to accelerate their implementation.

References

Ballestero, T.P., Roseen, R.M., Houle, J.P., & Watts, A.W. (2008, September 22). *Viewing stormwater as a valuable resource*. University of New Hampshire Stormwater Center. Presented at Ground Water Protection Council Annual Forum, Cincinnati, Ohio. Available at: http://www.unh.edu/erg/cstev/Presentations/ballestero_2008_gwpc.pdf.

Black & Veatch. (2007). *2007 stormwater utility survey*. Overland Park, Kan.: Enterprise Management Solutions. Available at: http://www.bv.com/Downloads/Resources/ems_brochures/rsrc_2007StormwaterUtilitySurvey.pdf.

Center for Watershed Protection. (1998). *Better site design: A handbook for changing development rules in your community* (Figure 11.1, p. 93). Ellicott City, Md.: CWP. Available at: http://www.cwp.org/Store/bsd.htm.

Center for Watershed Protection. (2003). *Impacts of impervious cover on aquatic systems* (Watershed Protection Research Monograph Number 1). Ellicott City, Md.: CWP. Available at: http://www.cwp.org/Resource_Library/Watershed_Management/planning.htm.

Clean Water Education Partnership. (2008). *Why is stormwater a problem?*. Retrieved July 28, 2008 from Web site for CWEP. Available at: http://www.nccleanwater.org/stormwater/stormwater101/stormwater_problem.php.

Commission to Review the Effectiveness of the Comprehensive Shoreland Protection Act. (2006). *Final Report of the Commission to Review the Effectiveness of the Comprehensive Shoreland Protection Act, SB 83, Chapter 209, Laws of 2005. November 30, 2006*. State of New Hampshire. Available at: http://des.nh.gov/organization/divisions/water/wetlands/cspa/commission_final_report.htm.

Deacon, J.R., Soule, S.A., & Smith, T.E. (2005). *Effects of urbanization on stream quality at selected sites in the Seacoast Region in New Hampshire, 2001-03* (U.S. Geological Survey Scientific Investigations Report 2005-5103). Available at: http://pubs.usgs.gov/sir/2005/5103/SIR2005-5103_report.pdf.

Guo, Y. (2006). Updating rainfall IDF relationships to maintain urban drainage design standards. *Journal of Hydrologic Engineering*, *11*(5), 506-509.

Hoskins, M. (2006). *Stormwater utilities in Illinois?*. Illinois Association for Floodplain and Stormwater Management newsletter. Available at: http://www.floods.org/PDF/IAFSM_Stormwater_Utilities.pdf.

Maryland Department of the Environment and Center for Watershed Protection. (2000). *2000 Maryland stormwater management manual volumes I & II*. Baltimore, Md.: MDE. Available at: http://www.mde.state.md.us/Programs/WaterPrograms/SedimentandStormwater/stormwater_design/index.asp.

National Research Council. (2008). *Urban stormwater management in the United States*. Committee on Reducing Stormwater Discharge Contributions to Water Pollution, Water Science and Technology Board, Division on Earth and Life Studies. Washington, D.C.: National Academies Press. Pre-publication copy. Available at: http://books.nap.edu/catalog.php?record_id=12465#toc.

New Hampshire Department of Environmental Services. (2008). New Hampshire 2008 Section 305(b) and 303(d) surface water quality report and RSA 485-A:4.XIV report to the Governor and General Court (R-WD-08-5). Prepared by G. Comstock and K. Edwardson, NHDES Watershed Management Bureau. Available at: http://des.nh.gov/organization/commissioner/pip/publications/wd/documents/r-wd-08-5.pdf.

New Hampshire Estuaries Project. (2006). *State of the estuaries*. University of New Hampshire, Durham, N.H. Available at: http://www.nhep.unh.edu/resources/pdf/2006_state_of_the-nhep-06.pdf.

Regional Environmental Planning Program. (2008). *Innovative land use planning techniques guide*. Available at: http://des.nh.gov/organization/divisions/water/wmb/repp/innovative_land_use.htm.

Society for the Protection of New Hampshire Forests. (2006). *105th Annual report*. Concord, N.H.: Capitol Offset Company, Inc. Available at: http://www.spnhf.org/pdf/annual-report-fy06.pdf.

Stack, L.J., Simpson, M.H., Crosslin, T.W., Spearing, W.S., & Hague, E. (2006). *A point process model of drainage system capacity under climate change*. Unpublished.

University of New Hampshire Stormwater Center. (2007). *University of New Hampshire Stormwater Center 2007 annual report*. Durham, N.H.: UNH. Available at: http://www.unh.edu/erg/cstev/2007_stormwater_annual_report.pdf.

U.S. Environmental Protection Agency. (1983). *Results of the nationwide urban runoff program: Executive summary* (National Technical Information Service Accession No. PB84-185545). Available at: http://www.epa.gov/npdes/pubs/sw_nurp_exec_summary.pdf.

U.S. Environmental Protection Agency. (2006). *Protecting water resources with higher-density development* (EPA 231-R-06-001). Available at: http://www.epa.gov/smartgrowth/pdf/protect_water_higher_density.pdf.

U.S. Environmental Protection Agency. (2007). *Reducing stormwater costs through low impact development (LID) strategies and practices* (EPA 841-F-07-006). Available at: http://www.epa.gov/owow/nps/lid/costs07/.

Chapter 11
Dams

NEW HAMPSHIRE DEPARTMENT OF
Environmental
Services

Overview

Dams are an important feature of the New Hampshire environment, creating some of the best water-based recreational areas in the state, providing water supply and hydropower, and, in a few cases, flood control. Some historic dams are closely tied to people's sense of community character and aesthetics. During droughts dams can be important in retaining water for water supply and industrial use. On the other hand, dams can block fish migrations and adversely impact downstream water quality and streamflows. Also, dams that are not maintained in good operational order can fail and cause loss of life and economic damage. In New Hampshire the risks associated with many dams are increasing rapidly because of: 1) the encroachment of businesses and homes downstream from dams in areas that would be flooded if the dams were to fail; 2) increasingly frequent extreme rainfall events due to climate change, as explained in Chapter 1 – Introduction and Overview; and 3) a lack of important maintenance on many privately owned and some publicly owned dams.

11.1 Description and Significance

11.1.1 Dam Classifications

There are 3,070 active dams in the state of New Hampshire. Eight hundred forty of these are classified as "hazardous" because the flooding produced by their failure would result in loss of life or property damage downstream. The remaining 2,230 active dams are classified as "non-hazardous." The hazardous classification of dams is based on the extent of development downstream within the potentially inundated area and is not related to the condition of the dam. Many dams in New Hampshire are small: 35 percent are less than 8 feet high. Almost 50 percent have less than 50 acre-feet of storage (New Hampshire Department of Environmental Services [NHDES], 2008).[1] The largest dam in New Hampshire is the Moore Reservoir dam on the Connecticut River in Littleton at 193 feet high and 2,920 feet long. This dam holds the largest conventional hydropower station in New England with a capacity of generating 192 megawatts (Connecticut River Joint Commissions, 2008).

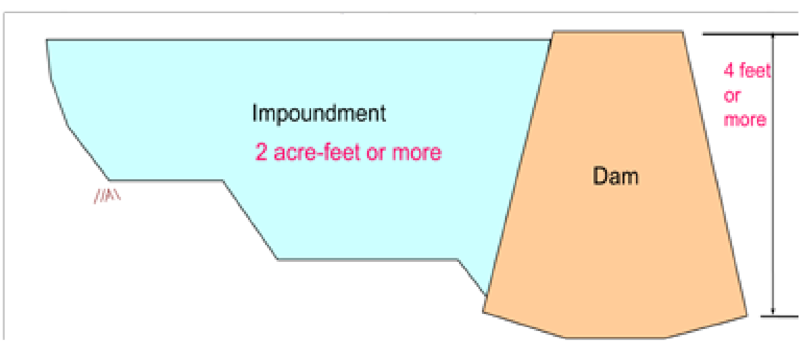


Figure 11-1. Diagram of New Hampshire's definition of a dam. See "Statutory Definition of a Dam" (next page) for additional information. ***Source: NHDES, 2006.***

Hazardous Dams

There are 90 dams in New Hampshire that are currently classified as High Hazard Dams because

[1] One acre-foot of water is about 325,851 gallons or one foot of water covering an area of one acre.

Statutory Definition of a Dam

II.(a) "Dam" means any artificial barrier, including appurtenant works, which impounds or diverts water, and which has a height of 4 feet or more, or a storage capacity of 2 acre-feet or more, or is located at the outlet of a great pond. A roadway culvert shall not be considered a dam if its invert is at the natural bed of the water course, it has adequate discharge capacity, and it does not impound water under normal circumstances. Artifi cial barriers which create surface impoundments for liquid industrial or liquid commercial wastes, septage, or sewage, regardless of height or storage capacity, shall be considered dams.

(b) An artificial barrier at a storm water detention basin, which impounds 0.5 acre-foot or less of water during normal conditions, shall not be considered a dam unless its height is 10 feet or greater or its maximum storage is 6 acre-feet or greater. (RSA 482:2, effective August 18, 2006). See also Figure 11-1.

their failure would inundate homes or other occupied structures downstream and likely cause loss of life. Another 192 are classified as Significant Hazard Dams because their failure would cause major property damage downstream, and 558 are classified as Low Hazard Dams because their failure would cause minor property damage downstream, such as damage to a town road. The New Hampshire Department of Environmental Services estimates that there are more than 10,000 homes, 500 state road crossings, and more than 4,500 town road crossings that would be destroyed or damaged if these hazardous dams were to fail (NHDES, 2008).

11.1.2 Dam Ownership

The breakdown of all dams by type of owner is shown on the pie chart in Figure 11-2. Governmental organizations or utilities own about one-quarter of the dams in the state. Utilities own 12 dams, various municipalities own 389, the federal government owns 38, and the state of New Hampshire, through its various state agencies, owns 273. However, the vast majority of the dams, 2,358, are owned by private organizations or individuals.

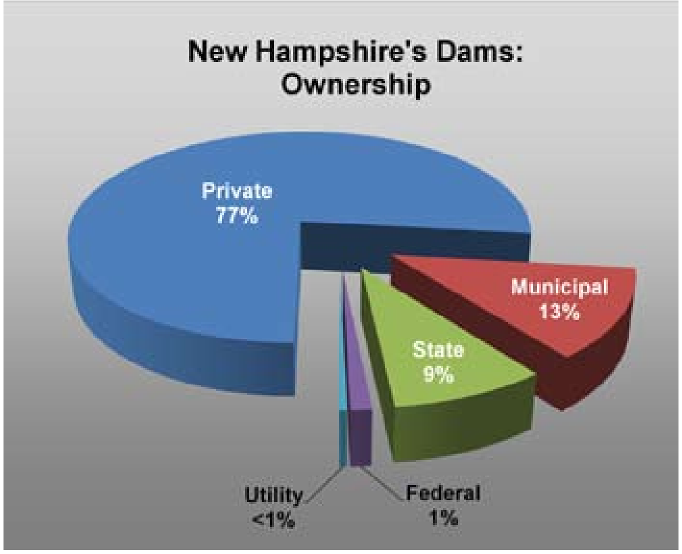


Figure 11-2. Dam ownership percentages in New Hampshire. *Source: NHDES, 2008.*

The privately-owned Meadow Pond Dam in Alton was a Significant Hazard Dam that failed in 1996 (Figure 11-3). It caused approximately $8 million worth of property damage and one fatality when the State Route 140 road crossing downstream was destroyed. Using the costs of this tragedy as a benchmark, it is clear that many thousands of lives and hundreds of millions of dollars of property are at risk downstream of dams. Recent events in Alstead dramatically illustrate the destructive force of a sudden release of stored water. There, a roadway embankment was overtopped and failed causing loss of life and enormous devastation downstream.

Figure 11-3. Meadow Pond Dam in Alton looking downstream at road damage. One life was lost when the dam failed. *Source: NHDES, Dam Bureau File Photo.*

11.1.3 Benefits and Purposes of Dams

Most dams in New Hampshire were originally built for recreation (1,448), or conservation/ farm ponds (759 – includes small ponds for wildlife and other miscellaneous purposes). Others have been built for stormwater detention (295), fire ponds (239), hydropower (132), sewage treatment (60), water supply storage (76), flood control (45) and mill process water (16) (NHDES, 2008). A pie chart depicting the breakdown of the number of dams by use is shown in Figure 11-4.

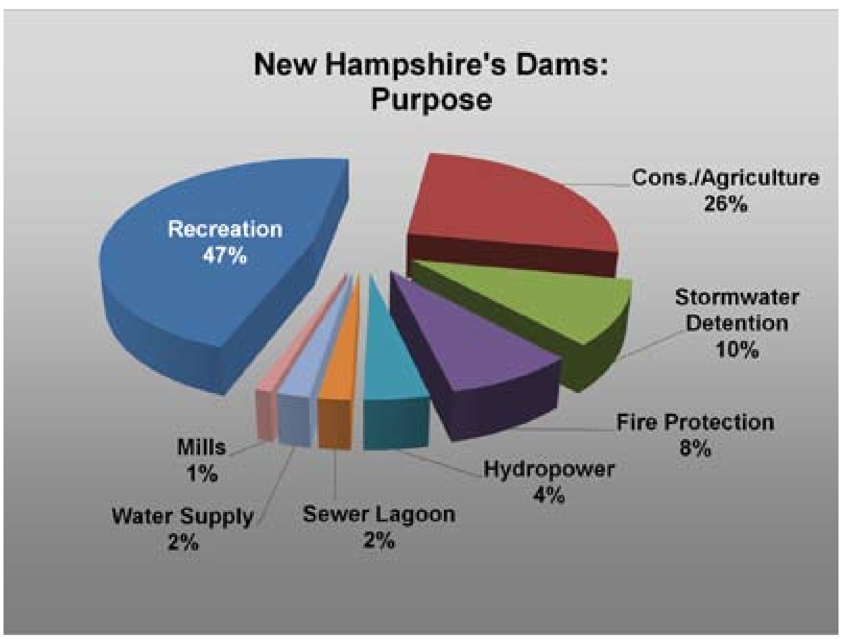


Figure 11-4. As shown in the figure, the single largest purpose of New Hampshire dams is recreation, of which there are 1,448. Dams that impound conservation or farm ponds make up the next largest category with 759, followed by stormwater detention ponds (295), fire ponds (239), hydropower dams (132), sewage lagoons (60), water supply reservoirs (76), flood control dams (45) and mill dams (16). *Source: NHDES, 2008.*

Recreation

In many places where dams provide for the enlargement of existing water bodies, they have created the largest and most important recreational lakes in the state, including Winnipesaukee, Squam, Winnisquam, Newfound, Sunapee and Ossipee. The impoundments behind dams provide habitat for waterfowl, wildlife, fish and other aquatic species, as well as recreation opportunities for boaters, anglers, hunters and bird watchers.

Economic Benefits

According to the New Hampshire Lake Association's Report on the Economic Value of New Hampshire's Surface Waters, New Hampshire's lakes provide up to $1.5 billion annually of economic benefit to the state, and waterfront property owners pay nearly a quarter billion dollars annually in property taxes (Nordstrom, 2007). Since the majority of New Hampshire's surface waters are impounded by dams, the upkeep of these dams is important, not only to protect public safety and the environment, but also to maintain the significant economic benefits that they provide.

Industrial and Community Benefit

Dams have a variety of benefits to New Hampshire's businesses and communities, including water supply storage, hydropower generation, fire ponds, stormwater or sewage detention, mill process water, and farm ponds. These encompass about 50 percent of the total number of dams in the state, most of them rather small.

Flood Control

Although dams are inherently associated with flooding, a common misconception is that most dams reduce flooding. In fact, most create flooding risks that are greater than they would be without the dam present. Only 45 (less than two percent of the total number) of New Hampshire's dams were built primarily for flood control (NHDES, 2008).

11.2 Issues

11.2.1 Dam Failures and the Increased Risk from Downstream Development, Climate Change, and Lack of Dam Maintenance

Why Dams Fail

Although the majority of dams in New Hampshire have responsible owners and are properly maintained, dams can and do fail, particularly when they are stressed by high flows such as those that have occurred during the three major floods that New Hampshire experienced in 2007 and 2008. Dam failures are most likely to happen for one of five reasons:

- Overtopping (water spilling over the top of a dam).
- Structural failure of materials used in dam construction.
- Cracking caused by movements such as the natural settling of a dam.
- Inadequate maintenance and upkeep.
- Piping: when seepage through a dam is not properly filtered and soil particles continue to progress and form sink holes in the dam.

Historically dams that failed had some deficiency, as characterized above, which caused the failure. These dams are typically termed "deficient." Currently, DES records indicate that there are about 155 deficient dams in New Hampshire (NHDES, 2008).

Expanding development downstream, not new dam construction, is increasing the number of High Hazard Dams, and the state has little control over it.

There Are an Increasing Number of High Hazard Dams

The number of high-hazard structures is increasing, not because more high-hazard dams are being built, but because there is more encroachment on areas that would be inundated should a dam fail. The state has no control over land use within the area downstream of dams that could potentially be inundated from a dam failure. Local control through floodplain zoning and other mechanisms is possible, but many communities have not adopted these mechanisms.

Extreme Events Are Increasing the Likelihood of Failures

Landscape change associated with development and higher frequencies of extreme precipitation events, explained in Chapter 1 – Introduction and Overview, both put greater pressures on existing dams. Continuing increases in watershed imperviousness escalate the percentage of precipitation that runs off the land, boosting the frequency and magnitude of high stream flows. Climate change is also predicted to increase the intensity and frequency of high-runoff events (Madsen & Figdor, 2007), compounding the pressure on dams.

New Hampshire Ranks Third in the Country in Numbers of Known Dam Deficiencies

Problems with dams are not peculiar to New Hampshire. According the American Society of Civil Engineers (ASCE) 2005 Infrastructure Report Card, "The combined effect of rapid downstream development, aging/non-compliant structures and inadequate past design practices, coupled with a predicted increase in extreme events, demands fully funded and staffed state dam safety programs, as well as substantial and proactive funding for (private) dam repairs" (ASCE, 2005).

Dams must be maintained to keep them safe. Occasional upgrade or rehabilitation is necessary due to deterioration, changing technical standards, improved construction techniques, better understanding of the area's precipitation conditions, increases in downstream populations, and changing land use. When a dam's hazard classification is changed to reflect an increased hazard potential, the dam may need to be upgraded to meet an increased need for safety.

The lack of funding for dam upgrades has become a serious concern, especially within the private sector. Unfortunately, operation, maintenance and rehabilitation of dams can range in cost from the low thousands to millions of dollars, and owners are responsible for these expenses. In New Hampshire more than three-quarters of the dams are privately owned and many owners cannot afford these costs.

The DES Dam Bureau regularly inspects, on a schedule based on hazard classification, the 840 hazardous dams. Following those inspections, DES issues reports to the dam owners identifying the deficiencies observed during the inspection and specifying a schedule to correct the deficiencies. However, compliance inspections and follow-up on deficient dams currently lag performance goals. At this time, there are 155 dams with known deficiencies of some form, including six with major deficiencies (NHDES, 2008). This ranks New Hampshire third in the country in the number of dams with identified deficiencies (Association of State Dam Safety Officials, 2007).

The Program for the Maintenance of State Owned Dams Has Become Insolvent

The DES Dam Bureau is charged with repairing and reconstructing all 273 state-owned dams. Financing these repairs and reconstruction is as much of a problem for the state as it is for private owners.

The state Dam Maintenance Fund is supposed to support the operation, maintenance, repair and reconstruction costs for state owned dams. However, the sole source of revenue to the fund is rent payments that DES receives from leasing 12 of the dams that it owns to private hydropower developers to generate electricity at the sites. Under the terms of the leases, the rent that is paid to DES is a percentage of the revenue from the sale of power at the facilities. Eleven of these lessees sell the power to Public Service of New Hampshire (PSNH). In 2002 PSNH initiated actions to renegotiate their above-market power purchase agreements with the small power producers from whom they purchase power. The result was a 40 percent drop in revenue to the state Dam Maintenance Fund, which, combined with the continuing obligations of the fund, has caused the fund to become insolvent.

11.2.2 Dams Can Have a Negative Ecological Impact

Although well-maintained dams can provide many benefits, they can also cause a number of environmental problems, including blockage of fish passage, interruption of sediment and nutrient transport, changes in temperature and chemical constituents, interference with the reproduction of aquatic life, and fragmentation of natural habitats. The effects can be felt significantly downstream and can modify, sometimes dramatically, the operation of a dam. For example, flows have changed significantly in the Lamprey River when the management of the Dolloff dam in Nottingham was changed in 1955 and also when leakage was repaired (see Figure 11-5).

As water is detained behind larger dams, sediments tend to settle to the bottom behind the dam, building up in layers. This factor may actually improve the water quality in ponds downstream of a series of dams, but the riverine characteristics of habitat and fisheries are lost. Water temperatures are usually higher and oxygen levels lower because of a dam. Fish passage both up and downstream may be entirely lost. The sediment built up behind a dam may lead to increased oxygen consumption and create internal cycling of nutrients that can lead to algal blooms. Algal blooms can result in fish kills and threats to human health.

Downstream of the dam there can be significant negative effects. Flow may be significantly reduced, stranding aquatic life and cutting off usable habitat upstream. Anadromous fish that swim upstream may be prevented from migration, and most fish ladders, where they exist, are far from perfect.

11.2.3 Lack of Awareness of Dam Hazards and Problems

As described previously in this chapter, the interruption of streams by dams impacts water quality, flows, and habitat of fish and other aquatic life. In addition, there is a general lack of awareness of these issues and the risks of dams failing.

The ordinary citizen is unaware that the beautiful lakes on which he or she boats, skis or fishes are only there because of man-made dams. Often they are equally unaware of the higher quality fisheries and recreational opportunities that might be there without the dam.

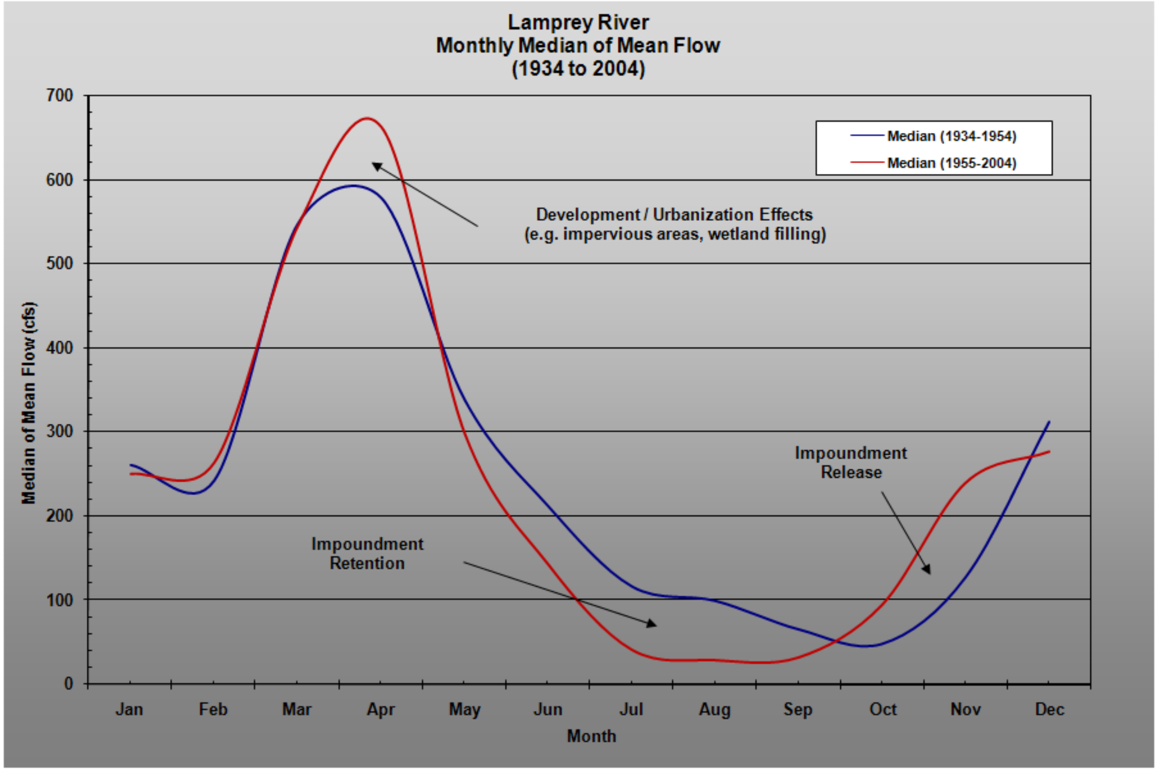


Figure 11-5. Flows in the Lamprey River have been significantly affected over the years by the construction of dams and changes in their operation. *Data Source: U.S. Geological Survey, 2005.*

Owners of homes or commercial interests that have built in areas that could be inundated from a dam failure flood typically know little about the potential devastation that an upstream dam could cause should it fail. Even if people are aware of dams, they still have unrealistic expectations of the ability of the dams to reduce flooding downstream. Many dam owners do not realize their responsibility and liability toward the downstream public and environment. Adequate understanding of proper dam maintenance and upgrade techniques is a typical problem among many owners.

11.3 Current Management and Protection

11.3.1 Ongoing and Recently Passed Legislation

Increased Fees to Support Inspection

During the 2006 legislative session, the New Hampshire Legislature passed HB 664, which increases the fees charged for a permit to construct or reconstruct a dam as well as the annual dam registration fees. In addition to covering the costs of inspection and permitting, the resources provided with these fee increases will allow DES to increase follow-up inspections and institute enforcement actions, where necessary, to reduce the number of non-compliant dams by 75 percent.

Study Committee on Funding Alternatives

Since 2004 the New Hampshire Legislature has been working to identify a new source of funding for the operation, maintenance and repair of state-owned dams. In 2004 the Legislature formed a committee to study funding alternatives.

The committee's final report predicted that the shortfall in the Dam Maintenance Fund could be over $1 million per year in the short-term and average $900,000 per year over the next nine years (Committee, 2004). The committee concluded that since the dams could not be dismantled or turned over to others, another source of funding needed to be found to fill this gap. Two sources that were examined by the committee, but were determined to be impractical, included: 1) leasing additional dams for hydropower generation; and 2) increasing fees derived from fishing licenses, boat registrations, boat moorings and state parks.

The committee then focused on those who benefit most directly from the impoundments created by state-owned dams, namely, shorefront property owners. One possible solution would be to assess them a fee of per linear foot of shorefront property.

Another recommendation by the committee was to allocate a portion of the unrefunded road toll taxes to the Dam Maintenance Fund. Bills introduced in the Legislature to implement each alternative failed to pass, but the House Ways and Means Committee is currently examining the issue with possible legislation to be introduced in the 2009 session.

Comprehensive Flood Management Study Commission

This commission, created by House Bill 648 in 2007, was charged with studying possible measures for controlling floods to minimize their impact on communities and individual properties. The scope of the commission's work included land use management to reduce flood runoff, flood hazard assessment, evaluation of dams and reservoirs, implementing possible zoning and floodplain regulations, cooperative efforts between private dam owners and the New Hampshire Office of Emergency Management in the event of serious flood threats, and flood forecasting practices. The commission issued its report in September 2008 (Comprehensive Flood Management Study Commission, 2008); more information can be found in Chapter 12 – Floods and Droughts.

Dam Removal and River Restoration Programs

In January 2000 the New Hampshire River Restoration Task Force was formed with the goal of exploring opportunities to selectively remove dams for a variety of reasons, most notably for the purposes of restoring rivers and eliminating public safety hazards. The task force is an initiative with diverse representation, including multiple state and federal agencies, conservation organizations, local interests and others. Through its work the task force is enabling an efficient and effective process of removing dams in New Hampshire. Due to the collaborative efforts of the task force, two dams have been removed from the Ashuelot River for the purpose of river restoration: the McGoldrick Dam in Hinsdale in 2001 and the Winchester Dam in 2002. These dam removals are critical pieces of a basin-wide plan to restore anadromous fish to the Ashuelot River, a historically significant Connecticut River tributary for American shad, blueback herring and Atlantic salmon. Several additional dam removals statewide are currently in the planning and permitting stages.

11.3.2 DES Programs

Dam Inspection and Repair Program

As previously described, DES's Dam Bureau inspects the 840 dams that could cause loss of life or property damage downstream, but the follow-up lags performance goals due to staffing. There are 155 dams with known deficiencies at present, with six that have major deficiencies.

Dam Permitting Program

New dams and the reconstruction of existing dams require a permit from DES through both the Dam Bureau and the Wetlands Bureau. Each dam is classified as to hazard potential and the owner must prepare an Emergency Action Plan for all dams that may be a menace to public safety due to their condition, height and location. The Emergency Action Plan is a document establishing: 1) a notification plan; 2) information on the potential extent of downstream flooding; and 3) pre-planned emergency actions to be taken upon indication of an impending dam failure or unsafe condition.

Alteration of Terrain Program

The Alteration of Terrain rules (Env-Ws 415) cover land disturbances that exceed 100,000 square feet. The cumulative effects of increasing development on peak flows and flows during small storm events will be minimized through Alteration of Terrain rule changes taking effect on January 1, 2009. The rule changes require infiltration of stormwater, helping to minimize the hydrologic impacts of new development.

Wetlands Permitting

Wetlands play an important role in moderating the flow of runoff and, consequently, the stress placed on dams. The Wetlands Bureau within the Water Division of DES regulates activities in wetlands in New Hampshire. More information on wetlands issues can be found in Chapter 5 – Wetlands.

11.3.3 Non-DES Programs

National Flood Insurance Program (Floodplain Management)

The National Flood Insurance Act of 1968 established the National Flood Insurance Program (NFIP). The NFIP enables property owners in participating communities to purchase insurance as a protection against flood losses in exchange for state and community floodplain management regulations that reduce future flood damages. People can only participate if their community has established the required floodplain regulations and participates in the program. This insurance is designed to provide an insurance alternative to disaster assistance to reduce the escalating costs of repairing damage to buildings and their contents caused by floods (NFIP, 2002).

Federal H.R. 3224 the Dam Rehabilitation and Repair Act

H.R. 3224, which was introduced in the 110th Congress, would have provided funding for the repair of publicly-owned dams (H.R. 3224, 2007). Under the allocation formula in the bill, New Hampshire would have received approximately $2.5 million over a five-year period for the repair of publicly-owned dams. The bill, which was co-sponsored by both representatives from New Hampshire, passed the House in 2007 but died in the Senate and is expected to be reintroduced in 2009.

11.4 Stakeholder Recommendations

11.4.1 Improve Dam Maintenance

Dams must be maintained to keep them safe. The lack of funding for dam maintenance and upgrades has become a serious concern, within both the private and public sectors. The funding needs for the repair of both publicly and privately owned dams must be addressed to ensure that the state's dams continue to be operated and maintained so that they do not pose a threat to life and property downstream and continue to provide economic and recreation benefits to the state. While some initial progress is being made on the state and federal levels to fund the operation and maintenance of publicly owned dams, unsafe privately owned dams can also cause loss of life and severe economic damage to private property and public infrastructure.

As previously stated, the state Dam Maintenance Fund is insolvent. Another source of funding is needed to make up the shortfall created by the 40 percent reduction in lease payments on state-owned hydro dams. Establishment of a dependable funding source for the operation, maintenance and repair of state-owned dams is now critical. One way to address the shortfall would be to establish a low interest loan program in New Hampshire, similar to those developed in other states, to finance the repair and upgrade of both publicly and privately-owned dams.

11.4.2 Remove Unnecessary Dams

Because of the negative ecological impacts caused by dams and the high cost of maintenance, private dam owners should be further encouraged to remove unneeded dams, especially those that are old or in disrepair. The N.H. River Restoration Task Force should facilitate these dam removals through technical assistance, identification of funding sources, and streamlining of dam removal permits.

11.4.3 Increase Public Awareness

There needs to be improved outreach to increase public awareness about the benefits, risks and ecological impacts associated with New Hampshire's dams.

References

American Society of Civil Engineers. (2005). *Report card for America's infrastructure.* Reston, Va. Available at: http://www.asce.org/reportcard/2005/page.cfm?id=23.

Association of State Dam Safety Officials. (2007). *State dam safety performance report, January 1, 2006 – December 31, 2006*. Lexington, Ky.

Committee to Study the Effects of Electric Utility Restructuring on the State's Hydro-lease Program and Dam Maintenance Fund and the Alternatives for Funding the Operation and Maintenance of State-Owned Dams. (2004). *Final report*. (SB 488, Chapter 121:1, Laws of 2004). State of New Hampshire.

Comprehensive Flood Management Study Commission. (2008, September). New Hampshire House Bill 648, Chapter 179 Laws of 2007, Comprehensive Flood Management Study Commission: Final report. State of New Hampshire. Available at: http://gencourt.state.nh.us/statstudcomm/reports/1853.pdf.

Connecticut River Joint Commissions. (2008). *Boating on the river, Map 3: Moore Reservoir*. Retrieved September 9, 2008, from CRJC web site. Charlestown, N.H. Available at: http://www.crjc.org/boating/boating3.htm.

H.R. 3224--110th Congress. (2007). *Dam Rehabilitation and Repair Act of 2007*. Retrieved August 1, 2008 from Library of Congress THOMAS dataset base. Available at: http://thomas.loc.gov/cgi-bin/bdquery/z?d110:h.r.03224.

Madsen, T. & Figdor, E. (2007). *When it rains, it pours: Global warming and the rising frequency of extreme precipitation in the United States.* Environment New Hampshire, Research and Policy Center, Concord, N.H. Available at: http://www.environmentnewhampshire.org/uploads/Rx/_8/Rx_8sa-IUrwjnmsIIL1Xyg/When-It-Rains-It-Pours.pdf.

National Flood Insurance Program. (2002). *National Flood Insurance Program description*. Federal Emergency Management Agency, Federal Insurance and Mitigation Administration. Available at: http://www.fema.gov/library/viewRecord.do?id=1480.

New Hampshire Department of Environmental Services. (2006). *New Hampshire's definition of a dam*. RSA 482:2, II and Env-Wr 101.12. Available at: http://des.nh.gov/organization/divisions/water/dam/documents/damdef.pdf.

New Hampshire Department of Environmental Services. (2008). Dam Bureau Database, NHDES. Unpublished data. Retrieved on August 6, 2008.

Nordstrom, A. (2007). *The economic impact of potential decline in New Hampshire water quality: The link between visitor perceptions, usage and spending*. New Hampshire Lakes Association, Concord, N.H. Available at: http://www.nhlakes.org/docs/Surface-Waters-PhaseIV-Final-Report.pdf.

U.S. Geological Survey. (2005). *National Water Information System: Web interface, USGS 01073500 Lamprey River near Newmarket, NH.* Unpublished data. Retrieved May 19, 2005 from USGS web site. Available at : http://waterdata.usgs.gov/nh/nwis/nwisman/?site_no=01073500&agency_cd=USGS.

Chapter 12
Floods and Droughts

NEW HAMPSHIRE
DEPARTMENT OF
Environmental
Services

Photo: Damage to infrastructure due to the
Patriots Day Flood of April 2007, Epsom, N.H.
By: Eric Orff, Courtesy of New Hampshire
Friends of Suncook River

Overview

Floods and droughts have caused, and continue to cause, serious economic and environmental losses. These events are the result of both natural disasters and human actions. Due to climate change and landscape change (see Chapter 1 – Introduction and Overview), there is an increasing need to emphasize prevention, preparedness, mitigation, and risk management to respond to these events in order to protect our safety, quality of life, economy and environment.

12.1 Description and Significance

Floods and droughts are the most frequent natural disasters that strike New Hampshire. They are both natural phenomena; however, landscape change and climate change can alter the intensity and frequency of these phenomena and lead to greater losses. Further development in floodplains and in areas with limited water supplies also increase losses. Flooding events in New Hampshire are generally confined to localized areas within the state. Drought conditions may exist concurrently over several states or be confined to a smaller region within New Hampshire.

12.1.1 Flood Background

New Hampshire has nearly 17,000 miles of rivers and streams, approximately 1,000 lakes, and 238 miles of ocean and estuarine coastline. The state's settlement pattern historically coincides with these natural features. Communities developed along waterways, which provided ports for trading, harbors for commerce, and power and transportation for mills. In addition to being easily accessible, river valleys are some of the easiest lands to develop. As a result of this development pattern, the floodplains and shorelands of the state were rapidly settled. The shift to industrialization during the mid-nineteenth century compounded the problem, with residents moving to the floodplains of cities and larger villages (Figure 12-1). Such encroachment has led to flooding problems, since floodplains are extensions of watercourses and have evolved to carry excessive runoffs naturally (New Hampshire Department of Safety [NHDOS], 2007).

Riverine flooding is the most common natural disaster in New Hampshire. Significant riverine flooding impacts some areas in the state at intervals of less than ten years. NHDOS, 2007).

Development tends to exacerbate flooding in several ways. First, as described in Chapter 10 – Stormwater, removing vegetation and soil, grading and paving the land surface, and constructing drainage networks increase runoff to streams from rainfall and snowmelt. As a result, the peak discharge, volume, and frequency of floods increase in nearby streams. Second, changes to stream channels during urban development (hardening stream channels, building in floodplains) can limit their capacity to convey floodwaters. Structures that encroach on the floodplain, such as bridges, can increase upstream flooding by narrowing the width of the

Figure 12-1. Flooding in 1936, Bridge Street, Concord. ***Photo from New Hampshire Historical Society.***

channel and increasing the channel's resistance to flow. As a result, the water is at a higher stage as it flows past the obstruction, creating a backwater that will inundate a larger upstream area (Konrad, 2003). Finally, many residential and commercial developments have relied on detention basins to manage stormwater for the last 30 years or so. While these basins may detain major storms temporarily, they are generally too large to hold back flows from smaller, more frequent storms and they can lead to downstream flooding problems because they do not reduce runoff volume (National Research Council, 2008).

Erosion and Inundation

Flood damage is caused by two processes: erosion and inundation. Erosion that changes the course of a river, the shoreland of a lake, or the beach of a coast can also damage waterfront buildings and infrastructure by washing away the ground they are built upon (Figure 12-2). Inundation, the rising of a body of water and its overflowing onto normally dry land, also causes damage to buildings and infrastructure.

A study completed in Vermont found that most flood damage in that state is caused by erosion from rivers, not by inundation (Dolan, 2007). Much of the flood damage is due to landscape change (from forested to impervious), including historic settlement and land use. Currently, homes and infrastructure are often in areas where attempts have been made to contain meandering rivers in concrete or otherwise hardened channels or with berms. The erosive power of floodwaters, no longer able to dissipate in a natural channel, threatens homes and infrastructure. The greatest damage tends to be to roadways, which are often adjacent to channelized rivers. Streams and rivers are not static systems, and treating them as such puts homes and infrastructure in harm's way.

Figure 12-2. Flood-related erosion along Warren Brook in Alstead. ***Photo by Chris Covel.***

Debris and Contaminants

Storm debris, such as trash, downed trees, or leaves, carried by floodwaters can clog bridges and culverts, narrow river channels, or interfere with the functioning of water diversion structures such as bypass pipes, spillways and gates. Blockage caused by debris may exacerbate a given flood event by obstructing stormwater flow at otherwise adequately sized bridges, dams, culverts or buffer zones. Chemical and other contaminants, particularly hazardous materials and sewage, carried by floodwaters can also contaminate land, surface waters, and wells, making them unsafe for humans and wildlife.

Ice Jams and Snow Melt

Ice formed in rivers and against structures such as bridges, roads, docks and buildings can damage these structures and erode abutments and riverbanks. Warm temperatures and heavy rains, usually during spring, can speed the melting of snow pack, leading to flash-flood incidents or inundation events. Rapid melting can also lead to the formation of ice jams, a collection of ice chunks that has a damming effect. This can create cold weather flood hazard conditions where none exist during warm weather. The more development in floodplains and alteration of river channels or shorelines, the greater the potential for flood damage associated with ice jams.

Lakes

Flooding associated with lakes in New Hampshire is not as common as in river systems; however, it does occur during extreme rainfall and snowmelt events. Dams are used to regulate the levels of many of the state's lakes. Even though flood control is not the primary purpose for the majority of these dams, their operation during potential flooding situations can affect flooding of adjacent shorelands. If water is released or withheld incorrectly, dams can cause flooding above or below dams on lakes and rivers.

Bridges and Dams

Bridges are designed using the flood of record or the 50-year storm event, whichever is greater. Neither future alterations of the landscape by development nor likely climate change-related increases to the frequency of intense storms are considered when designing bridges or culverts. Currently, of the 3,661 state and municipally owned bridges, 498 are in need of replacement (Pillsbury, 2008). As noted in Chapter 10 – Stormwater, a significant percentage of culverts are under-sized as a result of watershed development and changes in hydrology that are expected as a result of climate change.

New Hampshire's flood control dams, most operated by the U.S. Army Corps of Engineers, have prevented $4.3 billion in flood damages with construction costs of $482 million (Kennelly, 2008). Only 45 of the 3,070 dams in the state have available storage for flood control; therefore, aside from some isolated opportunities, the feasibility of significantly achieving a cost-effective reduction in flood damages through the construction of additional flood control impoundments is quite low (Comprehensive Flood Management Study Commission, 2008). More information on New Hampshire Dams is found in Chapter 11 – Dams.

Coastal Flooding

Flooding of low-lying areas on New Hampshire's coast is a natural phenomenon that has occurred for centuries. Coastal flooding in New Hampshire primarily occurs due to major rain storms and nor'easters. The flooding caused by these storms is compounded by full-moon tides, which intensify storm surge and wave effects. Human activities, particularly the disruption of natural protective coastal features, e.g. dunes or wetlands, or the lowering of land as a consequence of drainage, may also aggravate the coastal flooding hazard in some areas. A recent study by the National Oceanic and Atmospheric Administration (NOAA) identified 96 major inundation and storm surge events between 1914 and 2007, and 37 events between 1980 and 2007 for the coastal area of northern New England (Cannon, 2007). This study identified several important aspects of storm surges on New Hampshire's coast:

- Eighty-three percent of storms happen in the colder months of October through March.
- Tidal flooding, although relatively infrequent, tends to cluster with two or more events in a single year.
- While most flooding occurs with high tides (above 12 feet), many happen at lower tides due to wind, wave and tidal water "piling."
- Storm surge can be very difficult to predict due to the complexities of the shape of New Hampshire's coast and variability in meteorological data.

Figure 12-3. Coastal flooding damage in 1978 approximately 0.5 miles from the coast at High Street, Hampton, N.H. *Source: Seacoast SAD, 1978.*

Climate change will also aggravate existing coastal flooding hazards through rising sea levels and increasing frequency and intensity of coastal storms. Sea level has been rising at an average rate of 2 – 2.7 millimeters per year for the last millennium, which equates to about 8-10 inches per century. This rate of sea level rise will reduce the recurrence interval of today's 100-year storm surge to between two and 15 years (Kirshen et al., 2008). This means that, on average, a large flooding storm will happen every few years to a decade. As a point of reference, the Blizzard of 1978 storm is considered to be a 10- to 20-year storm surge (Figure 12-3).

12.1.2 Adverse Impacts of Floods

"*The devastation wrought by flood…The power of an irresistible mass of water was never more fully realized by our citizens than at this time, when the city's debt has been swelled over a hundred thousand dollars, some of our businessmen almost financially ruined by losses which no insurance covers, to say nothing of losses small in comparison that poor and even well off persons who live on the river's bank have suffered. At no time could the city and its inhabitants have stood such a calamity so poorly.*" (March, 1896 Dover Enquirer, New Hamsphire newspaper account of the flood that devastated the city. *Source: Dover Public Library*).

Buildings and Infrastructure

Structures within a floodplain can be extensively damaged by the force of moving water, the pressure of standing water, or the debris and sediment associated with flooding. Suspended sediments in floodwaters can settle, leaving a layer of mud on all flooded areas including building interiors. After floodwaters have receded, repairing damage caused by mold growth or contaminants can continue to increase costs associated with flood damage.

The federal, public, and individual assistance for damage resulting from New Hampshire's three flood events October 2005, April 2006 and May 2007 has totaled $60 million (NHDOS, 2007). The total amount the Federal Emergency Management Agency has paid for flood losses though the National Flood Insurance Program in New Hampshire is shown in Table 12-1.

Table 12-1. Total amount the Federal Emergency Management Agency has paid for flood losses though the National Flood Insurance Program in New Hampshire, 1978-2008. *Source: FEMA, 2008.*

County	NFIP Policies	Insurance In Force	Total Paid Losses	Total Paid Amount	Total Repetitive Loss Properties
Belknap	331	$62,819,300	91	$754,070	13
Carroll	542	$103,710,800	205	$917,674	11
Cheshire	552	$104,428,400	175	$4,418,672	0
Coos	196	$26,653,200	64	$358,739	4
Grafton	895	$136,516,500	192	$1,296,235	19
Hillsborough	1,317	$277,353,200	530	$9,120,271	64
Merrimack	610	$120,398,600	258	$5,128,165	49
Rockingham	3,790	$638,515,800	1,552	$15,002,917	132
Strafford	450	$92,592,800	111	$1,853,638	10
Sullivan	172	$31,745,700	33	$260,776	2
Total	**8,855**	**$1,594,734,300**	**3,211**	**$39,111,157**	**304**

"Repetitive Loss" means flood-related damage sustained by a structure on two separate occasions during a 10-year period for which the cost of repairs at the time of each such flood event, on the average, equals or exceeds 25 percent of the market value of the structure before the damage occurred.

Water Contamination

Flooding can cause water to become contaminated from oil, gasoline, and other chemicals, as well as with fecal matter from sewage systems and septic tanks. Most municipal water supplies are capable of ensuring safe drinking water during flood events; however, private drinking water wells can easily become contaminated by floodwaters. Heavy precipitation tends to mobilize bacteria, which can contaminate wells that are in poor condition. When flooding occurs, private well owners are urged to boil their drinking water and have their wells tested for contamination after the floodwaters have receded.

Habitat Destruction

The plants and animals that occupy floodplain areas have evolved to cope with floods, and many species in floodplains rely on changing water levels associated with flooding as part of their life cycles; however, they often fare poorly with frequent, intense flood events. Landscape change and climate change will increase flooding frequency and intensity, causing inundation and erosion that can alter habitat, destroy breeding grounds, or simply kill native plants and animals in flooded areas.

12.1.3 Drought Background

Droughts of varying duration and intensity are natural events that have occurred throughout history and they are part of the cyclical fluctuations of the climate. Droughts may last from several months to years. The occurrence of droughts can be characterized in terms of duration and magnitude of dryness. Research is being conducted that will likely lead to accurately predicting months ahead of time when a drought may occur. However, there currently is no reliable method to accurately predict a drought.

> ***Drought***: a sustained and regionally extensive occurrence of appreciably below-average natural water availability in the form of precipitation, streamflow or groundwater.

Even in the northeastern U.S., where water is generally abundant, recent drought conditions accompanied by increasing human demands on freshwater resources require that we gain a better understanding of extremes in regional hydrologic variability. Drought is of particular concern because extended periods of low stream flows often result in significant ecological damage from high surface water temperatures, reduced levels of dissolved oxygen, higher concentrations of pollutants, the landward migration of salt-water estuaries, and resulting impacts on aquatic life. Impacts of drought on human activity promise to be more severe in the future because of a rapidly growing population (Bradbury et al., 2002).

12.1.4 The Occurrence of Water in the Environment and New Hampshire's Susceptibility to Drought

New Hampshire, on average, receives roughly the same amount of precipitation each month of the year. Based on records from 1895 to present for all weather observation stations in the state, the average annual precipitation for the state is 43 inches per year. Figure 12-4 summarizes rainfall variation from the average for each year from 1895 to present (National Oceanic and Atmospheric Administration [NOAA], 2008b).

Approximately half of all precipitation evaporates, is taken up by vegetation, or immediately runs off the land to surface water. Just less than half of all precipitation is recharged to groundwater. Recharge occurs primarily in the spring when snow pack melts and the growing season for vegetation has not yet begun. The second highest seasonal occurrence of recharge is during the late fall and winter when much vegetation is again dormant. Although consistent rainfall takes place, on average, during the summer, there is minimal groundwater recharge because precipitation evaporates from the land surface and vegetation, or is captured in the shallow subsurface and transpired by vegetation. This means the groundwater table and instream flows generally decline between June and October and recover from November through May of each year. Figure 12-5

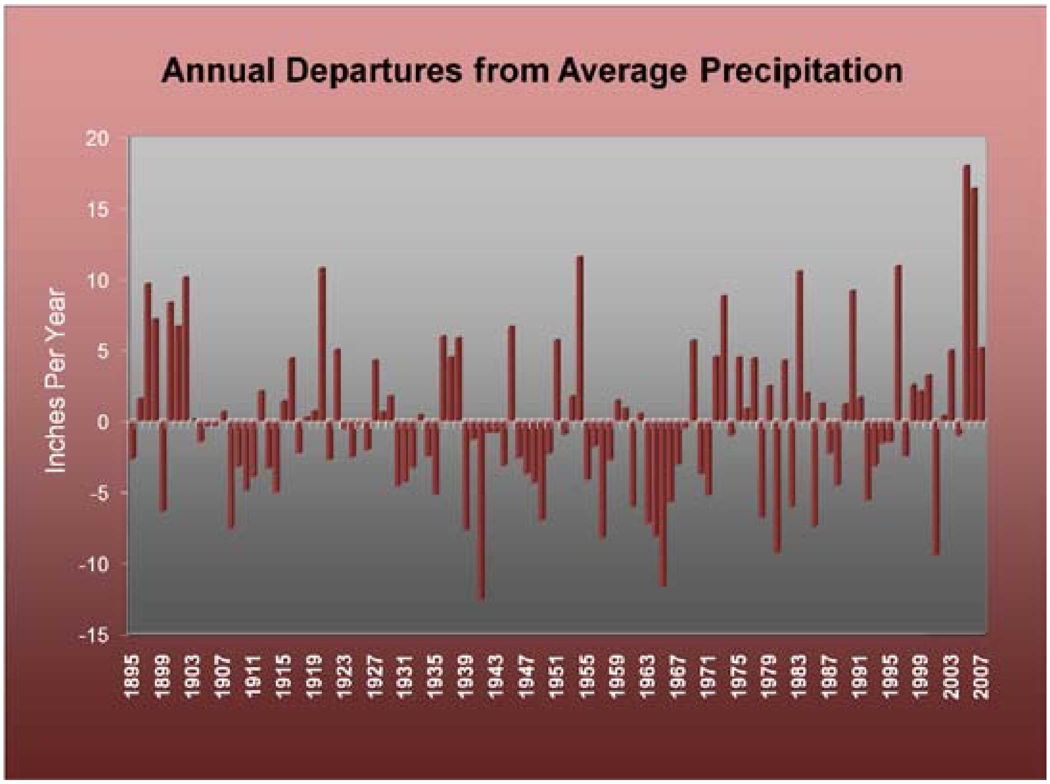


Figure 12-4. Annual departures from average precipitation. ***Data Source: NOAA, 2008b.***

summarizes average precipitation and recharge data for each month of the year based on an analysis of seasonal ground recharge completed by the U.S. Geological Survey (USGS) in 2004 (Flynn & Tasker, 2004).

New Hampshire is perhaps more susceptible than many other states to droughts. This is because New Hampshire's watersheds are not able to store large volumes of water due to their geology and general lack of storage capacity in lakes and impoundments. For instance, aquifers in many other parts of the country have coarse unconsolidated deposits that store groundwater thousands of feet underground. Surface water supply reservoirs in other areas of the country can store the volume of water needed by major cities for many years. In contrast, only 14 percent of New Hampshire's land surface sits over coarse unconsolidated deposits (Medalie and Moore, 1995) and where present, these materials are usually less than 100 feet thick. Storage of water in bedrock aquifers is limited, and water-bearing fractures are found less frequently at depths of 800-1000 feet. Surface water impoundments in the state generally have been designed to support flood control or recreational rather than water supply needs.

Due to the relative lack of water storage in New Hampshire, even short-term deficits in precipitation can cause adverse impacts. In years when New Hampshire has received 30-35 inches of rainfall (approximately 70 percent of average), severe drought conditions have developed, wells have become dewatered, and record low flows in rivers have occurred. Recent drought conditions in 2001-2003 caused many water systems to institute bans on outdoor lawn watering. So many private wells became dewatered during the 2001-2003 drought that water well contractors had up to a three-month waiting list of customers requiring services to address wells impaired by drought.

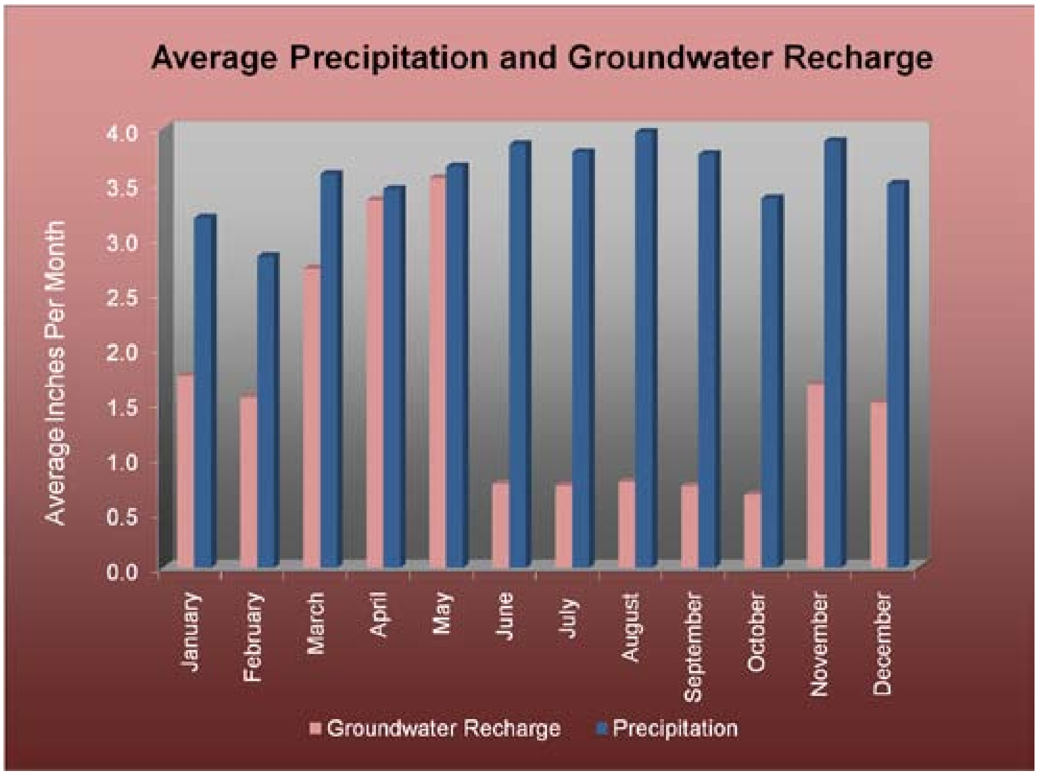


Figure 12-5. Average precipitation and groundwater recharge conditions in New Hampshire. ***Data Source: Flynn & Tasker, 2004.***

Mild drought conditions are far more common in New Hampshire than many realize. Based on data collected and averaged from weather observations throughout the state over the last 113 years, New Hampshire has been in a mild drought condition that has extended for a period of at least three months approximately 25 percent of the time (Figure 12-6). These drought conditions occurred on average every 27 months with a median recurrence period of 17 months (NOAA, 2008a).

12.1.5 Adverse Impacts Associated with Drought

No studies have been conducted that quantify the social or economic costs of past droughts in New Hampshire. It is apparent, however, that drought can affect many economic sectors. Drought may impact farm production if sufficient rainfall or irrigation water is not present to support the growth of crops or maintenance of livestock. When combined with lightning strikes and human actions, drought may facilitate the occurrence of wildfires. Reduced lake, reservoir and river levels hamper boating, swimming, angling, wildlife watching and other activities. A snowless winter reduces skiing opportunity. A shortage of water caused by drought can also affect a number of industries. For example, drought may significantly reduce the generation of electricity from hydropower, biomass, or fossil fuel facilities. Drought also affects the availability of aquatic habitat, drinking water, and food for wildlife. Drought may cause sources of water for community water systems or private residential wells to be diminished or fail. During droughts that occurred in 1999 and 2001-2003, a number of community water systems and private residents had to replace wells that failed. Some community water systems had to make emergency connections to other nearby water systems to maintain their water supply.

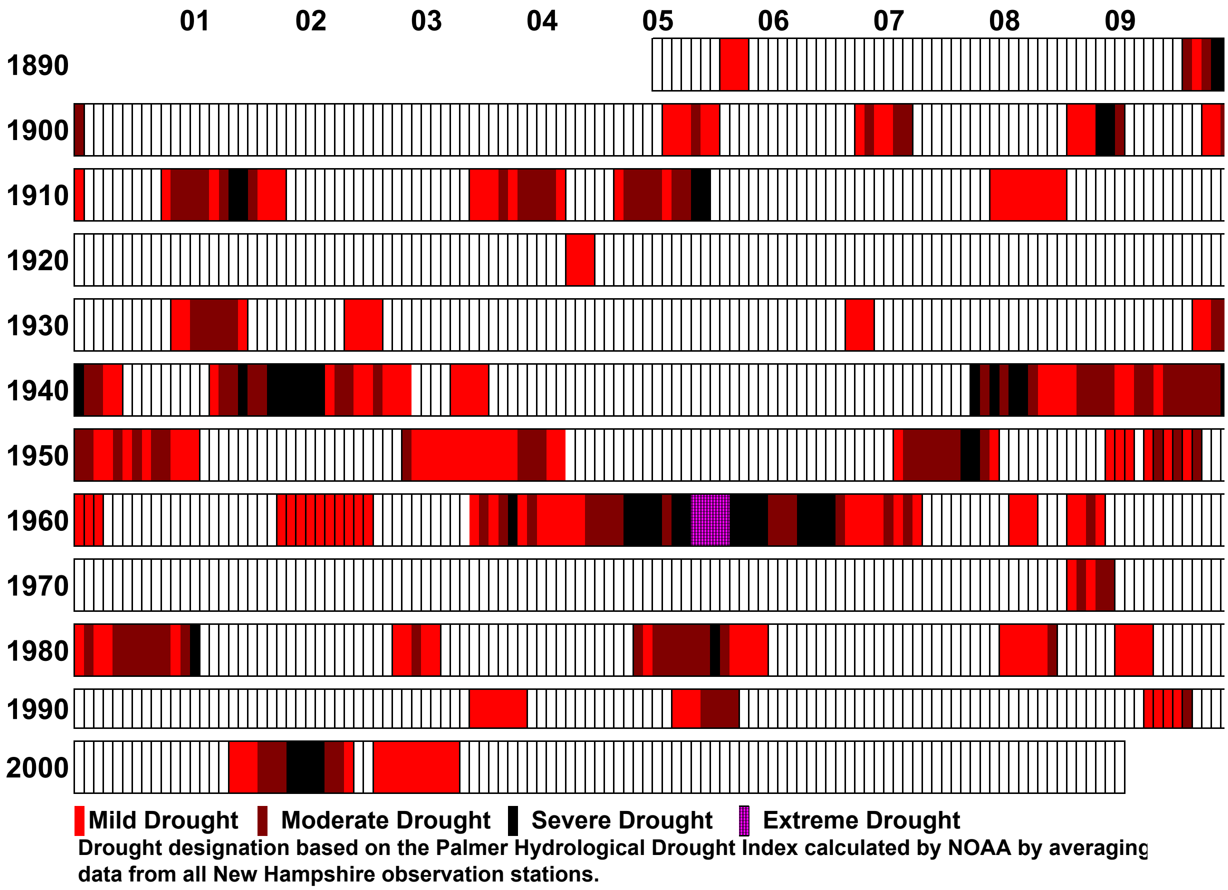


Figure 12-6. Occurrences of drought conditions for three or more months in New Hampshire, 1895 - 2008. ***Data Source: NOAA, 2008a.***

12.2 Issues

12.2.1 Floods and Droughts are Likely to Become More Frequent and More Severe

A preponderance of data and analyses indicate that flooding, and in particular coastal flooding, will become more frequent and destructive due to climate change and landscape change (see Chapter 1 – Introduction and Overview). It does not appear that measures are in place to ensure that new developments and infrastructure are protected from the impacts of all types of floods. Droughts are also expected to become more frequent as a consequence of climate change (Frumhoff et al., 2007; Field et al., 2007).

12.2.2 Inadequate Mapping of Floodplains

Floodplain maps in New Hampshire are based on historical data that may or may not be accurate given current and future changes to the landscape. Without accurate floodplain mapping and information, it is impossible to identify areas that may have an increased risk of flooding due to these changes. Current Flood Insurance Rate Maps (FIRMs) are being digitized by the Federal Emergency Management Agency as part of its Map Modernization program (Figure 12-7). These maps utilize aerial photography for their base layer; for New Hampshire this means aerial photos from

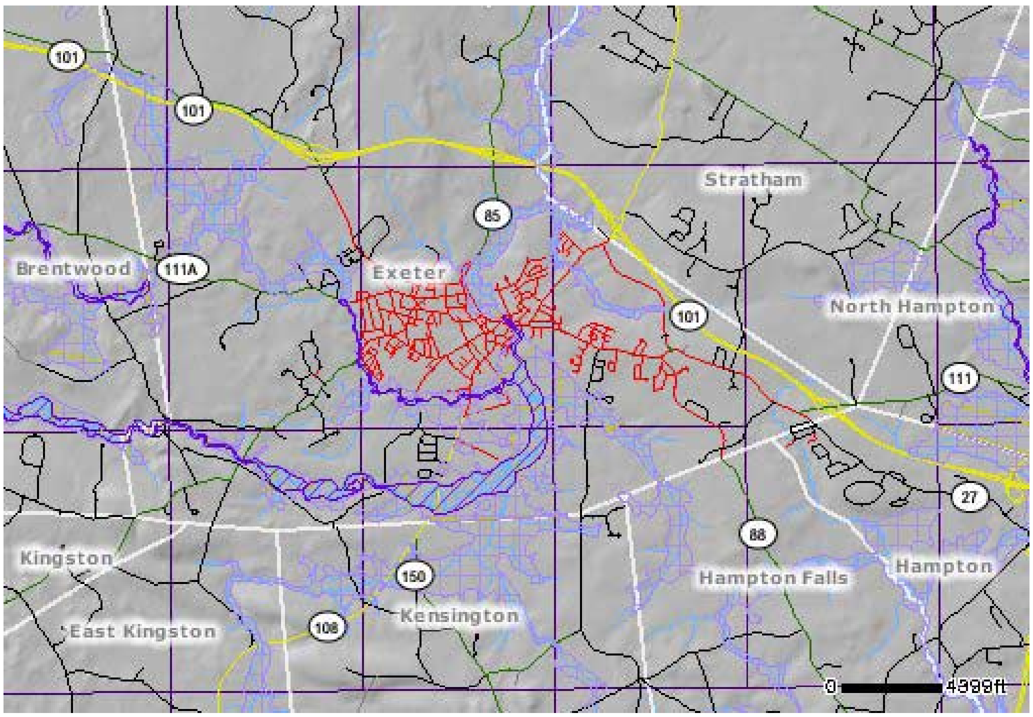


Figure 12-7. Example of a digital Flood Insurance Rate Map. The dark and light purple areas represent floodplains inundated by 100-year frequency flooding. The dark purple also depicts the water course or portion of the floodplain which must be reserved in order to carry or discharge the regulatory flood without cumulatively increasing the flood elevation of the floodplain more than a foot at any point. ***Data Source: NH GRANIT, 2008.***

1998. The flood elevation and topographic data are usually older, from the 1970s and early 1980s. These digital Flood Insurance Rate Maps (DFIRMs) have already been produced for Rockingham, Strafford, Cheshire, Sullivan and Grafton counties. Merrimack and Hillsborough will be the next two counties to have their maps digitized (Comprehensive Flood Management Study Commission, 2008). The updated maps are intended to provide local officials with better references when regulating floodplain development.

The majority of the flood hazard data used for these new DFIRMs is not being updated and sufficient funding is not available to complete new flood studies. The best data available include five-foot land elevation contours in the seacoast area, but those contour data do not continue inland or around Great Bay's 144 miles of shoreline. According to a study by the National Academy's Committee on Floodplain Mapping Technologies, detailed studies cost approximately $20,000 per stream mile and this does not include new elevation data (National Academy of Sciences, 2007).

12.2.3 The Drought Management Plan Is Outdated

The state's Drought Management Plan, last updated in 1990, does not reflect the current structure of government agencies, nor does it include any assessment of groundwater levels in bedrock for assessing drought conditions (NHDES, 1990). The plan and state law generally do not provide any entity with authority to proactively manage water resources in a drought condition unless the governor declares a state of emergency.

12.2.4 Prevention and Mitigation Strategies for Water Supplies Adversely Affected by Drought Are Lacking

Approximately 40 percent of the state's residents rely on a private water supply (U.S. Census Bureau, 1990). During the drought of 2001-2003, so many private wells went dry that homeowners had to wait up to three months to have wells replaced or deepened. Many homeowners were not able to afford the thousands of dollars required to retrofit or replace their private wells.

The distribution networks of community water systems in many areas are in close enough proximity to one another that interconnections can be established to provide back-up emergency water supplies, although this is not a viable option for the majority of small water systems. The state provides grants to encourage such interconnection of water systems for emergency preparedness. Many water systems have already entered into mutual aid agreements to provide water supply in the event of man-made or natural disasters, but many systems do not yet have such measures in place.

12.3 Current Management and Protection

12.3.1 Floods

Disaster Response

The New Hampshire Department of Safety, Bureau of Emergency Management, is responsible for coordinating responses with all state, federal, and local agencies when flooding or other natural disasters occur. DES has authority to regulate the operation of dams and can order impoundments to store or release water when needed to protect public safety. The state and federal government also operate a series of flood control impoundments throughout the state.

National Flood Insurance Program – An Incentive for Local Regulation

The development of land in and near flood prone areas is regulated by municipal governments. Municipal governments are encouraged to amend their subdivision and site plan review regulations to ensure that projects are not prone to losses associated with flooding. The New Hampshire Office of Energy and Planning (OEP) provides communities with assistance to develop these

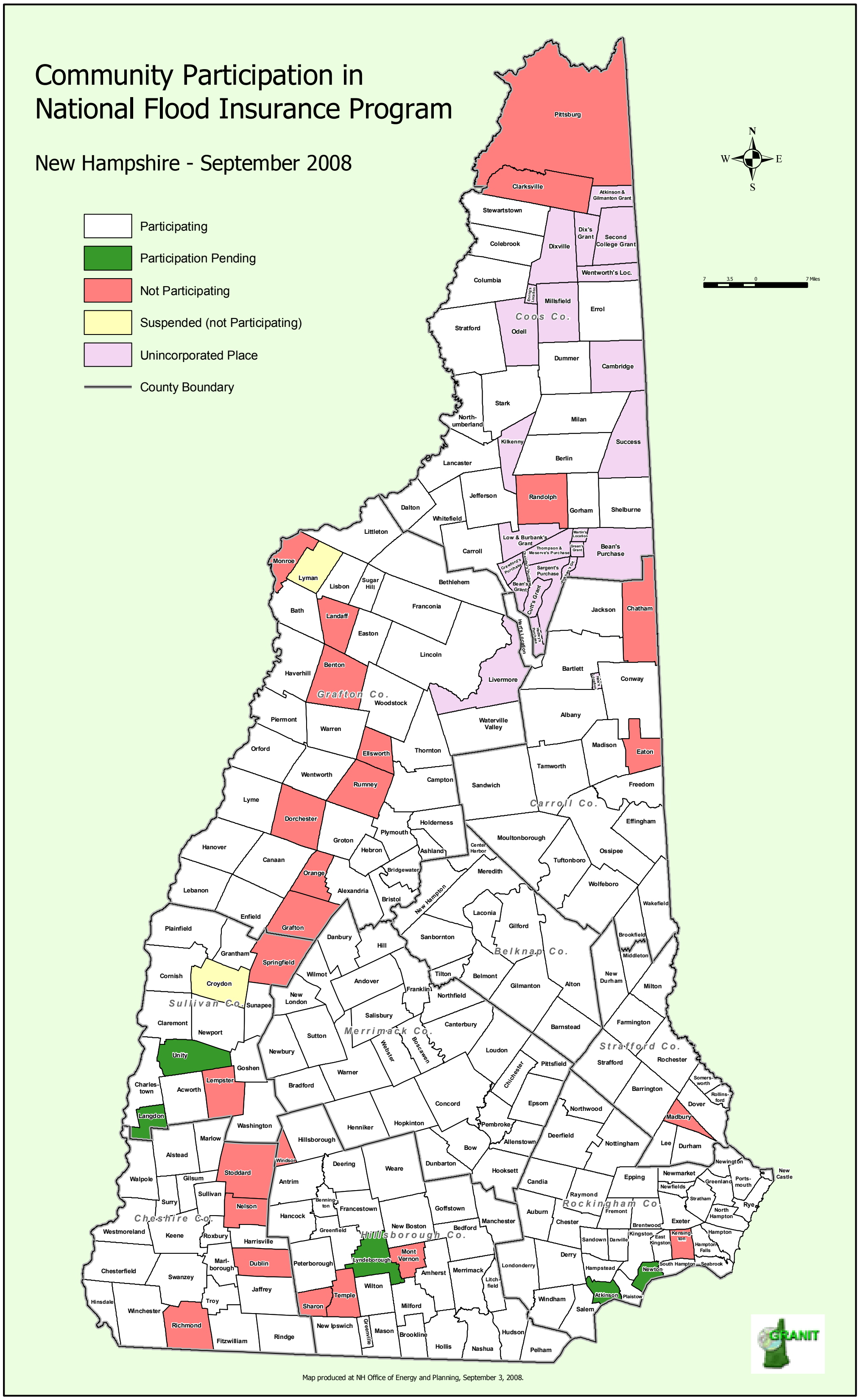


Figure 12-8. New Hampshire communities that are participating in the NFIP. ***Source: New Hampshire Office of Energy and Planning, 2008.***

regulations. OEP also administers the National Flood Insurance Program (NFIP) in New Hampshire and receives a grant from FEMA for this work. OEP conducts community assistance visits to ensure that communities participating in the NFIP are meeting program goals. As an incentive for communities to participate in the NFIP, residents in participating communities can purchase federally subsidized flood insurance. Anyone who applies for a federally-funded mortgage or refinancing on an existing home in a flood-prone area is required to carry flood insurance for the life of the mortgage. Flood insurance is necessary because homeowner's insurance does not cover flood losses. For residents in non-participating communities, private insurance for such at-risk structures can be very expensive and difficult to obtain. In order to participate in the NFIP, communities must

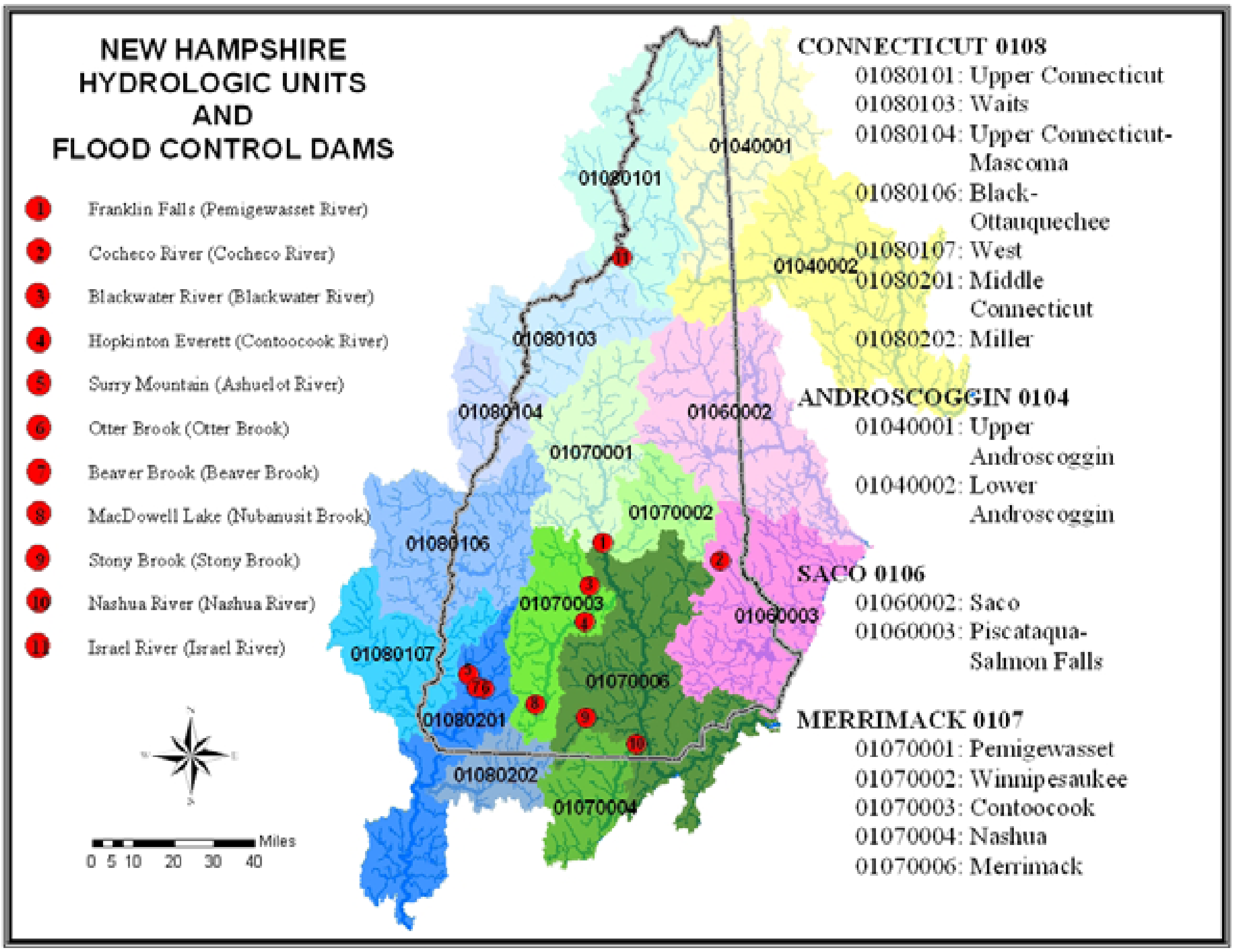


Figure 12-9. Federal flood control projects. ***Data Source: NHDES GIS Database.***

implement subdivision and site plan review regulations that prevent the development of projects in areas subject to flooding. Figure 12-8 on the previous page shows the communities that are participating in the NFIP.

Federal Flood Control Projects

The U.S. Army Corps of Engineers has developed a series of flood control dams in New Hampshire. These structures have been designed to capture peak flow to reduce downstream flooding impacts during periods of rapid snow melt or significant precipitation. Figure 12-9 shows the locations of these structures. As noted in section 12.1.1, New Hampshire's dams have prevented nine dollars in flood damages for every dollar of construction costs (Kennelly, 2008).

Flood Management Commission

Flooding events in 2005, 2006 and 2007 prompted the state Legislature to create a Flood Management Commission to develop a comprehensive flood management plan for the state. The commission's September 2008 report looks at New Hampshire's historical and predicted floods, current and expected dam inventory, the trends and regulation of development, as well as the current state and needs for both short- and long-term weather forecasts. It presents current thinking on actual and future risks to guide the wise investment of taxpayer funds to efficiently reach a more reasonable level of protection. The report contains 50 recommendations, which are listed in Appendix B (Comprehensive Flood Management Study Commission, 2008).

12.3.2 Drought

Drought Management Plan

An interagency task force prepared a Drought Management Plan in 1990 (NHDES, 1990). The plan was developed because during the 1980s the southeastern United States experienced an extensive drought and concerns were raised that the same could occur in New Hampshire. The Drought Management Plan establishes methods to describe drought conditions and suggested response actions for different classifications of drought (Table 12-2). The plan relies on a Drought Management Team to disseminate information to the public regarding drought conditions and appropriate water conservation measures that should be implemented by water users. The responsibility for implementing water conservation measures rests with the water users.

The Drought Management Plan divides New Hampshire into five drought management areas (Figure 12-10). The management areas largely coincide with watershed and county political boundaries which are reasonably proximal to each other. Table 12-2 lists the suggested response actions for each drought classification as specified in the plan.

Drought Management Team

- Governor's Office
- Office of Energy and Planning (formerly Office of State Planning)
- Department of Safety - Bureau of Emergency Management (formerly of the Office of Emergency Management in the Governor's office)
- Department of Environmental Services
- Department of Agriculture, Markets and Food
- Department of Health and Human Services
- Department of Resources and Economic Development
- New Hampshire Municipal Association
- New Hampshire Water Works Association
- New Hampshire Business and Industry Association
- New Hampshire State Climatologist
- United States Geological Survey

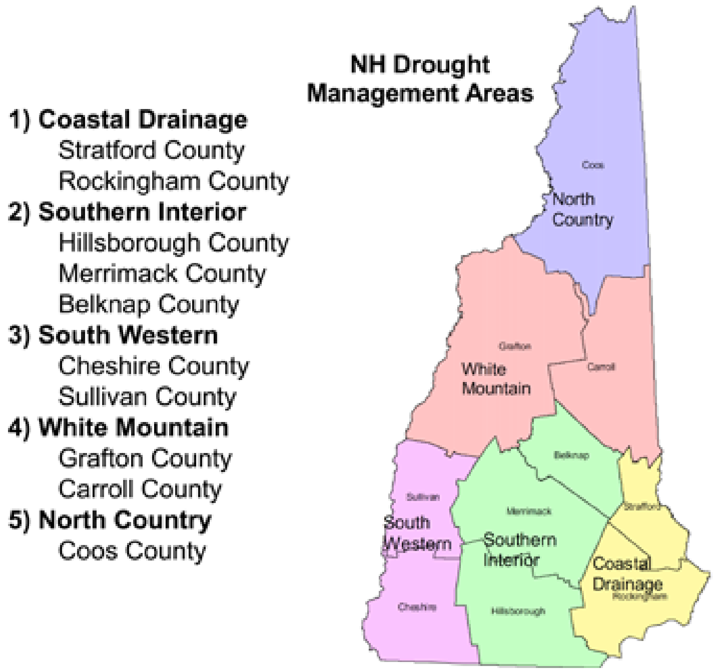


Figure 12-10. New Hampshire drought management areas. ***Source: NHDOS, 2007.***

The Drought Management Plan classifies drought based on measurements of precipitation, soil moisture, stream flow, groundwater in sand and gravel, forest moisture, and reservoir levels. The plan does not contain criteria for drought classification for groundwater levels in bedrock.

The Drought Management Plan was developed outside of any statutory mandate and therefore water conservation measures recommended by the Drought Management Team cannot be mandated unless the governor declares a state of emergency and mandates these conservation measures be implemented.

In response to the large number of private wells becoming dewatered during the drought of 2001-2003, the Legislature adopted RSA 41:11-d in 2007 to provide municipalities with the authority to restrict residential lawn watering if the state or federal government declares a condition of drought. Additionally, new ground-

Table 12-2. Suggested response actions for different classifications of drought for the Drought Management Plan. ***Source: NHDOS, 2007.***

Drought Classification	Suggested Response Action
Level 1 - Alert	Assess conditions
Level 2 - Warning	Initiate voluntary water conservation Investigate potential source augmentation Evaluate need for mandatory action
Level 3 - Emergency	Implement mandatory conservation measures
Level 4 - Disaster	Impose water use restrictions with significant economic implications Exercise emergency powers of Governor

water withdrawals exceeding 57,600 gallons over a 24-hour period and new surface water withdrawals permitted by DES are required to reduce or terminate water use when drought is reducing the amount of water in the environment. There is limited statutory authority to require other water users to implement conservation in response to a drought condition.

Bureau of Emergency Management

The Drought Management Plan predates the establishment of the Bureau of Emergency Management within the Department of Safety which was established pursuant to RSA 21-P:36 in 2002. In accordance with RSA 21-P-35:5, the Bureau of Emergency Management is responsible for preparing and carrying out all emergency prevention and response functions for any natural or man-made disasters, including drought.

12.4 Stakeholder Recommendations

This section contains key recommendations that have been developed through collaboration with a group of volunteer stakeholders who have reviewed and contributed to this chapter.

12.4.1 Develop Improved Mapping Programs for Floods

Action needs to be taken to prepare for floods and to prevent or reduce the damage to property and human life that could result from floods. An initial step towards achieving this goal is to characterize where and how much water will be moving across a landscape. Because flooding is influenced by the topography of the land, accurate elevation data is needed. Current flood maps in the state are not based on high resolution data; consequently, we do not know with a high degree of certainty where floods will impact humans or the potential severity of flooding. Light Detection and Ranging (LIDAR) should be used to help update and develop new flood maps. High resolution imagery maps need to be collected on a cyclical basis to overlay with the flood maps generated by LIDAR.

Other states along the east coast are implementing LIDAR and imagery data collection programs after witnessing millions of dollars in costs and loss of life associated with flood disasters. New Hampshire should not wait for similar disasters to occur within the state before initiating this effort. This information will also be critical for developing adaptive strategies to address climate change.

12.4.2 Increase the Number of Stream Gages to Better Predict Flooding

When floods occur, stream gages are indispensable tools for flood forecasting and warning along rivers and streams. Relying on historical data is not adequate, since the severity and duration of precipitation events in New Hampshire may increase due to climate change, and summer flows may decline causing more low-flow periods. After the installation of 15 new gages from the 2007 capital budget request and an Emergency Management Performance Grant, the state will have a total of 54 continuous USGS gage stations. This will exceed the number of gages that were present in 1962. However, the state will lose 15 gages in October 2009 if state funding is not developed, bringing the number of gages in the state below the number operating in the 1930s. Funding for operating and maintaining one gage in 2009 is $14,450 annually (NHDES, 2008). This amount does not include the installation cost of new gages or contributions from the USGS, which helps to share the cost of many gages in the state.

12.4.3 Develop and Implement Disaster Prevention for Floods

Floods in New Hampshire historically have been the most costly and most frequently recurring natural disasters. More intense storms and rising sea levels associated with climate change will make floods an even more significant problem in the future. New Hampshire needs to take action to prevent loss of property or human life as a result of flooding. New or upgraded infrastructure (culverts, bridges, stormwater management systems) should be developed to prevent flooding from causing loss of life or property. Existing developments should be retrofitted, relocated or insured to mitigate losses that may occur due to flooding. New developments should be located in areas not prone to flooding or flood-related erosion as determined by state-of-the-art land elevation and erosion hazard mapping.

12.4.4 Revise the Drought Management Plan

The Drought Management Plan needs to be updated to reflect the current structure of state government. The plan also needs to include criteria for assessing bedrock groundwater levels because approximately 60 percent of the state's population relies on this resource for drinking water. The Drought Management Team should assess whether the state or other levels of government need to have authority to manage water resources when extensive drought conditions persist.

12.4.5 Establish Prevention and Mitigation Strategies for Water Supplies Adversely Affected by Drought

Government agencies and all water users, including water systems, businesses, agriculture, and residents with private water supply wells, need to understand that droughts do occur in New Hampshire. Drought contingency plans, insurance, financial resources, and mutual aid agreements need to be established to effectively cope with the effects of drought.

References

Bradbury, J.A., Dingman, S.L., & Keim, B.D. (2002). New England drought and relations with large-scale atmospheric circulation patterns. *Journal of the American Water Resources Association*, *38*(5), 1287–1299.

Cannon, J.W. (2007). *Northern New England coastal flooding (*Eastern Region Technical Attachment, No. 2007-03). National Oceanic and Atmospheric Administration. Available at: http://www.erh.noaa.gov/er/hq/ssd/erps/ta/ta2007-03.pdf.

Comprehensive Flood Management Study Commission. (2008, September). *New Hampshire House Bill 648, Chapter 179 Laws of 2007, Comprehensive Flood Management Study Commission: Final report*. State of New Hampshire. Available at: http://gencourt.state.nh.us/statstudcomm/reports/1853.pdf.

Dolan, K. (2007, September 18). *Fluvial erosion*. Presentation to New Hampshire House Bill 648 Flood Management Study Commission. Vermont Department of Environmental Conservation.

Federal Emergency Management Agency. (2008). FEMA's Community Information System database, National Flood Insurance Program. Unpublished Data. Retrieved on September 10, 2008.

Field, C.B., Mortsch, L.D., Brklacich, M., Forbes, D.L., Kovacs, P., Patz, J.A., Running, S.W., & Scott, M.J. (2007). North America. In M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden & C.E. Hanson, (Eds.), *Climate change 2007: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 617-652). Cambridge, UK: Cambridge University Press. Available at: http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-chapter14.pdf.

Flynn, R.H. & Tasker, G.D. (2004). *Generalized estimates from streamflow data of annual and seasonal groundwater recharge rates for drainage basins in New Hampshire* (Scientific Investigations Report 2004-5019). U.S. Geological Survey. Available at: http://pubs.usgs.gov/sir/2004/5019/.

Frumhoff, P.C., McCarthy, J.J., Melillo, J.M., Moser, S.C., & Wuebbles, D.J. (2007). *Executive summary: Confronting climate change in the U.S. Northeast: Science, impacts, and solutions*. Synthesis report of the Northeast Climate Impacts Assessment. Cambridge, MA: Union of Concerned Scientists. Available at: http://www.climatechoices.org/assets/documents/climatechoices/executive-summary-necia.pdf.

Kennelly, J. (2008, January 7). *USACOE planning programs: USACOE planning & technical assistance programs.* U.S. Army Corps of Engineers New England District Chief of Planning testimony before New Hampshire House Bill 648 Comprehensive Flood Management Plan Study.

Kirshen, P., Watson, C., Douglas, E., Gontz, A., Lee, J., & Tian, Y. (2008). Coastal flooding in the northeastern United States due to climate change. *Mitigation and Adaptation Strategies for Global Change*, *13*, 437-451.

Konrad, C.P. (2003). *Effects of urban development on floods* (U.S. Geological Survey Fact Sheet FS-076-03). Available at: http://pubs.usgs.gov/fs/fs07603/pdf/fs07603.pdf.

Medalie, L. & Moore, R.B. (1995). Ground-water resources in New Hampshire: Stratified-drift aquifers (U.S. Geological Survey Water-Resources Investigations Report 95-4100). Available at: http://pubs.usgs.gov/wri/wrir_95-4100/html/pdf.html.

National Academy of Sciences. (2007). *Elevation data for floodplain mapping*. Committee on Floodplain Mapping Technologies, National Research Council. Washington, D.C.:The National Academies Press.

National Oceanic and Atmospheric Administration. (2008a). *Climate data online*. Data retrieved June 2008 from Web site for National Climatic Data Center, NOAA, U.S. Department of Commerce. Accessed at: http://www7.ncdc.noaa.gov/CDO/CDODivisionalSelect.jsp#.

National Oceanic and Atmospheric Administration. (2008b). *New Hampshire climate summary*. Data retrieved June 2008 from Web site for National Climatic Data Center, NOAA, U.S. Department of Commerce. Unpublished data. Accessed at: http://www.ncdc.noaa.gov/oa/climate/research/cag3/nh.html.

National Research Council (2008). *Urban stormwater management in the United States* (WSTB-U-06-01-A). Committee on Reducing Stormwater Discharge Contributions to Water Pollution, Water Science and Technology Board, Division on Earth and Life Studies. Washington, D.C.: The National Academies Press. Pre-publication copy. Available at: http://books.nap.edu/catalog.php?record_id=12465#toc.

New Hampshire Department of Environmental Services. (1990). *New Hampshire drought management plan* (NHDES-WRB-90-1). New Hampshire Water Resources Division. Available at: http://des.nh.gov/organization/commissioner/pip/publications/wd/documents/nhdes-wrb-90-1.pdf.

New Hampshire Department of Environmental Services. (2008). New Hampshire Geological Survey. Unpublished Data.

New Hampshire Department of Safety. (2007). *Natural hazard mitigation plan 2007: Hazard analysis.* Homeland Security and Emergency Management. Available at: http://www.nh.gov/safety/divisions/bem/HazardMitigation/haz_mit_plan.html.

New Hampshire Office of Energy and Planning. (2008). *Participation status for New Hampshire communities: Flood Management Program*. Retrieved September 17, 2008 from OEP Floodplain Management Web site. Available at: http://www.nh.gov/oep/programs/floodplainmanagement/documents/nfipstatusmap.pdf.

NH GRANIT. (2008, August). *New Hampshire's statewide GIS clearinghouse*. University of New Hampshire. Data retrieved August 2008. Available at: http://www.granit.unh.edu/.

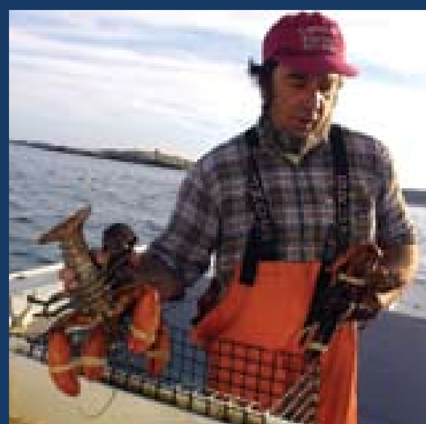
Pillsbury, M. (2008, January 7). *Highway drainage and crossing structures.* Presentation to New Hampshire House Bill 648 Study Commission. New Hampshire Department of Transportation.

Seacoast SAD. (1978, February 15). *The Blizzard of 1978.* Hampton, N.H. Retrieved September 17, 2008 from Website for WebLane Memorial Library, Hampton, N.H. Available at: http://www.hampton.lib.nh.us/hampton/history/storms/78sad.htm.

U.S. Census Bureau. (1990). *Historical census of housing tables. Source of water.* Retrieved July 5, 2008 from Web site for U.S. Census Bureau, Census of Housing. Available at: http://www.census.gov/hhes/www/housing/census/historic/water.html

EXECUTIVE SUMMARY

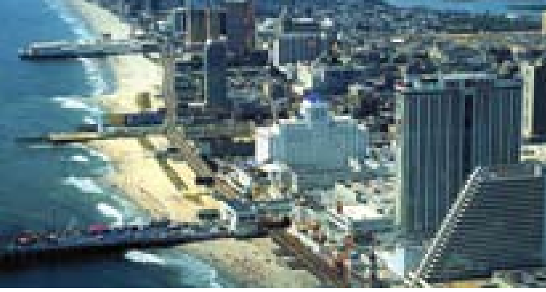
Confronting Climate Change in the U.S. Northeast



SCIENCE, IMPACTS, AND SOLUTIONS

A Report of the
Northeast Climate Impacts Assessment



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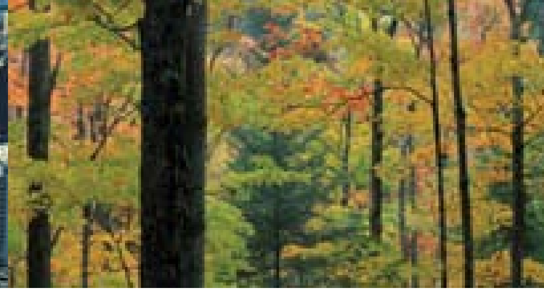


Jerry and Marcy Monkman

AP Photo/Robert E. Klein

From the sandy beaches of New Jersey to the rocky shores of Maine, and inland from the cornfields of Pennsylvania to the forested mountains of Vermont, the northeastern United States boasts enormous geographical and climatic diversity within a relatively small expanse. The character and economy of the Northeast have been profoundly shaped over the centuries by its varied and changeable climate—the pronounced seasonal cycle that produces snowy winters, verdant springs, humid summers, and brilliant autumns, and the year-to-year and seasonal variability that includes extreme events such as nor'easters, ice storms, and heat waves.

This long-familiar climate has already begun changing in noticeable ways, however. Since 1970 the Northeast has been warming at a rate of nearly 0.5 degree Fahrenheit (°F) per decade. Winter temperatures have risen even faster, at a rate of 1.3°F per decade from 1970 to 2000. This warming has been correlated with many other climate-related changes across the region, including:

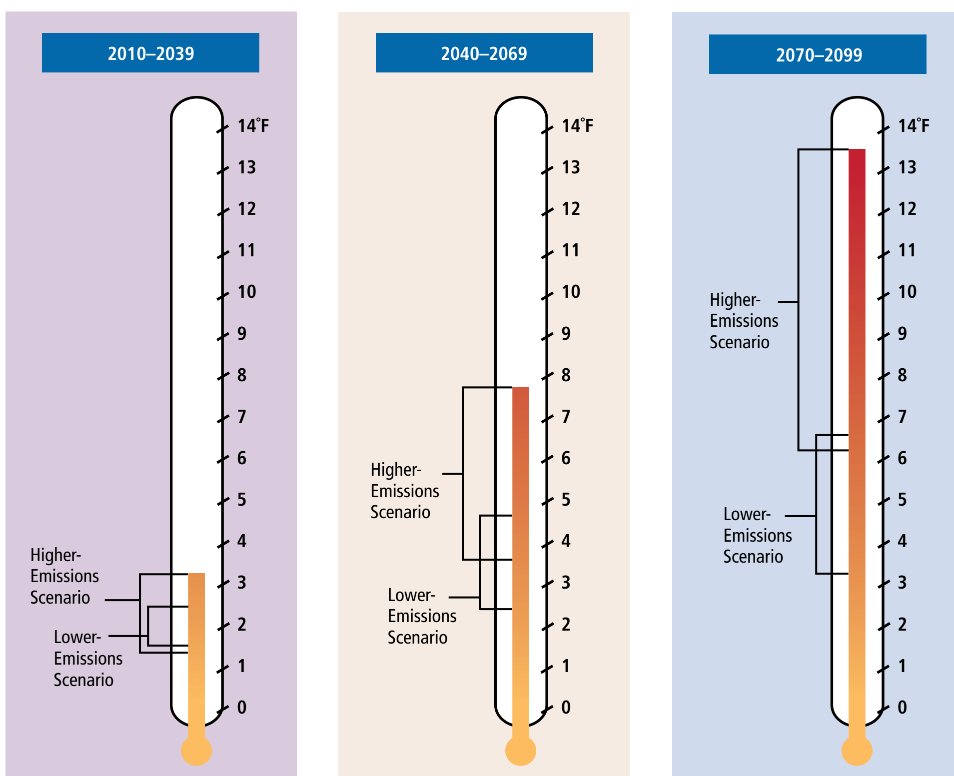
- More frequent days with temperatures above 90°F
- A longer growing season
- Less winter precipitation falling as snow and more as rain
- Reduced snowpack and increased snow density
- Earlier breakup of winter ice on lakes and rivers
- Earlier spring snowmelt resulting in earlier peak river flows
- Rising sea-surface temperatures and sea levels

All of these observed changes are consistent with those expected to be caused by global warming. The Intergovernmental Panel on Climate Change (IPCC), representing the world's leading climate scientists, concluded in February 2007 that it is "unequivocal" that Earth's climate is warming, and that it is "very likely" (a greater than 90 percent certainty) that the heat-trapping emissions from the burning of fossil fuels and other human activities have caused "most of the observed increase in globally averaged temperatures since the mid-twentieth century." Thus, the Northeast and the rest of the world face continued warming and more extensive climate-related changes to come—changes that could dramatically alter the region's economy, landscape, character, and quality of life.

The research summarized here describes how climate change may affect the Northeast states under two different scenarios of future emissions of heat-trapping gases. The first

Changes in Regional Average Summer Temperature

The Northeast is already experiencing rising temperatures, with potentially dramatic warming expected later this century, especially if emissions of heat-trapping gases continue along the path of the higher-emissions scenario. These "thermometers" show projected increases in regional average summer temperatures for three time periods: early-, mid-, and late-century.



Geoff Kuchera

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Community Energy, Inc.

(the higher-emissions scenario) is a future where people—individuals, communities, businesses, states, and nations—allow emissions to continue growing rapidly over the course of this century. The second (the lower-emissions scenario) is a future in which societies choose to rely less on fossil fuels and adopt more resource-efficient technologies.

Cities across the Northeast that today experience few days above 100°F could average 20 to 30 such days per summer by late-century under the higher-emissions scenario.

These scenarios represent strikingly different emissions choices that societies may make. However, they do not represent the full range of possible emissions futures. A number of factors, including unrestrained fossil-fuel use, could drive global emissions above the higher-emissions scenario used in this study, while rapid, concerted efforts to adopt clean, efficient technologies could reduce emissions below the lower-emissions scenario.

HOW WILL EMISSIONS CHOICES AFFECT THE NORTHEAST'S FUTURE CLIMATE?

NECIA climate projections found that over the next several decades, temperatures across the Northeast will rise 2.5°F to 4°F in winter and 1.5°F to 3.5°F in summer regardless of the emissions choices we make now (due to heat-trapping emissions released in the recent past). By mid-century and beyond, however, today's emissions choices generate starkly different climate futures. By late this century under the higher-emissions scenario:

- Winters in the Northeast could warm by 8°F to 12°F and summers by 6°F to 14°F above historic levels.
- The length of the winter snow season could be cut in half across northern New York, Vermont, New Hampshire, and Maine, and reduced to a week or two in southern parts of the region.
- Cities across the Northeast that today experience few days above 100°F each summer could average 20 such days per summer, and more southern cities such as Hartford and Philadelphia could average nearly 30 days.
- Short-term (one- to three-month) droughts could occur as frequently as once each summer in the area of the Catskills and the Adirondacks, and across the New England states.

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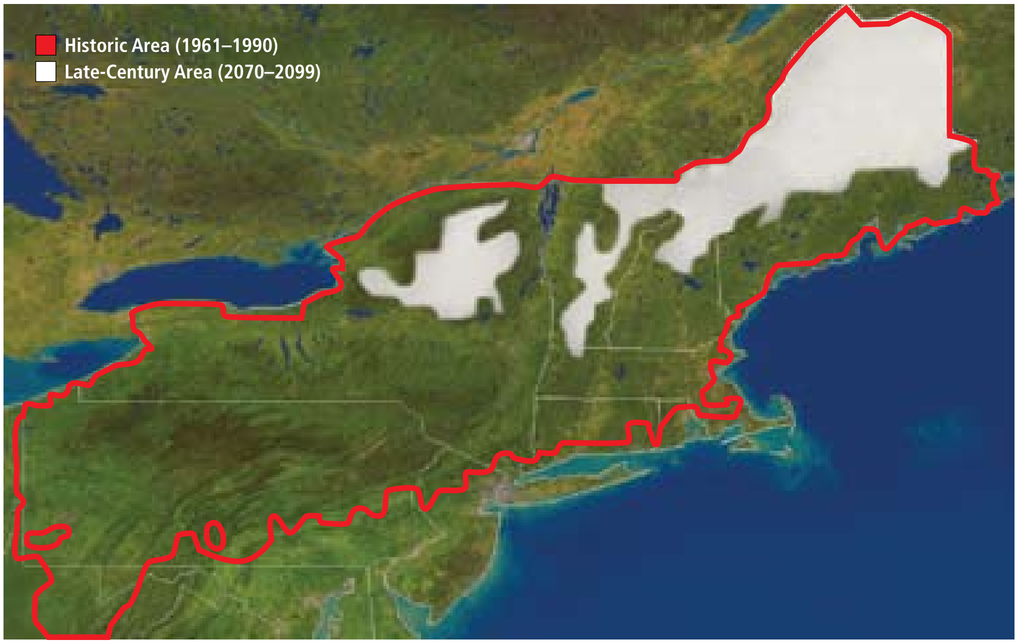
The Changing Face of Winter



If higher emissions prevail, a typical snow season may become increasingly rare in much of the Northeast toward the end of the century. The red line in the map captures the area of the northeastern United States that, historically, has had at least a dusting of snow on the ground for at least 30 days in the average year. The white area shows the projected retreat of this snow cover by late-century to higher altitudes and latitudes, suggesting a significant change in the character of a Northeast winter.

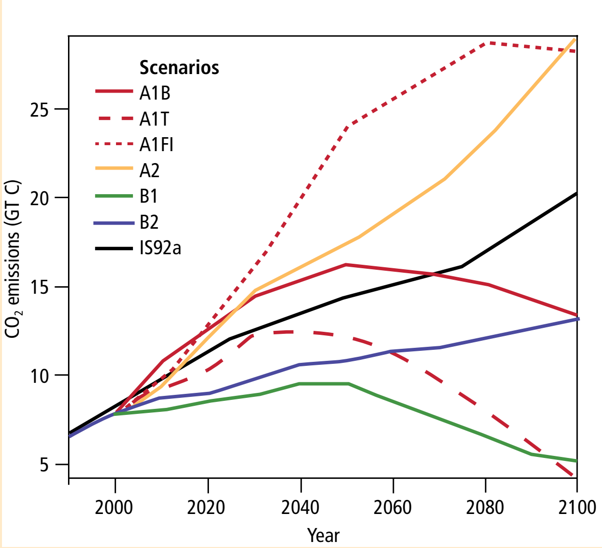
Assessing Future Climate Change in the Northeast

In order to project changes in temperature and other climate variables over the coming decades, scientists must address two key uncertainties. The first is directly related to human activity: how much carbon dioxide (CO_2) and other heat-trapping gases will our industrial and land-use activities emit over the coming century? The second is scientific in nature: how will the climate respond to these emissions (e.g., how much will temperatures rise in response to a given increase in atmospheric CO_2)?

To address the first uncertainty, the IPCC has developed a set of possible futures, or scenarios, that project global levels of emissions of heat-trapping gases based on a wide range of development variables including population growth, energy use, and other societal choices. Analyses of the Northeast Climate Impacts Assessment (NECIA) used the IPCC's A1fi and B1 scenarios to represent possible higher- and lower-emissions choices, respectively, over the course of the century. The higher-emissions scenario represents a world with fossil fuel-intensive economic growth. Atmospheric CO_2 concentrations reach 940 parts per million (ppm) by 2100—more than triple pre-industrial levels.

The lower-emissions scenario assumes a relatively rapid shift to less fossil fuel-intensive industries and more resource-efficient technologies. This causes CO_2 emissions to peak around mid-century then decline to less than our present-day emissions rates by the end of the century. Atmospheric CO_2 concentrations reach 550 ppm by 2100—about double pre-industrial levels.

To estimate the range of potential changes in the Northeast's climate and address the second uncertainty—how the climate will respond to increasing emissions—NECIA researchers used the IPCC's higher- and lower-emissions scenarios as input to three state-of-the-art global climate models, each representing different climate "sensitivities" (see below).



IPCC Emissions Scenarios

Projected carbon emissions for the IPCC SRES scenarios. The higher-emissions scenario (A1fi) corresponds to the dotted red line while the lower-emissions scenario (B1) corresponds to the green line.

Climate sensitivity is defined as the temperature change resulting from a doubling of atmospheric CO_2 concentrations relative to pre-industrial times, and determines the extent to which temperatures will rise under a given increase in atmospheric concentrations of heat-trapping gases.

The greater the climate sensitivity of the global climate model, the greater the extent of projected climate change for a given increase in CO_2. That is why NECIA analyses used three different climate models to generate the projections described in this study: the U.S. National Oceanic and Atmospheric Administration's Geophysical Fluid Dynamics Laboratory (GFDL) CM2.1 model, the United Kingdom Meteorological Office's Hadley Centre Climate Model version 3 (HadCM3), and the National Center for Atmospheric Research's Parallel Climate Model (PCM). The first two have medium and medium-high climate sensitivities, respectively, while the third has low climate sensitivity.

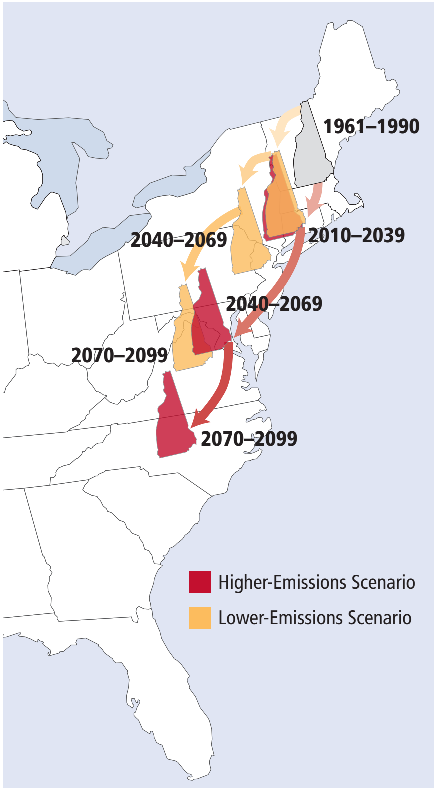
These models are among the best of the latest generation of climate models. Confidence in using these global models to assess the Northeast's future climate is based on results from a detailed analysis that indicates these models are able to reproduce not only key features of the regional climate but also climate changes that have already been observed across the region over the past century (e.g., rising temperatures, increases in precipitation and storms producing heavy precipitation).

Uncertainties in climate modeling and the workings of the earth-atmosphere system remain and several lines of evidence suggest that the climate-model projections used in the NECIA assessment may be relatively conservative. The models do not, for instance, capture the rapid winter warming observed in the Northeast over the past several decades. Projections of sea-level rise used in this report may also be quite conservative because they do not account for the rapid rate of decay and melting of the major polar ice sheets currently being observed, nor the potential for further acceleration of this melting.

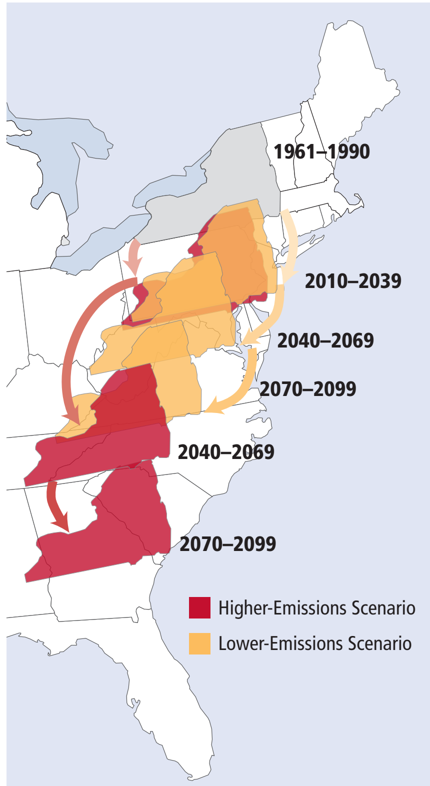
Global climate models produce output in the form of geographic grid-based projections of daily, monthly, and annual temperatures, precipitation, winds, cloud cover, humidity, and a host of other climate variables. The grid cells range in size from 50 to 250 miles on a side. To transform these global projections into "higher-resolution" regional projections (which look at changes occurring across tens of miles rather than hundreds), NECIA scientists used well-established statistical and dynamical downscaling techniques. The results of this collaborative climate research were presented in an earlier NECIA report titled *Climate Change in the U.S. Northeast*.

Migrating State Climates

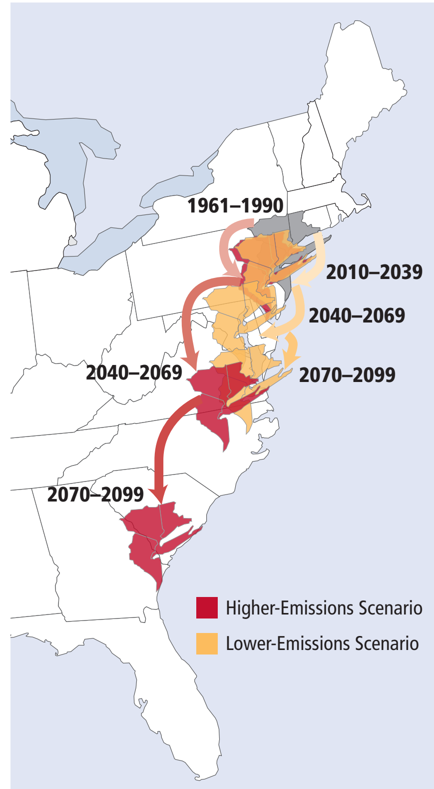
New Hampshire



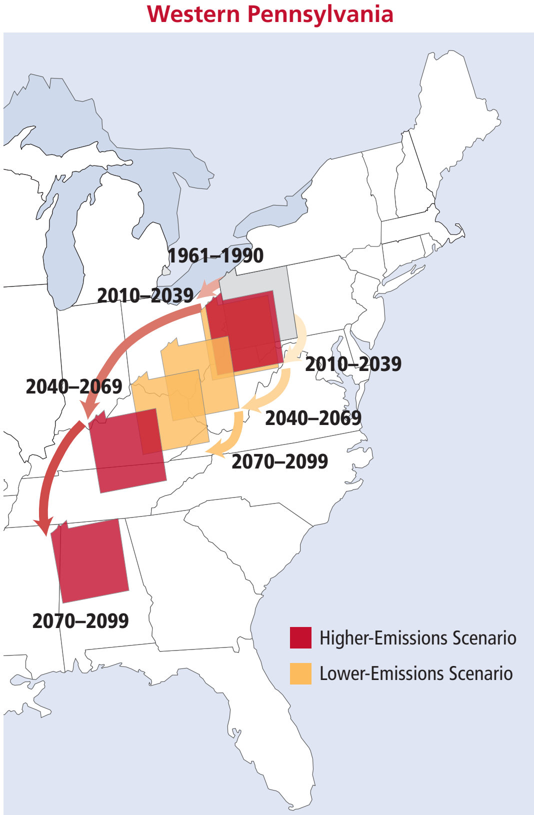
Upstate New York



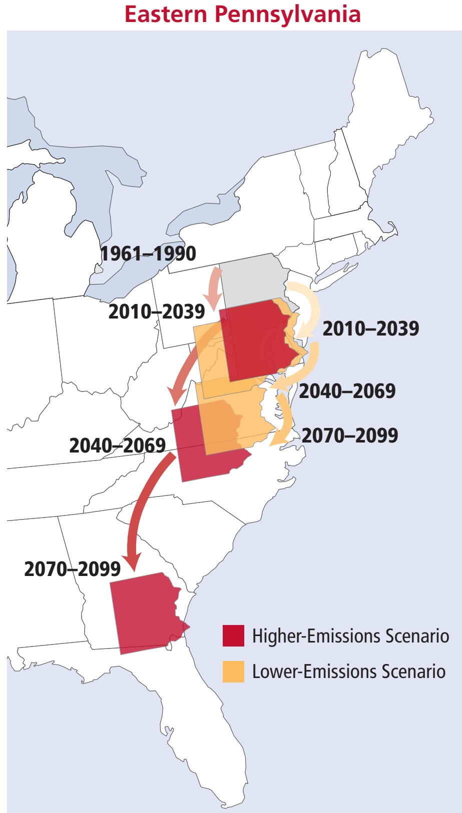
NYC Tri-State Region



Western Pennsylvania



Eastern Pennsylvania



Changes in average summer heat index—a measure of how hot it actually feels, given temperature and humidity—could strongly affect quality of life in the future for residents of the Northeast. Red arrows track what summers could feel like in, for example, the NYC Tri-State region (the greater New York City metropolitan region, encompassing parts of New Jersey and Connecticut) over the course of the century under the higher-emissions scenario. Yellow arrows track what summers in these states would feel like under a lower-emissions scenario.

AP Photo/Seth Wenig

Angel Franco/The New York Times/Redux

Peter LaTourrette/birdphotography.com

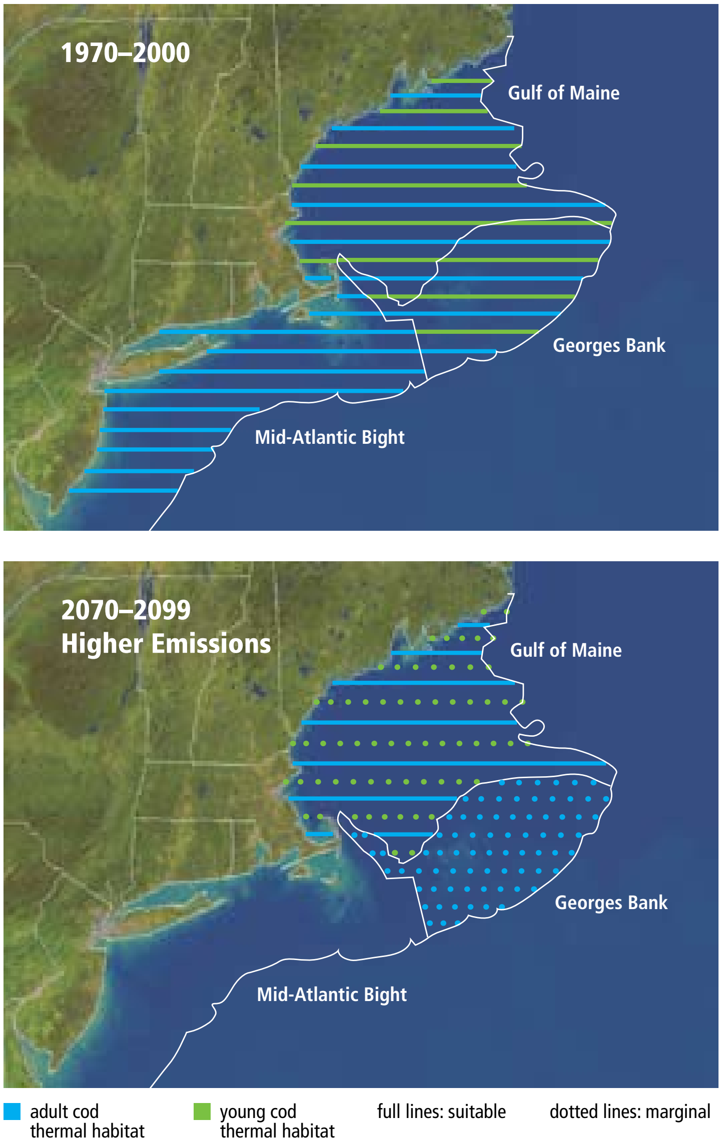
CONTINUED FROM PAGE 3

- Hot summer conditions could arrive three weeks earlier and last three weeks longer into the fall.
- Global average sea level is conservatively projected to rise one to two feet.

In contrast, substantially smaller climate-related changes can be expected if the Northeast and the world reduce emissions consistent with the lower-emissions scenario used in this study—typically, about half the change expected under the higher-emissions scenario. For example, Northeast winters are projected to warm 5°F to 8°F above historic levels by late-century, and summers by 3°F to 7°F.

Leading scientists and economists from universities and research institutions across the Northeast and the nation have used these new climate projections to assess the impacts of these two very different future Northeast climates on vital aspects of the region's life and economy: coastal areas, marine fisheries, forests, agriculture, winter recreation, and human health. These experts also describe actions that can be taken today in the Northeast to reduce emissions and help avoid the most severe impacts of global warming and to adapt to the unavoidable changes that past emissions have already set in motion.

Emissions Choices May Redefine Waters Suitable for Cod

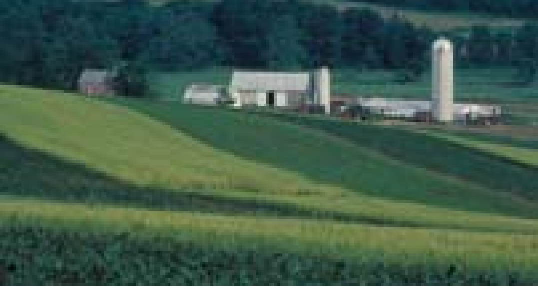


In the waters off of the Northeast states, cod are currently at the southern edge of their favored temperature range, or suitable thermal habitat. Waters that historically provide suitable temperatures for adult and young cod (bottom temperatures less than 54˚F and 47˚F, respectively) are illustrated in the top map, while the bottom map shows changes in this area by late-century under the higher-emissions scenario. Historically productive Georges Bank is expected to no longer support the "recruitment" (growth and survival to harvestable size) of young cod and to be only marginally suitable for adult cod. The Gulf of Maine is expected to continue to support adult cod throughout the century, but the warmer waters would hinder recruitment.

WHAT MIGHT THE PROJECTED CLIMATE CHANGES MEAN FOR THE NORTHEAST'S ECONOMY AND QUALITY OF LIFE?

By late this century, if the higher-emissions scenario prevails:

- The extreme coastal flooding that now occurs only once a century could strike New York City on average once every decade.
- Increasing water temperatures may make the storied fishing grounds of Georges Bank unfavorable for cod.
- Pittsburgh and Concord, NH, could each swelter through roughly 25 days over 100°F every summer—compared with roughly one day per summer historically—and even typically cool cities such as Buffalo could average 14 days over 100°F each year, amplifying the risk of heat-related illnesses and death among vulnerable populations.
- In Philadelphia, which already ranks tenth in the nation for ozone pollution, the number of days failing to meet federal air-quality standards is projected to quadruple


Tim McCabe/USDA


AP Photo/The Herald, Lauren Tagliatela


AP Photo/Steven Senne

(if local vehicle and industrial emissions of ozone-forming pollutants are not reduced).

- Only western Maine is projected to retain a reliable ski season.
- The hemlock stands that shade and cool many of the Northeast's streams could be lost—much like the American elm—to a pest that thrives in warmer weather, further threatening native brook trout in the Adirondacks and elsewhere.
- Climate conditions suitable for maple/beech/birch forests are projected to shift dramatically northward, while conditions suitable for spruce/fir forests—a primary source of sawlogs and pulpwood as well as a favored recreation destination—would all but disappear from the region.
- As their forest habitat changes, many migratory songbirds such as the Baltimore oriole, American goldfinch, and song sparrow are expected to become less abundant.
- Parts of Massachusetts, New Jersey, Pennsylvania, and other areas in the Northeast are likely to become unsuitable for growing certain popular varieties of apples, blueberries, and cranberries.
- Unless farmers can afford cooling technologies, milk production across much of the region is projected to decline 5 to 20 percent in certain months.

If, instead, the region and the world begin now to make the transition to the lower-emissions pathway:

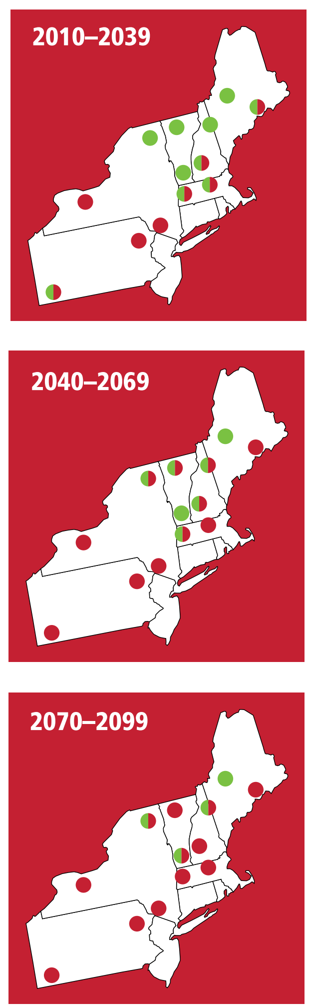
- New York City is projected to face today's 100-year flood every two decades on average.
- Georges Bank would remain suitable for adult cod, although yield and productivity may decline as these waters become less hospitable for the spawning and survival of young cod.
- Philadelphia's severe ozone-pollution days will increase by 50 percent (assuming that local vehicle and industrial emissions of ozone-forming pollutants are not reduced).
- In addition to western Maine, the North Country of New York and parts of Vermont and New Hampshire may retain reliable ski seasons.
- Climate conditions suitable for maple/beech/birch forests would shift only in the southern part of the region.
- Winter temperatures may prevent a deadly hemlock pest from infesting the northern part of the region.
- Less extensive (although still substantial) changes in the region's bird life are expected.
- Much of the region is projected to remain suitable for traditional apple and berry crops.
- Reductions in milk production (up to 10 percent) would remain confined primarily to New Jersey and small areas of Pennsylvania.

In many cases, however, the impacts of global warming are projected to be similar under either of the two emissions scenarios presented here:

- Atlantic City, NJ, and Boston are expected to experience today's once-a-century coastal flooding once every year or two on average by the end of the century.
- The lobster fisheries in Long Island Sound and the coastal waters off Rhode Island and south of Cape Cod are likely to decline significantly by mid-century, and cod are expected to disappear from these southern waters by century's end.

Vulnerability of Ski Resorts to Climate Change

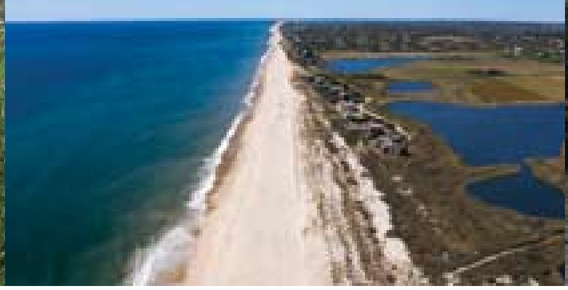
Higher Emissions



Ski resorts in "highly vulnerable" areas (red) are projected to fail to meet two criteria for sustainability (season length greater than 100 days, and high probability of being open during the profitable Christmas–New Year's holiday period). Those in "vulnerable" areas (red and green) are projected to fail to meet one of these criteria, and those in "viable" areas are projected to meet both criteria. Under lower emissions, several additional areas (northern New Hampshire, northeastern New York, and southern Vermont) are projected to retain viable resorts.

- highly vulnerable
- vulnerable
- viable

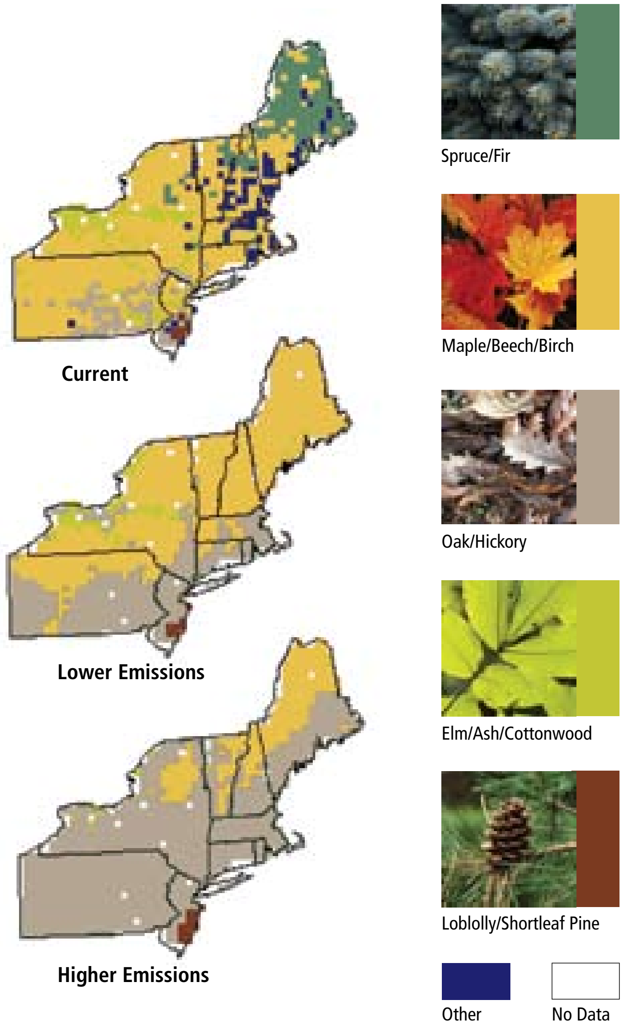
AP Photo/Robert F. Bukaty



Jupiter Images

Tim McCabe, USDA Natural Resources Conservation Service

Changes in Habitat Suitability for Different Forest Types by Late-Century



Much of the Northeast is currently dominated by hardwood forests composed of maple, beech, and birch; higher altitudes and latitudes are dominated by spruce/fir forests. As the climate changes this century, suitable habitat for spruce and fir species is expected to contract dramatically under either emissions scenario (compared with observed forest distribution in the 1990s, shown here as "current"). Suitable maple/beech/birch habitat is projected to move significantly northward under the higher-emissions scenario, but shift far less under the lower-emissions scenario. (The "other" category includes species such as red, white, and jack pine.)

- The number of days over 90°F is expected to triple in many of the region's cities, including Boston, Buffalo, and Concord, NH.
- Hotter, longer, drier summers punctuated by heavy rainstorms may create favorable conditions for more frequent outbreaks of mosquito-borne disease such as West Nile virus.
- Most of the region is likely to have a marginal or non-existent snowmobile season by mid-century.
- Warmer winters will shorten the average ski and snowboard seasons, increase snowmaking requirements, and drive up operating costs.
- Spruce/fir forests such as the Great North Woods are expected to lose significant area, diminishing their value for timber, recreation, and wildlife habitat. Certain species that depend on these forests, such as the Bicknell's thrush, are projected to disappear from the region.
- Weed problems and pest-related damage are expected to escalate, increasing pressures on farmers to use more herbicides and pesticides.

Clearly, under either of the emissions scenarios explored by NECIA, the Northeast can anticipate substantial—and often unwelcome or dangerous—changes during the rest of this century. Heat-trapping emissions released in the recent past have already committed the world to further warming over the next few decades. Decision makers at all levels of society should recognize the need to adapt to these unavoidable changes.

The intensity of the warming and the severity of the related impacts)the Northeast will face beyond mid-century, however, depends on actions to curb further emissions starting now.

As noted above, the emissions scenarios used in this assessment represent neither a ceiling nor a floor on future levels of carbon dioxide (CO_2) and other heat-trapping gases in the atmosphere. The lower-emissions scenario describes a world in which atmospheric concentrations of CO_2 rise from ~380 parts per million (ppm) today to ~550 ppm by the end of the century, in contrast to 940 ppm under the higher-emissions scenario. However, many lines of evidence indicate that even greater emissions reductions, and thus less severe impacts, are well within our reach. The latest assessment of the IPCC describes the technical and economic potential for stabilizing atmospheric concentrations of heat-trapping gases at or below the equivalent of 450 ppm of CO_2. Achieving such a target would require the United States and other industrialized nations to make deep emissions reductions by mid-century—on the order of 80 percent below 2000 levels—along with substantial reductions by developing countries.

AP Photo/Lee Marriner

AP Photo/Michael Dwyer

Brad Feinknopf

HOW CAN DECISION MAKERS, BUSINESSES, AND INDIVIDUALS IN THE NORTHEAST MEET THE CHALLENGE OF A CHANGING CLIMATE?

In the Northeast, as well as elsewhere in the United States and the world, there is growing momentum to pursue deep emissions reductions consistent with staying below the lower-emissions pathway described in this report. In 2001, for example, New England governors and Eastern Canadian premiers signed an agreement committing their states and provinces to a comprehensive Climate Change Action Plan that includes a long-term goal of reducing regional emissions 75 to 85 percent below then-current levels. More recently, policy makers in California and New Jersey have set ambitious near- and longer-term targets for reducing emissions, and similar measures are being debated in statehouses across the country and in Congress.

Of course, actions in the Northeast alone will not be sufficient to stem global warming. But as both a global leader in technology, finance, and innovation and a major source of heat-trapping emissions, the Northeast is well positioned to help drive national and international progress in reducing emissions. Concerted, sustained efforts to reduce emissions by just over 3 percent per year on average would achieve nearly half of the total reductions needed by 2030, putting the region well on track for achieving the 80 percent mid-century goal.

Unrestrained fossil-fuel use could drive global emissions above the higher-emissions scenario used in this study, while rapid, concerted efforts to adopt clean, efficient technologies could reduce emissions below the lower-emissions scenario.

From individual households to industry and government, decision makers across the Northeast have myriad options available today to move toward this goal across the region's four major CO_2-emitting sectors (electric power, buildings, transportation, and industry), and many are already taking innovative steps to do just that. These options include:

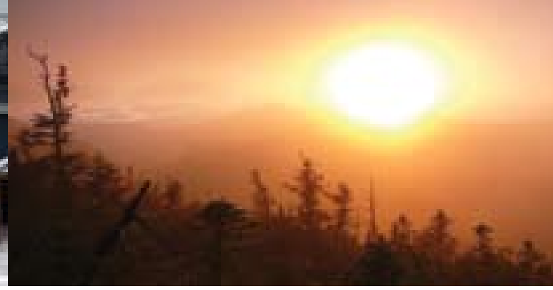
- Accelerating the region's transition from fossil fuels to clean, renewable energy resources (e.g., solar, wind, geothermal), through wise energy choices aided by market incentives and regulations.
- Embracing efficiency by purchasing energy-efficient lighting and small appliances and replacing vehicles, heating and cooling systems, motors, and large appliances with more efficient models as the existing equipment reaches the end of its useful life.

Eric Michaud

Traditional Fruit Crops May Suffer in a Warmer Climate

Many apple varieties, and a number of other fruits, require roughly 1,000 hours below 45°F each winter in order to produce good fruit yields the following summer and fall. By late this century under the higher-emissions scenario, winter temperatures are projected to be too warm across much of the Northeast to consistently meet these requirements. Growers across much of the region may need to switch to varieties with lower chilling requirements where such options exist.

AP Photo/Michael Dwyer



Kent McFarland Photos

New England Futures/Maine DOT

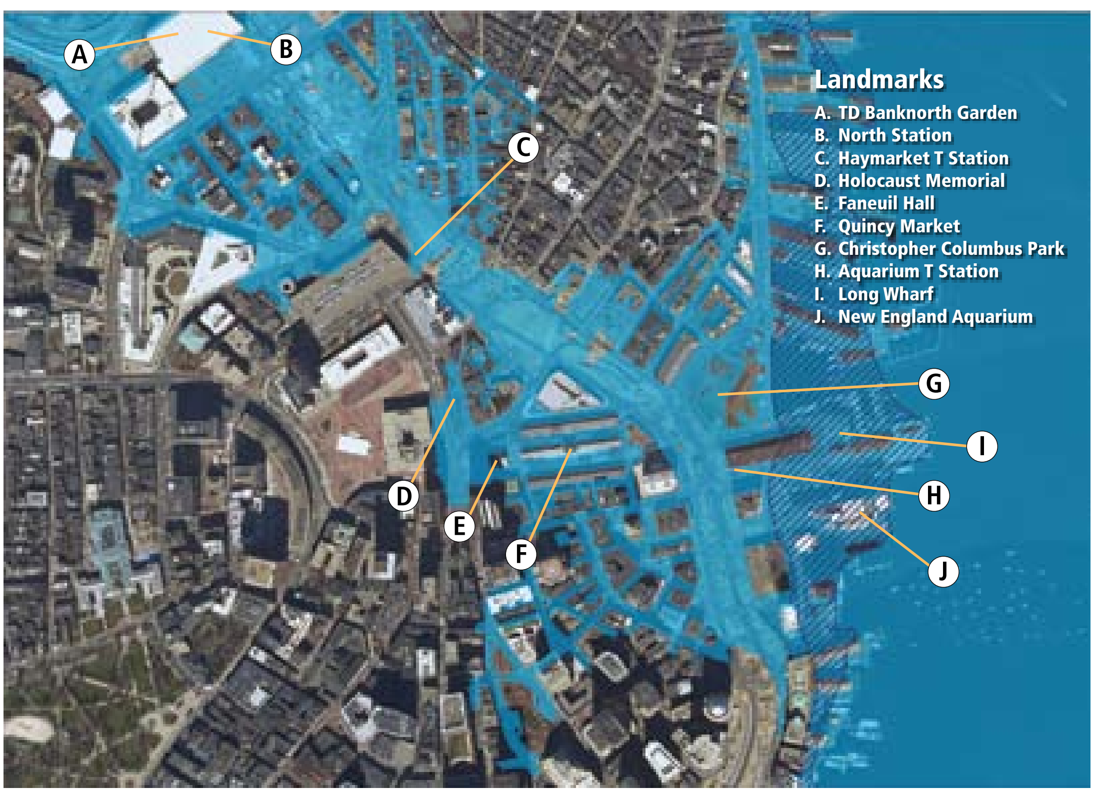
- Using state and municipal zoning laws, building codes, and incentives to encourage energy-efficient buildings, discourage urban sprawl, provide low-emissions transportation alternatives, and avoid development in vulnerable coastal areas and floodplains.

Concerted actions such as these to meet the climate challenge can also advance other widely shared goals in the Northeast such as enhancing regional energy and economic security, creating jobs, producing cleaner air, and building a more sustainable economy.

What is needed now is a strong, sustained, and well-coordinated effort between governments at all levels, businesses, civic institutions, and individuals to adopt policies, programs, and practices that accelerate the adoption of clean, efficient energy choices. The costs of delay are high. For every year of delay in beginning significant emissions reductions, global concentrations of heat-trapping gases rise higher and the goal of avoiding dangerous climate change becomes more difficult and more costly to achieve. Given the century-long lifetime of CO_2 in the atmosphere, the longer we wait to take action, the larger and more concentrated in time our emissions reductions will need to be to limit the extent and severity of climate change.

Although the task of reducing emissions may seem daunting, the nation achieved a similarly rapid energy transformation only a century ago as it shifted from gaslights and buggies to electricity and cars over a few short decades. In 1905 only 3 percent of U.S. homes had electricity, virtually none had cars, and few could envision how these innovations would transform America and its economy half a century later. Similarly, slightly less than 3 percent of our electricity is

Because past emissions have committed the region to a certain level of global warming over the next several decades, we must also begin to adapt to the unavoidable consequences.



Current 100-year flood zone
Projected 100-year flooded area (higher-emissions scenario)

Boston: The Future 100-Year Flood under the Higher-Emissions Scenario

This image shows the current Federal Emergency Management Agency (FEMA) 100-year flood zone (hatched darker blue) as well as the extent of the projected 100-year flood zone in 2100 (lighter blue) under the higher-emissions scenario for the waterfront/Government Center area of Boston. Important Boston landmarks (such as Faneuil Hall) and transportation infrastructure currently not at great risk of flooding could witness repeated flooding in the future unless protected from such events. Flood elevations under the lower-emissions scenario are roughly half a foot lower than the flooding depicted here (but still two feet higher than the current 100-year flood).

Dr. Norbert P. Psuty

Jerry and Marcy Monkman

Save the Bay

currently generated by non-hydroelectric renewable energy technologies. Yet with foresight, perseverance, and bold leadership, we can dramatically modify our energy system once again, moving from fossil fuels to renewables and, in doing so, avoiding severe climate change.

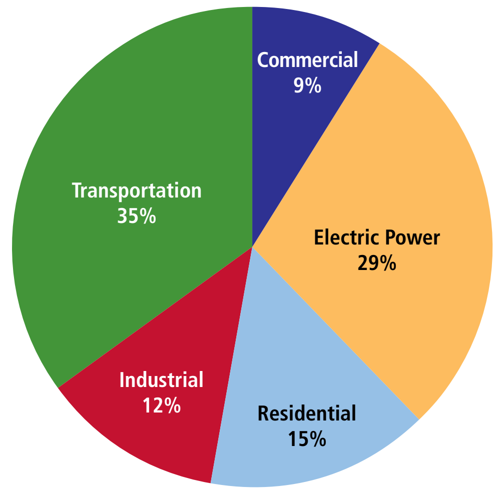
Because past emissions have committed the region and the world to a certain unavoidable level of global warming over the next several decades, decision makers in the Northeast must also begin to develop timely and forward-looking strategies that can help vulnerable constituencies adapt to the consequences. Aggressive steps to reduce emissions can limit the regional impacts of climate change and thus improve the prospect that ecosystems and societies will find effective ways to adapt. In turn, timely and effective adaptation measures will help reduce the vulnerability of people and ecosystems to the warming that cannot be avoided.

As both a global leader in technology, finance, and innovation and a major source of heat-trapping emissions, the Northeast is well positioned to help drive national and international progress in reducing emissions.

Decision makers can help the region adapt through policies and management actions that reduce our exposure to climate risks (such as catastrophic flooding) and also increase the ability of vulnerable sectors and communities to cope with ongoing changes and recover from extreme events or disasters. For each adaptation measure considered, policy makers and managers must carefully assess the potential barriers, costs, and unintended social and environmental consequences.

The very character of the Northeast is at stake. NECIA findings make clear that the emissions choices we make here in the Northeast and globally will have dramatic implications for the climate our children and grandchildren will inherit. The Northeast states and their municipal governments have a rich array of proven strategies and policies available to meet the climate challenge in partnership with businesses, institutions, and an increasingly concerned and supportive public. The time to act is now.

Northeast States—Regional Emissions of CO_2 by Sector, 2003



Source: State Energy Data System. Table 2, 2003 State Emissions by Sector.

In the Northeast, transportation is the largest source of heat-trapping emissions. Combined with electricity generation, these sectors account for nearly two-thirds of the region's emissions. Combustion of fossil fuels for water and space heating in homes and businesses and for powering industrial activities accounts for the remaining third. Fortunately, a rich array of strategies and policies exist to reduce emissions across these sectors.

PPM Energy

Bringing Renewable Energy Online

New York state's 320 MW Maple Ridge wind farm, pictured here, generates enough electricity to serve up to 160,000 average homes.

The full text of the report *Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions* is available online at www.climatechoices.org.

NECIA oversight and guidance is provided by a multidisciplinary Synthesis Team of senior scientists:

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The material presented in this summary is based primarily on the peer-reviewed research of the NECIA collaborators listed below. Most of this research is also presented in more technical detail in the formal scientific literature, including a special issue of the journal *Mitigation and Adaptation Strategies to Global Change* (in press, 2008).

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About the Northeast Climate Impacts Assessment

The Northeast Climate Impacts Assessment (NECIA) is a collaborative effort between the Union of Concerned Scientists (UCS) and a team of independent experts to develop and communicate a new assessment of climate change and associated impacts on key climate-sensitive sectors in the northeastern United States. The goal of the assessment is to combine state-of-the-art analyses with effective outreach to provide opinion leaders, policy makers, and the public with the best available science upon which to base informed choices about climate-change mitigation and adaptation.

For more information on our changing Northeast climate and what you can do visit *www.climatechoices.org*.
For information on the NECIA and the technical papers behind the report visit *www.northeastclimateimpacts.org*.

IMPLEMENTATION TABLE OF IDENTIFIED NEEDS

Recommended Solution	Action Required	Entity Responsible	Potential Funding Source and Predicted Amount	Report Section
Landscape Management				
State and Critical Facilities				
Need: Limit the construction of new critical facilities or state facilities in fluvial hazard zones (mapped 100- and 500-year floodplains or identified fluvial erosion hazard zones).				
Prohibit construction of new state facilities or state-funded facilities in fluvial hazard zones. This prohibition would not apply to water dependent facilities.	Legislation or Executive Order	State	Not applicable	3.1.1
Relocate existing state facilities out of fluvial hazard zones, if feasible. If not feasible, mitigation measures should be used to protect existing state structures up to the 500-year flood level. Relocating existing state facilities out of fluvial hazard zones is the preferred option when considering expansion or improvements to a facility within a flood hazard zone.	Legislation or Executive Order	State	Not applicable	3.1.1
Avoid and minimize expansion of existing state facilities in fluvial hazard zones to the maximum extent practicable.	Legislation or Executive Order	State	Not applicable	3.1.1
Protect new critical facilities from and be accessible during the 500-year flood. If a new or existing critical facility must be located in a floodplain it should be provided a higher level of protection so that it can continue to function and provide services after the flood. When new critical facilities are constructed, at least the primary access road should also be at the 500-year flood elevation.	Legislation or Executive Order	State	Not applicable	3.1.1
Increase state facilities stormwater requirements: the sponsor of any development or redevelopment project involving a state facilities project with a footprint that exceeds 5,000 square feet shall use site planning, design, construction and maintenance strategies for the property to maintain or restore, to the maximum extent technically feasible, the predevelopment hydrology of the property with regard to the temperature, rate, volume and duration of flow.	Legislation or Executive Order	State	Not applicable	3.1.1

Recommended Solution	Action Required	Entity Responsible	Potential Funding Source and Predicted Amount	Report Section
Land Protection				
Need: Increase the preservation of land in floodplains to help retain natural flood storage capacity while also providing significant ecological benefits for fish and wildlife.				
Create a mechanism within existing land protection grants, such as the Land and Community Heritage Investment Program, to identify floodplains and fluvial erosion areas protection as a priority.	Modification of grant requirement Identification of fluvial erosion area	DES DRED OEP	Existing grant programs Unknown	3.2.1.
Increase use of Natural Resource Conservation Service (NRCS) watershed and land conservation programs for floodplain and fluvial erosion areas.	Evaluate existing NRCS funding criteria	NRCS	Existing program	3.2.1
Create a new land protection grant program focused solely on floodplains (example: DES Source Water Protection Land Grants).	Funding for grant program	DES	Unknown	3.2.1
Floodplain Management				
Need: Establish a state - level regulatory approach for floodplain management.				
Incorporate floodplain management into existing state regulatory programs, specifically the DES Alteration of Terrain program (AoT) and Wetlands Bureau.	Legislation & Administrative Rule	State	Not applicable	3.3.1
Incorporate floodplains into Wetlands Bureau (DES) jurisdiction	Legislation Administrative Rules	DES	Not applicable	3.3.1
Develop a state watershed HEC-RAS model as basis for build out analysis.	Develop scope of work and requirements for model	DES OEP	FEMA	3.3.1
State adopts a higher National Flood Insurance Program standard.	Legislation	OEP	Not applicable	3.3.1
Need: Increased funds for flood management activities.				
Create a state funding source for "Floodplain Management Initiative": • Identify existing funding mechanisms to linked or contribute to Floodplain Management Initiative (restrictions for existing funding sources would have to be considered) • Establish criteria within existing funding sources to provide an advantage to floodplain management projects.	Legislation	DES F&G OEP DOT	Existing funding sources.	3.3.2

Recommended Solution	Action Required	Entity Responsible	Potential Funding Source and Predicted Amount	Report Section
Need: Locating structures within the 100 year floodplain and determining flood insurance status.				
Encourage local floodplain managers to research maps and building addresses in the 100-year floodplain. (Recommendation from 2008 FEMA report on flooding in New Hampshire.)	Develop program	OEP DES RPCs Municipalities	Not applicable	3.3.3
Need: Increase knowledge of flood building codes at the local level.				
Establish a formal training program for local building officials relevant to flood related building codes.	Develop program	OEP DOT DES	Not applicable	3.3.4
Need: Establish a state-level fluvial erosion hazard program similar to Vermont's Fluvial Erosion Hazard Program.				
Work with Federal Emergency Management Agency (FEMA) to incorporate fluvial erosion into National Flood Insurance Program and to provide technical and financial support for local implementation in accordance with FEMA's Riverine Erosion Mapping Feasibility recommendations.	Legislation	DES OEP	FEMA Emergency Management Grants Hazard Mitigation Grants 319 High Quality Water Grants	3.3.5
Provide a state funding mechanism to support staffing for the program.	Legislation (Biennial Budget)	DES OEP	$150,000 annually	3.3.5
Amend state law, if necessary, to allow the establishment of fluvial erosion hazard ordinances.	Legislation	DES OEP	Not applicable	3.3.5
Need: Increase ability for the state and municipalities to manage stormwater.				
Local fee on impervious surfaces could be used to address/upgrade stormwater management to minimize hydrologic changes.	None	Municipalities	Local fee	3.3.6
DES should actively support the creation of stormwater utilities.	Outreach and Education	DES OEP	Not applicable	3.3.6
New Hampshire House Bill 1295 establishes a commission to study issues relating to stormwater. The following issues should be further investigated by the Stormwater Study Commission in relation to floodplain management.	Commission activities	Commission members	Not applicable	3.3.6
Continue support for DES and Regional Planning Commissions Innovative Land Use Controls stormwater ordinance.	Legislation (Biennial Budget)	DES Regional Planning Commissions	$224,000 annually for the Regional Environmental Planning Program (REPP).	3.3.6
Encourage municipalities to submit stormwater infrastructure needs to DES as part of the *2008 Clean Water Needs Survey*.	Outreach and Education	DES	State Revolving Fund State Aid Grant Program	3.3.6

Recommended Solution	Action Required	Entity Responsible	Potential Funding Source and Predicted Amount	Report Section
Need: Ensure that bridges and culverts are adequately sized.				
Improve connection between hazard mitigation plans and master plan.	Education and Outreach	OEP DOS	Municipal Capital Improvement Programs DOS Hazard Mitigation Funding	3.3.7
Develop an in-lieu mitigation option (DES) for projects that impact floodplains and stream channels.	Legislation	DES	Existing program	3.3.7
Adopt wetland rules that incorporate the following design guidance: • To allow for passage of the 100-year frequency storm • To ensure to the maximum extent possible that there is no increase in flood stages on abutting properties. • Flow and sediment transport characteristics will not be affected in a manner which could adversely affect channel stability	Administrative Rule changes	DES	Not applicable	3.3.7
Flow and sediment transport characteristics will not be affected in a manner which could adversely affect channel stability as described in the *NH Fish and Game Stream Crossing Guidance (September 2008)*	Administrative Rule changes	DOT DES F&G	Not applicable	3.3.7
DOT should address climate change and impervious surface effects when updating its *Manual on Drainage Design for Highways*.	Update Manual	DOT	Existing program	3.3.7
State agencies should work with the UNH Technology Transfer Center to educate communities on culvert sizing criteria and potential funding sources to address floodplain issues and culvert upgrades.	Education and Outreach	UNH State Agencies	Existing Program	3.3.7
DOT, DES and F&G, with input by The Nature Conservatory, should be tasked to develop the procedure and database for a standard culvert assessment data collection.	Funding for development	DOT DES F&G	Unknown	3.3.7
Need: Establish protocol for mitigation procedures for removal of woody material that may pose an imminent threat to infrastructure.				
Develop a program for regular inspection and removal of fallen trees along river banks that pose an imminent threat to infrastructure.	Program Development	DOS	Unknown	3.3.8
Need: Local Floodplain ordinances should prohibit development within a 100 year floodplain.				
Encourage New Hampshire municipalities to adopt floodplain ordinances that prohibit fill, new construction or substantial improvement within the 100 year floodplain, specifically the Regional Environmental Planning Program Innovative Land Use Controls model Flood Hazard Area Zoning ordinance authorized by RSA 674:21.	Outreach	OEP	Existing Program	3.3.9

Recommended Solution	Action Required	Entity Responsible	Potential Funding Source and Predicted Amount	Report Section
Flood Insurance				
Need: Increase education and outreach to communities regarding floodplain management and insurance options.				
Develop a multidisciplinary team to assist communities who request help to improve floodplain management. This could be based on the Natural Resources Outreach Coalition model.	Develop Team	OEP DES	Existing grant program	3.4.1
OEP and GRANIT web based education module on floodplain management for local officials www.nhflooded.org should contain guidance for more restrictive NFIP standards and CRS (Community Rating System).	Continue Action Already in Progress	OEP	Existing grant program	3.4.1
OEP *Flood Lines* newsletter is available quarterly and should continue to focus on communities who exceed NFIP standards.	Continue Action Already in Progress	OEP	Existing grant program	3.4.1
Promote community "flood audits" as an outreach tool.	Continue Action Already in Progress	OEP	Existing grant program	3.4.1
Need: Encourage all NH communities participate in NFIP and its Community Rating System.				
Adopt legislation to encourage participation in the NFIP. The legislation would include the following: • Non-participating communities will not be eligible for matching state funds for state or federally declared flood disasters. • CRS communities pay less in local match requirements for state or federally declared disasters; the state would make up the difference.	Legislation	DES OEP BEM	Not applicable	3.4.2
Floodplain Buyouts				
Need: A dedicated state-funding source for floodplain buyouts.				
Develop a state funding dedicated to buyouts. This is a significant deficiency considering the potential to match federal dollars and eliminate long term costs.	Legislation	State	$500,000 per biennium	3.5.1

Recommended Solution	Action Required	Entity Responsible	Potential Funding Source and Predicted Amount	Report Section
Flood Forecasting & Data Collection				
Need: Increase information collection to improve flood forecasting				
Enhance data collection and sharing on ice cover of rivers to improve ice-jam monitoring and forecasting by the National Weather Service.	Memorandum of agreement between the NWS, US ACOE, and USGS	NWS USACE USGS	$50,000/yr	6.1.1
Enhance data collection and sharing with the National Weather Service Northeast River Forecasting Center (NERFC) for daily information on precipitation, temperature and snow-water equivalent throughout the State.	Cooperative agreement between the State, NWS, USACE and USGS	DES	$300,000/yr	6.1.2
Enhance stream flow/dam outflow data at selected locations in the state.	Enhance stream flow/ dam outflow data at selected locations in the State	DES	$100,000/yr with possible USGS cooperative matching funds	6.1.3
Improved communication between the National Weather Service and emergency management personnel and other “spotters” identifying where flooding is occurring	Memorandum of agreement between NWS and OEP	BEM	$50,000/yr	6.1.4
Additional flood flow prediction modeling sites in the state by the National Weather Service NERFC.	Request additional flood predictions to the NWS	NWS	Not applicable	6.1.5
Improved geographic information system (GIS) and LIDAR data for the state to help identify potential flood inundation areas for different size flood events; initiate a flood inundation mapping program for the state	Legislation	OEP BEM	$500,000/yr for flood inundation mapping; $1.0 million for statewide LIDAR data	6.1.6
Quicker adoption of new flood insurance rate maps, better estimation of flood prone areas, and completion of flood map modernization for the entire state (DFIRMs)	Unknown	FEMA OEP	Unknown	6.1.7
Develop a data command center that collects flood forecasting data and distributes to emergency management officials statewide.	Unknown	BEM	Unknown	6.1.8
Identify high risk areas for catastrophic flooding due to culvert failure.	Legislation	DES	Unknown	6.1.9

Recommended Solution	Action Required	Entity Responsible	Potential Funding Source and Pre-dicted Amount	Report Section
Flood Forecasting & Data Collection				
Expand stream-gage network to include more sites in urbanizing areas of the state.	Cooperative agreement between the State and USGS	DES	Unknown	6.1.10
Develop watershed models and plans that identify flood storage potential within the watershed, where land protection is needed to preserve flood storage, and how flood storage could be used to mitigate peak water demand periods/low flows	Legislation	DES	Unknown	6.1.11
Need: Improved flood insurance rate maps and watershed planning				
Quicker adoption of new flood insurance rate maps, better estimation of flood prone areas, and completion of flood map modernization for the entire state (DFIRMs)	Unknown	FEMA OEP	Unknown	6.2.1
Identify critical facilities and infrastructure in flood prone areas for assisting with emergency operations.	Unknown	BEM	Unknown	6.2.2

Recommended Solution	Action Required	Entity Responsible	Potential Funding Source and Predicted Amount	Report Section
Dams				
Need: Funding for the repair or removal of aged dams				
Establish a funding source for the operation, maintenance and repair or removal of state-owned dams.	Legislation	DES	$3 million per year	9.1
Establish a low-interest loan program, similar to that developed in other states, to finance the repair, upgrade or removal of municipally-owned and privately owned dams.	Legislation/ Administrative Rules	DES	$10 million from fines and Capital Appropriation	9.1
Need: Increase public awareness				
Develop and distribute an educational program that helps the public and prospective real estate purchaser to understand the advantages and disadvantages of building/living near the shoreline of a lake, pond, and river.	Outreach	DES	Not applicable	9.2
Develop and distribute an educational program that helps the public understand the limitations of dams in the state to reduce flooding.	Outreach	DES	Not applicable	9.2
Need: Improve flood forecasting for dam operations during flood events				
Engage the National Weather Service to gain timely access to forecasting products at all important locations in New Hampshire.	Coordination, Development of Forecast Model	DES/NWS	$1 million Federal funds for NWS to develop models	9.3
Revitalize the forecasting component of DES's data management, flood forecasting and reservoir operations systems to provide forecasts for locations that NWS does not serve.	Resource Allocation	State	$30,000 to $50,000 per year contract support for proprietary forecast model	9.3
Need: Improve dam operations during floods				
Have dam owners submit operating rules for each dam capable of flood abatement operations and have the DES Dam Bureau ensure that operations at each dam will collectively result in maximum flood abatement benefits to the watershed as a whole.	Outreach and Coordination	State/Dam Owners	Not Applicable	9.4

Water Resource Projects, Studies and Initiatives Matrix

Prepared by NHDES for SB 162 Water Resources Committee

Revised December 15, 2008

Matrix Overview: The following matrix was prepared by the New Hampshire Department of Environmental Services (DES) for the Water Resources Committee created under SB 162 in the 2003 legislative session. It provides information on water-related projects, studies and initiatives undertaken or funded by state agencies (DES, NH Geological Survey, and Office of Energy and Planning), New England Interstate Water Pollution Control Commission and the New Hampshire/Vermont Office of the United States Geological Survey. The matrix provides a project/program description, completion date, status, and contact information for each project, study or initiative. They have been organized into three categories: water resource characterization, water quality assessment, and water protection/planning and education. Within these categories, projects have been color coded and grouped to indicate whether they are primarily groundwater, surface water, both ground and surface water, coastal, or both coastal and freshwater projects. Many projects overlap categories and a judgment was made on placement. With some exceptions, ongoing programs of DES are generally not included in the matrix.

Water Resource Projects, Studies and Initiatives
Prepared by NHDES for SB 162 Water Resources Committee

Projects, Studies, and Initiatives of Statewide Significance

Water Resource Characterization Projects

Project Name	Water Resource Characterization Project Description Color Key: Groundwater Projects (Blue), Surface Water (Black), Both (Green), Coastal (Orange), Both coastal & freshwater (purple).	Date Completed	Project Status	Contact Information
Stratified Drift Aquifer Assessment & Mapping	This statewide project mapped and evaluated the following characteristics of stratified-drift (sand and gravel) aquifers: materials, hydraulic characteristics, saturated thicknesses, ground-water flow directions, potential yields, and ambient water quality. For more information go to http://nh.water.usgs.gov/	1995	Complete	Tom Mack USGS 226-7805
Bedrock Aquifer Resource Assessment	This statewide project mapped surface fracture traces (lineaments), established relationships between bedrock well yields and fracture, geologic, and physiographic characteristics, mapped bedrock well-yield probabilities and assessed ambient water quality characteristics of bedrock aquifers throughout the state. For more information go to http://nh.water.usgs.gov/projects/	2001	Complete	Richard Moore USGS 226-7825
Ground Water Sustainability in the Seacoast Region	This regional project will develop a detailed quantification of water availability at regional, watershed and town levels through analysis of available surface and groundwater data, new streamflow and ground-water data collection, surficial geological mapping, and the application of hydrologic models. The project will develop a detailed assessment of current and projected water use and will apply hydrologic modeling to evaluate the effects of future growth and alternative management strategies on water resources. The project is being conducted by the Office of State Planning, USGS, NHGS and DES. Many of the towns in the study area have contributed funding for this project.	2009	USGS water-use/demand analysis completed; USGS ground-water flow model report to be completed in 2009 Surficial map digitization ongoing. Fact sheets summarizing effort to be printed in 2009.	Ted Diers NHDES 271-7940 Keith Robinson USGS 226-7807 David Wunsch NHGS 271-6482

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STATEMAP Cooperative Geological Mapping Program	The New Hampshire Geological Survey (NHGS) participates in the USGS Cooperative STATEMAP geological mapping program. The NHGS is able to match federal dollars to perform geological mapping in New Hampshire at the 1:24,000 scale, which is the national standard for detailed mapping. This program concentrates on mapping of surficial geology, which comprises the base data for aquifer maps that are available for the state. NHGS cooperates with local governments to facilitate mapping to meet the needs of communities. For example, NHGS has partnered with Antrim, Hanover, Gilmanton, and Lyme. STATEMAP products will also be integrated into the Seacoast Ground Water Availability Study. A description of the NH program is at http://ncgmp.usgs.gov/statemap/NH03.pdf	Ongoing	Currently 91 out of 213 quads (tiles) are mapped at 1:24,000 scale for NH, which represents 43% of the state's area.	Ernst Kastning Mapping Program Manager NHGS 271-2875
Ground Water Monitoring Network	The New Hampshire Geological Survey (NHGS) collects monthly water level measurements from 25 wells located throughout the state. Only one of these wells is a bedrock well. NHGS staff measures water levels in 22 of these wells, volunteers measure water levels in two wells, and an automated data recorder that is managed by the U.S. Geological Survey records data from one well. NHGS has a contract pending to install additional bedrock wells in 2008/09, some of which will be instrumented with digital data loggers. The data are used by many state agencies, including the Governor's Drought Management Task Force. The data is shared with the USGS, and is available at http://nh.water.usgs.gov/WaterData/index.htm	Ongoing	On-going data collection in stratified drift wells. NHGS has a contract pending to install additional bedrock wells in 2008/09, some of which will be instrumented with digital data loggers.	David Wunsch NHGS 271-6482
Hydraulic Fracturing of Drilled Water Wells in Crystalline Rocks in New Hampshire	This study was completed by State Geologist Glenn Stewart, in cooperation with NH Department of Resources and Economic Development and University of New Hampshire. This study demonstrated that hydrofracturing (mechanically cracking a rock formation using high-pressure injection of water and additives) bedrock water wells could enhance yields.	1977	Complete, project reports available through the NHGS	David Wunsch NHGS 271-6482

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Water Well Inventory Program	Since 1984, all water well contractors working in New Hampshire have been subject to a statutory licensing requirement and have been required to submit a well completion report to the N.H. Water Well Board within 90 days of the construction of any new water well. No state-issued permit is required before the well is drilled, so the process is strictly one of after-the-fact reporting, with the construction itself subject to a set of performance standards and minimum specifications. From the beginning, the focus has been on digital data storage/retrieval and geo-referencing to enable the data to be used in a geographic information system (GIS) environment. The resulting database (more than 113,000 well records, 48 percent of which are geo-referenced) has been used to support statewide hydrogeologic investigations (i.e., stratified-drift and bedrock aquifer assessments and surficial geologic mapping) and continues to be used extensively as the state's most readily accessible and comprehensive source of subsurface hydrogeologic information. For more information go to http://des.nh.gov/organization/commissioner/pip/factsheets/geo/documents/geo-7.pdf	Ongoing	Ongoing data collection	Rick Chormann NHGS 271-1975
Favorable Gravel Well Analysis	This GIS based tool was developed to identify areas of high potential for future municipal gravel wells. It uses the stratified drift aquifer data and a variety of land use information to identify sites which would meet current regulations for municipal well siting. Municipalities are encouraged to use this information to plan for the protection of future water supply sources.	1999	Complete	Paul Susca NHDES 271-7061 Pierce Rigrod NHDES 271-0688
Surface Water Flow Monitoring Network	USGS maintains stream gages on a number of streams throughout New Hampshire. It is possible to obtain up to date and historical information from these gages on the USGS website. This information is the basis for regulatory decision making, planning and research. In addition there is a great amount of water level information on reservoirs that are controlled by state-owned dams. It is possible to obtain up to date information on these reservoirs though DES Dam Bureau. USGS web site: http://waterdata.usgs.gov/nh/nwis/current/?type=flow	Ongoing	Ongoing	Ken Toppin USGS 226-7808 Jim Gallagher NHDES 271-3501

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Instream Flow Statistics and Water Use Summaries for Watersheds of Designated Rivers	Studies of flow statistics and water use from water user reporting data for watersheds of designated rivers were done during development of instream flow rules and as a requirement of Env-Ws 1902. For more information go to http://des.nh.gov/organization/divisions/water/wmb/rivers/instream/flowstats.htm and http://des.nh.gov/organization/divisions/water/wmb/rivers/instream/studies.htm	Ongoing	Ongoing, summaries and reports available online	Wayne Ives NHDES 271-3548
Flood Forecasting and Reservoir Operations Modeling	DES has developed Flood-Forecasting and Reservoir Operations models for many of the river basins on which DES owns and operates state-owned dams. The basins include the Winnipesaukee, Pemigewasset, the Baker, the Newfound River, the Piscataquog, Mascoma, Salmon Falls, Powwow, and Suncook river basins. During precipitation events, DES water control managers use the models to predict, on a real-time basis, the amount of runoff that will flow into the basin based on the rainfall data obtained from radar imagery as well as data collected by the rain gages in the basin. They then use the operations component of the models to simulate the operation of the water control structures within the basins, and optimize the operation of those structures for flood control, recreation, fish and wildlife enhancement, and hydroelectric power.	2003	Ongoing	Jim Gallagher NHDES 271-1961
Flood-flow Frequency of New Hampshire Streams	The USGS, in cooperation with the New Hampshire Department of Transportation, is developing equations for estimating flow frequency. The equations will be incorporated into StreamStats. StreamStats is a web-based tool that will allow users to choose locations on an interactive map, obtain the basin and climatic characteristics that are required by the regression equations, and solve the equations. For more information go to http://nh.water.usgs.gov/projects/summaries/nh_floodfreq.htm	To be completed in 2009	On-going	Scott Olson USGS 226-7815
Watershed Recharge, and Low Flow Characteristics	This statewide project developed methods and GIS tools for estimating groundwater recharge in NH watersheds and for estimating the low-flow characteristics of NH rivers and streams. For more information go to http://nh.water.usgs.gov/	2005	Complete	Robert Flynn USGS 226-7824

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Watershed Restoration Plans	Based on EPA guidance under Clean Water Act Section 319, DES had worked with several watershed organizations to develop watershed restoration plans for impaired waters. The plans include establishment of a water quality goal based on water quality standards and a quantitative approach to reaching the goal. BMPs are specified along with costs and load reduction estimates. For the completed plans, see http://des.nh.gov/organization/divisions/water/wmb/was/watershed_based_plans.htm	Various	Ongoing	Eric Williams NHDES 271-2358
Water Use Registration and Reporting Program	Since 1987, all facilites that use 20,000 gallons or more of water per day averaged over any 7-day period, or 600,000 gallons during any 30-day period, must register with DES. These facilites include, but are not limited to, public water suppliers, industrial water users, irrigators, ski areas with snowmaking capability, wastewater treatment plants, and hydroelectric power plants. Registered water users must measure, record and report monthly water use totals for each source or destination on a quarterly basis, or once annually if use is for snowmaking or irrigation. The database currently contains 696 active registered facilities with 1,670 active sources and destinations. For more information go to http://des.nh.gov/organization/commissioner/pip/factsheets/geo/documents/geo-4.pdf	Ongoing	On-going data collection	Rick Chormann NHGS 271-1975 Derek Bennett NHDES 271-6685
Verification of Water Use in the Merrimack River Watershed	Water use in the Merrimack River watershed was examined by DES and the Massachusetts Department of Environmental Protection. Quantitative and descriptive data about water use were collected from those facilities that were either known or presumed to withdraw water within the watershed. The results were analyzed and compiled in order to create a database that combines measured water withdrawals with estimated withdrawals for all facilities whose self-supplied water use exceeds 20,000 gallons per day. Records for individual facilities were then aggregated by category of use, type of water source, and season of use for each of 54 sub-basins comprising the entire Merrimack River watershed and published in a final report. The determination of water use within the watershed allows the development of plans for water resource management and conservation to protect the Merrimack River watershed from unnecessary stress and dewatering impacts.	1997	Complete	Rick Chormann NHGS 271-1975

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Historical Legislative Water Authorizations	Pursuant to Chapter 307 Laws of 1993, DES researched and compiled a list of past legislative authorizations of water withdrawals. Historic authorizations were matched with currently registered water users and their sources in order to identify those that could not be conclusively associated with a registered user or currently active withdrawal. The unmatched authorizations were further characterized into two categories: 1) those known to be inactive; and 2) those that might be associated with an existing water user but whose association could not be confirmed.	1999	Complete	Rick Chormann NHGS 271-1975
Water Budget Methodologies	DES conducted a literature search and evaluation of different approaches for quantifying water availability within a specific hydrologic unit, including trial application of selected methods. The research was documented in a 2-volume final report.	1989	Complete	Rick Chormann NHGS 271-1975
Water Related Geographic Information System and OneStop	DES and other partners have developed a geographic information system (GIS), which allows users to locate and analyze resource and facility data (e.g. hydrography, aquifers/geology, regulated facilities, etc.) related to water resource management and protection. In particular, DES has been instrumental in promoting and obtaining funding for development of a statewide digital hydrographic network data layer to support many different water resources analysis and cataloging activities. Some examples of important GIS based projects are the identification of future potential gravel wells, the assessment of watersheds and drinking water source protection areas and the determination of recharge to streams. This geographic information system is part of GRANIT, the statewide GIS. DES has also developed a web based tool called OneStop where facility, permitting and GIS information can be obtained. For more information go to http://des.nh.gov/onestop/index.htm	Ongoing	GIS available to users via the internet. New uses and analysis constantly emerging	George Hastings NHDES 271-0399
Drinking Water Source Assessments	All of New Hampshire's 3000+ sources of public drinking water (wells and surface water) have been assessed for their vulnerability to contamination. This project involved delineation of protection areas for each source, inventory of land use within the protection area and ranking of vulnerability. For rivers it also involved time of travel studies and for lakes and reservoirs nutrient modeling. This information is being used by DES and municipalities to further protection efforts. For more information go to http://des.nh.gov/organization/divisions/water/dwgb/dwspp/dwsap.htm	January 2003	Complete	Paul Susca NHDES 271-7061

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Estimating current and future water demand in New Hampshire	This study is estimating 2005 and 2015 water demand by census block for the state as part of the State Water Plan process. Report describing methods to be printed in 2009; initial data delivered to DES in 2008.	On-going; final report to be completed in 2009	On-going	Marilee Horn USGS 226-7806

Water Quality Assessment Projects

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Occurrence & Distribution of MTBE in Public and Private Wells in NH	This project included sampling and analysis of water from over 500 randomly selected public and private wells throughout the state. Data were statistically analyzed to determine extent of contamination and relation of contamination to environmental and land use factors. For more information go to http://nh.water.usgs.gov/projects/summaries/mtbe_nh.htm	2007	Complete	Joseph Ayotte USGS 226-7810
Probability of Arsenic in Ground Waters of New England	A New England-wide statistical model of arsenic levels in bedrock waters. For more information go to http://nh.water.usgs.gov/projects/summaries/nci_bladder.htm	2006	Complete	Joseph Ayotte USGS 226-7810
Arsenic Contamination in Private Bedrock Wells in Southeast NH	This project included sampling and analysis of water from 400 randomly selected private wells for arsenic in Southeastern NH. For more information go to http://pubs.usgs.gov/fs/fs-051-03/	2004	Complete.	Joseph Ayotte USGS 226-7810
Determining the Source of Salinity in New Hampshire Ground Water Using Br/Cl Ratios	This study was conducted for the NH Department of Transportation to assist them with determining the source of salinity (chloride) in water wells that may have been impacted by road salting. Bromide to chloride ratio was used to fingerprint salt sources. Limited geochemical data suggested that road salting did not impact a well in question, and that the source of chloride is most likely trapped formation water or other contamination.	2002	Project complete, report available from NHGS	David Wunsch NHGS 271-6482
Pathogens in Public Drinking Water Wells	A multi-state study was done to evaluate the occurrence and causes of pathogens, in particular viral indicators, in public drinking water wells. The result of this study was that the occurrence was low and did not correlate with suspected sources (land uses such as septic systems, etc.)	2002	Completed	Bob Mann NHDES 271-2953
Ground Water Quality and Geology	NHGS has partnered with two communities where recent bedrock and surficial geological mapping has been completed. The comprehensive geologic database provided by mapping, coupled with the Water Well Inventory database, allowed wells within the mapped area to be selected for sampling to evaluate the inorganic water chemistry for individual geologic formations. Water analyses costs are supported by the towns. Presently NHGS has worked with Hollis and Dublin, NH.	On-going	Hollis samples complete, sampling and analysis still in progress in Dublin.	David Wunsch NHGS 271-6482

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Methane in Ground Water in NH	NHGS collected water samples for isotopic and major ion chemistry to ascertain the source of methane in deep wells in NH. Partnering with USGS, a comprehensive geologic and hydrogeologic evaluation of a deep borehole in NH resulted in a published report: Bedrock, Borehole, and Water-Quality Characterization of a Methane-Producing Water Well in Wolfeboro, New Hampshire, by Degnan and others, (USGS).	On-going	A report by Degnan and others, (USGS) published in 2008.	Jim Degnan USGS VT/NH 226-7807 David Wunsch NHGS 271-6482
Catalog of NH water bodies	A catalog of NH water bodies is being developed to facilitate information sharing about water quality data, water body characteristics, and water quality assessments. A preliminary catalog at 1:100,000 scale is complete and available online as part of the 2008 Surface Water Quality Assessment (http://des.nh.gov/organization/divisions/water/wmb/swqa/2008/index.htm). Now that the high resolution National Hydrography Dataset is complete the department can move forward with a detailed catalog at 1:24,000 scale. Estimated completion date for the preliminary catalog is May 2009. Additional details and attributes will then be added in 2010.	Ongoing	In Progress, target completion date 5/2009	Paul Currier NHDES 271-3289
305(b)/303(d) Surface Water Quality Assessments	Surface water quality assessments (SWQAs) involve analyses of existing water quality data to determine if the surface waters are healthy, (i.e., meeting water quality standards), impaired, threatened or if there is insufficient information to make an assessment. Assessments are conducted every 2 years in accordance with RSA 485-A:4, XIV, and the federal Clean Water Act [Sections 305(b) and 303(d)]. Assessment decisions are made in accordance with criteria specified in a document called the Consolidated Assessment and Listing Methodology (CALM). An assessment database (ADB) is used to conduct and track assessment status. To facilitate assessments and reporting, surface waters have been subdivided into over 5,200 open water segments and nearly 24,000 wetland segments called Assessment Units (AUs). Information stored in the ADB for each AU is spatially linked to allow preparation of maps and use of GIS analysis tools. Draft SWQA results are made available for public comment. Results of the final 2008 SWQA are available on the web at http://des.nh.gov/organization/divisions/water/wmb/swqa/index.htm	Ongoing	Next SWQA due April 2010	Ken Edwardson NHDES 271-8864

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Lake Assessments	Lake Monitoring NH DES operates a number of lake monitoring programs. The overall goal is to assess current conditions and trends in order to determine if the existing regulatory framework is sufficient to protect lake water quality or, conversely, if new controls are needed. The data is also used to educate the public about lakes and how to protect them. Lake Trophic Surveys were conducted on NH lakes from the mid-1970s through 2006. The lakes were sampled in both winter and summer for various physical, chemical, and biological parameters. The data provided information on current baseline conditions, long-term trends, and water quality compliance, and were used to classify the lakes according to trophic condition. The surveys also provided information on acid rain impacts and aquatic nuisance and exotic weed distributions. Most NH lakes were surveyed at least once and trophic reports are available upon request. Probability-based sampling of lakes was initiated in 2007 in conjunction with EPA's National Lake Assessment and New England Lake and Pond projects. A total of 50 randomly-selected lakes will be sampled during the 2007 through 2009 period to allow for an unbiased assessment of overall lake condition. Lake condition assessments will be based not only on water chemistry and bacteriology but on shoreline habitat and on the health of various biological communities (phytoplankton, zooplankton and macroinvertebrates). The Acid Rain-Lake Outlet Monitoring Program samples twenty accessible lake outlets twice each year, during the spring and fall overturn, for acid rain related parameters. Both short and long-term trends of the impacts of acid rain on non-remote lakes are documented. Trend data is available since 1983. Acid Rain-Remote Pond Monitoring is a cooperative program with the NH Fish and Game Department. Samples are collected each spring from the surface of a number of inaccessible remote trout ponds by helicopter in conjunction with the NHF&G's fish stocking program. Historically, approximately 25 lakes were sampled each year with a total of 57 different lakes sampled since 1981. The program was reduced in 2006 to ten lakes sampled per year because of budgetary issues at NHF&G. The program	Ongoing	Ongoing	Bob Estabrook NHDES 271-3357

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	provides short and long-term trend data on acid rain impacts to remote ponds. Data from the above two acid pond programs is reported as part of the New England Governors/Eastern Canadian Premiers Acid Rain Action Plan. Acid Precipitation Monitoring measures pH, alkalinity, nitrate and sulfate in precipitation (rain and snow) at Concord. Data records for pH go back to 1972. Fish Tissue Monitoring for mercury is a cooperative project with the Fish and Game Department to determine the risk to public health of fish consumption and to establish baseline and trend data to measure future improvements as mercury emissions to the environment are reduced. Over 100 fish are typically analyzed for mercury each year, collected primarily by NHF&G and volunteers. The fish are processed and analyzed in the Limnology Center.			
Biomonitoring	New England Wadeable Stream Project: A probabilistic based sampling effort of water chemistry, fish, and invertebrates in NH wadeable streams was completed during summer 2002-03 as part of the EPA-New England Wadeable Stream project. The project will enable the agency to complete a comprehensive statistical analysis of biological integrity in wadeable streams statewide. National Wadeable Stream Assessment: A probability-based national assessment of wadeable stream condition (2005-06) National Flowing Waters Assessment: A probability-based national assessment of all flowing waters (2007-08) State-based probability assessment of flowing waters: To be completed in 2009-10. Thirty-four additional streams/rivers will be sampled in conjunction with the national flowing waters assessment so that a state-wide assessment can be made. Instream Macroinvertebrate / Fish Monitoring Bioassessments: Biosassessments typically examine species richness, species composition, population size and trophic composition of resident aquatic organisms. Such information may help to reveal if aquatic organisms are adversely impacted by the integrated effects of different pollutant stressors over long periods.	2004 2006 2009 2010 Ongoing	Complete Completed Ongoing Ongoing Ongoing	David Neils NHDES 271-8865

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	In 1995 DES received a grant from the EPA to initiate a long-term biological monitoring program in the state of New Hampshire. The DES biomonitoring program utilizes GIS-based information in order to select non-impacted "reference" sites as well as impacted or "impaired" sites each year. Potential sites are selected based on road density, population statistics, adjacent land uses, and proximity to facilities such as wastewater treatment plants, landfills, and state/federal superfund sites. Sites are then randomly selected out of the candidate pool. Approximately 150 "reference" sites have been biologically assessed since 1995 and some "stressor" sites are beginning to be selected in order to have a complete range of water quality conditions in New Hampshire for development of numerical biological criteria.			
Multimetric Biological Index for Wadeable Streams (macroinverte-brates)	As part of the state's requirement for assessing water bodies for Aquatic Life Use under the Federal Clean Water Act, a mutimetric index of wadeable stream biological integrity has been developed for macroinvertebrates by the biomonitoring program. The index uses data collected since 1997 and incorporates GIS assessments of all watersheds sampled coupled with a complex statistical analysis of the responses by aquatic communities as related to the level of human disturbance. The result is an index that includes characteristics of aquatic communities that best describe water quality and the establishment of benchmarks indicative of impaired and unimpaired water bodies.	Complete	Complete	David Neils NHDES 271-8865
Multimetric Biological Index for Wadeable Streams (Strict coldwater fish assemblages)	As part of the state's requirement for assessing water bodies for Aquatic Life Use under the Federal Clean Water Act, a multimetric index of wadeable stream biological integrity has been developed for Strict Coldwater Fish Assemblages by the biomonitoring program. The index uses data collected since 1997 and incorporates GIS assessments of all watersheds sampled coupled with a complex statistical analysis of the responses by aquatic communities as related to the level of human disturbance. The result is an index that includes characteristics of aquatic communities that best describe water quality and the establishment of benchmarks indicative of impaired and unimpaired water bodies.	Complete	Complete	David Neils NHDES 271-8865
Stream Classification System	To facilitate biological index development the biomonitoring program has developed a stream classification system for fish and macroinvertebrates. It is hopeful that the system will eventually also be used for the full implementation of the state's dissolved oxygen criteria	Complete	Complete	David Neils NHDES 271-8865

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Ambient River Monitoring Program	DES has historically conducted ambient monitoring of rivers and streams. Approximately 300 samples are usually taken each year from approximately 100 stations, including 17 trend monitoring stations. Samples are analyzed for a variety of parameters. Data is primarily used to determine if a surface water is impaired or meeting water quality standards, and for trend analyses.	Ongoing	Ongoing	Ted Walsh NHDES 271-2083
Volunteer Assessment Programs	Water quality information collected by volunteers is a valuable addition to DES monitoring programs, as well as a valuable outreach and education tool. The volunteers usually live in close proximity to the water body they monitor, and possess an intimate knowledge of the history and present condition of the watershed area. Volunteers alert DES of water quality threats and potential violations for investigation. Volunteer data is used to gain an idea of water quality at times and locations not covered by DES sampling programs. With rigorous training and appropriate Quality Assurance/Quality Control (QA/QC), volunteer data can supplement the ambient sampling program and help build a strong set of baseline data statewide. Volunteer monitoring can result in the early detection of water quality changes, allowing DES to trace potential problems to their source before a more severe impact occurs. Volunteer Lake Assessment Program (VLAP): was initiated in 1985 in response to an expressed desire of lake associations to be involved in lake protection and watershed management. The program has grown to approximately 500 volunteer monitors collecting water quality data at approximately 175 lakes each year. The Volunteer River Assessment Program (VRAP): was initiated in 1998 to promote education and awareness of the importance of maintaining water quality in New Hampshire's rivers and streams. Today, over a dozen volunteer groups monitor rivers throughout the state and provide critical water quality data to the state to assist in assessing the ecological health of our rivers. Recently, a pilot program has been developed that allows volunteers to utilize a rapid field protocol for the collection of freshwater macroinvertebrates (VBAP). The protocol will be used to complete "screening-level" assessments of aquatic macroinvertebrate communities in wadeable streams and assist in making decisions on where detailed investigations must be completed. Six volunteer groups are participating in the pilot.	Ongoing	Ongoing	VLAP Jody Connor NHDES 271-3414 VLAP Sara Steiner NHDES 271-2658 VRAP Ted Walsh NHDES 271-2083 VBAP David Neils NHDES 271-8865

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Nutrient Criteria Development	Large amounts of nutrients in surface water can lead to excessive growths of algae and other aquatic plants and make the surface water undesirable for uses such as swimming or fishing. Most states, like NH, have narrative water quality standards for nutrients such as nitrogen and phosphorus. EPA, however, now wants states to adopt numeric water quality standards for nutrients. To help DES determine appropriate numeric nutrient limits, DES has formed stakeholder workgroups to develop nutrient criteria for lakes and estuaries. Development of draft criteria for these water bodies is well underway. For rivers, work conducted by other states suggests that nutrient criteria are largely controlled by the health of the benthic aquatic community. To determine if this holds true in NH, DES plans to submit a federal 104(b)(3) grant proposal in 2008 to collect and analyze data to determine relationships between nutrients and health of benthic community in streams.	Ongoing	Ongoing	Gregg Comstock NHDES 271-2983 Bob Estabrook NHDES 271-3357 Phil Trowbridge NHDES 271-8872
Watershed pollutant load allocation studies (TMDLs and Diagnostic Feasibility Studies)	In this ongoing program, pollutant load modeling studies are conducted to estimate the relative contributions of pollution sources to water quality impairments or threats. Diagnostic Feasibility Studies estimate phosphorus loading to lakes. DES has a library of approximately 20 completed studies and can be made available by contacting the Clean Lakes Program. A subset of recent Diagnostic Feasibility Studies can be found at (http://des.nh.gov/organization/divisions/water/wmb/cleanlakes/graphics/index.htm) The Perkins Pond Diagnostic Feasibility Study is currently in progress. Total Maximum Daily Load Studies (TMDLs) are comprehensive water quality studies required by the federal Clean Water Act for most impaired waters. The studies identify the sources of pollutant loadings and the necessary reductions from each source to meet water quality standards. DES has completed numerous TMDLs to date including a regional mercury TMDL with the Northeast States and the New England Interstate Water Pollution Control Commission to address the statewide mercury fish consumption advisories due to elevated levels of mercury in fish tissue. Most of the mercury is from atmospheric deposition. With EPA Contractor assistance, DES is currently working on 30 lake phosphorus TMDLs that are impaired for the swimming use because of excessive growths of algae or	Ongoing	Ongoing	Andy Chapman NHDES 271-5334 Lakes Bob Estabrook NHDES 271-3357 Rivers Gregg Comstock NHDES 271-2983 TMDL Coordinator Peg Foss NHDES 271-5448

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	Cyanobacteria and a statewide bacteria TMDL. In addition, DES is working with the U.S. Army Corps of Engineers and several communities to develop a TMDL for dissolved oxygen and nutrients along the Merrimack and Pemigewasset Rivers. Funding for this project is 75% federal and 25% other and is expected to be completed by 2012. For more information go to http://des.nh.gov/organization/divisions/water/wmb/tmdl/index.htm			
Connecticut River Sediment Quality Evaluation	In summer, 2000, EPA and its contractor, in cooperation with DES, VTDEC and the Connecticut River Joint Commissions sampled sediment at 100 locations from the Connecticut Lakes to the Mascoma River. Samples were analyzed for toxics, and a screening assessment of the potential for ecological risk was made and presented at public meetings. The data are available at DES or EPA Region 1.	June 2002	Complete	Paul Currier NHDES 271-3289
Connecticut River Nitrogen Action Plan	Following the EPA's approval of the Long Island Sound (LIS) Dissolved Oxygen Total Maximum Daily Load (TMDL) on April 3, 2001, the New England Interstate Water Pollution Control Commission (NEIWPCC) established the Connecticut River Nitrogen Workgroup in order to develop scientifically-defensible nitrogen load allocations, as well as an implementation strategy, for the Connecticut River Basin in Massachusetts, New Hampshire, and Vermont ("upper states"), which are consistent with TMDL allocations established for LIS. Following a 3-year monitoring and modeling study on the upper Connecticut River, Connecticut Department of Environmental Protection and New York State Department of Environmental Conservation are currently revising the LIS TMDL. NEIWPCC is coordinating with the "upper states" on providing input to the revised load allocations and implementation plan for the new TMDL.	Ongoing	Ongoing	Gregg Comstock NHDES 271-2983 Beth Card NEIWPCC 978-323-7929
Assessment of Nitrogen in the Upper Connecticut River Basin, New Hampshire, Vermont, and Massachusetts	The objective is to assess nitrogen loads in the Upper Connecticut River by determining the amount of nitrogen originating from various sources and regions in the 3 states. For more information go to http://nh.water.usgs.gov/projects/summaries/ct_nload.htm	2006	Complete	Jeff Deacon USGS 226-7812

Project Name	Water Quality Assessment Project Description **Color Key: Groundwater Projects (Blue), Surface Water (Black), Both (Green), Coastal (Orange), Both coastal & freshwater (purple).**	Date Completed	Project Status	Contact Information
New England SPARROW Water Quality Models	These are statistical water-quality models estimating nitrogen and phosphorus amounts in New England rivers and streams. For more information go to http://nh.water.usgs.gov/projects/sparrow/index.htm	2005	Complete	Richard Moore USGS 226-7825
Water Quality Database	Fashioned after EPA's STORET database, an Oracle database was created in March 2003 to store water quality related data. Data from many programs across DES (VRAP, TMDL, non-point source investigations, site remediation, VLAP, lake survey, shellfish, etc.) have been standardized and imported into the database. Data from other entities (such as UNH, NHDoT, and other monitoring groups) are also incorporated in the database. The hope is to work cooperatively with agencies and organizations that collect and manage water quality data to create a statewide water quality data system.	Ongoing	Ongoing	Deb Soule NHDES 271-8863
Watershed Pollution Source Investigations Providing Assistance and Technical Support to Local Entities and Municipalities	DES staff provide technical assistance to local entities and municipalities in priority watersheds to identify and eliminate pollution sources. Priority is given to urbanized areas where stormwater outfall pipes are surveyed during dry weather to detect direct wastewater discharges. Investigations and continued technical assistance in the Coastal watershed are ongoing and investigations in the Merrimack watershed are in progress.	Ongoing	Ongoing	Coastal Watersheds Rob Livingston NHDES 271-3398 Merrimack Watersheds Steve Landry NHDES 271-2969
Stormwater Characterization Study	In 1996, DES received a federal grant to study stormwater. Specifically, the purposes of this study were to: 1. Characterize urban stormwater which would be indicative of stormwater runoff from NH communities; 2. Determine the quality of rain and its relative contribution to stormwater; and 3. Show the effects of urbanization on stormwater quality. Two closed (piped) stormdrain systems in Concord, NH were sampled for a variety of parameters; one drained a very urbanized area and the other a light, residential site. Seven storms were sampled. Results showed that average concentrations of the majority of the parameters in the urban stormwater were between two to 14 times higher than the residental stormwater. Copies of the final report are available at DES (Stormwater Characterization Study, November, 1997, NHDES-WD-97-12)	1997	Complete	Gregg Comstock NHDES 271-2983

Project Name	Water Quality Assessment Project Description **Color Key: Groundwater Projects (Blue), Surface Water (Black), Both (Green), Coastal (Orange), Both coastal & freshwater (purple).**	Date Completed	Project Status	Contact Information
Stormwater Best Management Practice Verification	Working with UNH Jackson Estuarine Laboratory, DES will evaluate the effectiveness of various stormwater treatment technologies by storm event monitoring.	Ongoing	Quality Assurance Project Plan approved by EPA in 2003	Sally Soule NHDES 559-0032
NH Estuaries Project	Monitoring Program: DES, under contract with the NH Estuaries Project, developed a comprehensive monitoring program for NH's estuaries. The motivation for the plan was to gather the data needed for the NHEP's environmental indicators without duplicating the effort of the existing monitoring programs in the estuaries. Existing monitoring programs from a wide array of organizations were combined into a coordinated plan. Funding from the NHEP was used to fill in gaps in the monitoring regime not covered by the existing plans. The organizations involved include: DES, UNH, NH Fish and Game Department, NH Coastal Program, Cooperative Institute for Coastal and Estuarine Environmental Technology, and the Great Bay National Estuarine Research Reserve. The NHEP Monitoring Plan is located at: http://www.nhep.unh.edu/resources/pdf/nhep_monitoring_plan-nhep-08.pdf Environmental Indicators: DES, under contract to the NH Estuaries Project, developed a suite of environmental indicators for NH's estuaries in 2002 and 2003. An environmental indicator is some parameter that can be measured (e.g., bacteria concentrations or the number of harvestable oysters) that is indicative of a desirable environmental condition. Indicators were developed for water quality, shellfish resources, land use, and critical habitats and species. Reports on the status and trends of these indicators are available online at http://www.nhep.unh.edu/resources/soe_report.htm	2008 2006	The plan will be updated every 5 years. The indicator reports are updated every 3 years.	Phil Trowbridge NHDES 271-8872
National Coastal Assessment	The NCA monitoring program uses a probabilistic design with randomly-located stations to monitor water quality, sediment quality, and ecological response indicators throughout NH's estuaries. The probabilistic survey allows data managers to extrapolate to all estuarine resources with measured confidence limits. The base program suite of analyses conducted at each station includes the EPA recommended parameters. This monitoring project was funded by EPA between 2000 and 2006. DES and UNH have funded continued monitoring between 2007-2009. Federal funding is scheduled to resume in 2010. For more information go to http://www.epa.gov/emap/nca/	Ongoing	Ongoing	Phil Trowbridge NHDES 271-8872

Project Name	Water Quality Assessment Project Description **Color Key: Groundwater Projects (Blue), Surface Water (Black), Both (Green), Coastal (Orange), Both coastal & freshwater (purple).**	Date Completed	Project Status	Contact Information
Gulfwatch Monitoring Project	The Gulfwatch Project annually monitors the concentrations of toxic contaminants in the tissues of blue mussels at estuarine stations to track water quality trends in NH's estuaries. The NH data is combined with data from the rest of the Gulf of Maine to document pollution gradients in the Gulf. For more information go to http://www.gulfofmaine.org/gulfwatch/	Ongoing	Ongoing	Phil Trowbridge NHDES 271-8872
Shellfish Program Monitoring	Routine Monitoring: Water samples are collected for fecal coliform analysis from all shellfish growing waters (approximately 70 sites, sampled 6-12 times per year) to maintain an updated water quality database and annually assess the accuracy of shellfish growing area classifications. Emergency Closure Monitoring: Water and/or shellfish samples are collected for fecal coliform analyses following emergency closures of shellfish growing areas (wastewater treatment plant upsets, severe rainfall events, etc.) to determine when shellfish growing areas may be safely reopened for harvesting Post Rainfall Monitoring: Water and/or shellfish samples are collected for fecal coliform analyses following conditional (i.e., rainfall-related) closures of shellfish growing areas to determine when shellfish growing areas may be safely reopened for harvesting Sanitary Surveys: Sanitary surveys of shellfish growing areas are conducted, in accordance with National Shellfish Sanitation Program guidelines, to classify areas for the suitability for shellfish harvesting. Completed surveys include Atlantic Coast (2000), Little Harbor/Back Channel (2001), Hampton Falls and Taylor Rivers (2001), Oyster River (2002), Great Bay (2004), Bellamy River (2005), Little Bay (2005), Cocheco, Salmon Falls, Upper Piscataqua (2006), and Hampton/Seabrook Harbor (2006). Ongoing studies are in Portsmouth Harbor, Lower Piscataqua River, and Rye Harbor. "Red Tide" Monitoring: Weekly shellfish tissue samples are collected from selected locations to monitor for the presence of "red tide," or Paralytic Shellfish Poison, from April through October. Implement closures to shellfish harvesting areas as appropriate. Shellfish Program Wastewater Treatment Plant Dye Studies: The purpose of these dye studies is to develop hydrographic data on the dilution, dispersion, and time of travel of WWTF effluent in estuarine and coastal waters, for the purpose of delineating "safety zones" around WWTF outfalls, in which shellfish harvesting is permanently prohibited. Studies completed in	Ongoing	Ongoing	Chris Nash NHDES 559-1509

Project Name	Water Quality Assessment Project Description **Color Key: Groundwater Projects (Blue), Surface Water (Black), Both (Green), Coastal (Orange), Both coastal & freshwater (purple).**	Date Completed	Project Status	Contact Information
	Hampton, Seabrook, Portsmouth, Durham, Exeter, Newfields, Newmarket, Dover, Kittery, and Wallis Sands. Studies are planned for Portsmouth and Newington.			
Microbial Source Tracking	Working with UNH Jackson Estuarine Laboratory, DES piloted microbial source tracking techniques using DNA analysis to determine bacteria sources in Hampton Harbor. The project resulted in a DNA reference library and institutionalized the capability to perform the required laboratory analysis for future projects at UNH.	2003	Complete. Follow-up projects planned	Sally Soule NHDES 559-0032
NH Coastal Watershed Studies	Over the past 25 years the NH Coastal Program (formerly in the Office of Energy and Planning and the Office of State Planning) has funded over 400 projects related to coastal resources. This includes many watershed assessments such as ones in the Oyster, Berry's Brook, Winnicut River and Crommet Creek watersheds. The NHCP has also funded reports such as "Assessment of atmospheric nitrogen inputs to Great Bay" and other technical studies of water. These can be found at the DES website searching under "NHCP".	Varies	Ongoing	Ted Diers NHCP 271-7940
Factors Influencing Stream Water Quality in Coastal New Hampshire	Assessed effects of urbanization on the water quality of 10 streams in the seacoast region. For more information go to http://pubs.water.usgs.gov/sir2005-5103/	2004	Complete	Jeff Deacon USGS 226-7812
NHDES/US Fish and Wildlife Service's Clean Vessel Act and Boat Inspection Programs	DES operates the Clean Vessel Act (CVA) program to protect our public waters from the discharge of black and grey water from boats. The state has approximately 25 pumpout facilities and two pumpout boats to service New Hampshire waters. While the CVA provides grants to place pumpout facilities on fresh and coastal waters, the boat inspection program provides enforcement action for non-compliance. The CVA provides a mechanism to pump out sewage from boats while the boat inspection program provides a thorough inspection of the boat plumbing to make sure the boat is compliant with the state's no discharge law. Non-compliant boats are given a 48 hour period to remedy defects or surrender the boat registration.	Ongoing	Ongoing	Jody Connor NHDES 271-3414
Beach Monitoring	Beach Monitoring occurs each summer at over 170 freshwater beaches while weekly monitoring occurs at 14 coastal beaches. Freshwater beaches are monitored for E. coli and cyanobacteria while coastal waters are monitored	Ongoing	Ongoing	Jody Connor NHDES 271-3414

Project Name	Water Quality Assessment Project Description **Color Key: Groundwater Projects (Blue), Surface Water (Black), Both (Green), Coastal (Orange), Both coastal & freshwater (purple).**	Date Completed	Project Status	Contact Information
	for Enterococci levels. The program is available to all beach owners throughout the state. The Beach Program focuses on sample collection, quick analyses, water quality standard evaluation and quick public notification if public bathing beach bacterial standards are exceeded. EPA, DES and Earth911 all maintain websites that give up-to-date information about all coastal beaches while DES maintains a website for all public designated beaches within the program. For more information go to http://www.des.nh.gov/Beaches			

Water Protection/ Planning / Education Projects

Project Name	Water Protection/ Planning / Education Project Description **Color Key: Groundwater Projects (Blue), Surface Water (Black), Both (Green). Coastal (Orange) Both coastal & freshwater (purple)**	Date Completed	Project Status	Contact Information
Private Well Strategy	The goal of this award-winning initiative is to improve awareness of the need for private well testing and consequently to increase the number of private wells that are tested, expand the range of parameters for which the water is tested, and increase the frequency of testing. From 2001 to 2002, DES produced and distributed fliers and displays to local health officers, and produced and aired a series of radio public service announcements. From 2002 to 2003, DES developed and presented a series of workshops for home inspectors and real estate agents. In 2008 DES convened a working group to consider additional outreach as well as various legislative and regulatory options.	Working group expected to complete recommendations in 2009.	Ongoing	Paul Susca NHDES 271-7061
Water Well Survey	Water well contractors and pump installers are required to hold a license from the Water Well Board to conduct business in New Hampshire. DES and the Board have adopted well construction, placement, and abandonment regulations to protect drinking water quality and groundwater resources. Some communities have also adopted local ordinances pertaining to private wells including permits to construct wells, placement criteria, water quality testing, and minimum quantity needs. In a cooperative effort to gain a comprehensive understanding of local requirements, DES, the Board, the former Office of State Planning, and the NH Water Well Association (NHWWA) have contributed to the mailing and processing of questionnaires to NH townships concerning local regulation of private wells and local water resources protection. Questionnaire returns are entered into a database by DES staff and the information will contribute to its overall understanding of local water resources management and protection efforts. The NHWWA publishes the information in a booklet to assist licensed water well contractors and pump installers.	First survey completed in 1995, repeated in 2003	Complete	Rick Schofield NHDES 271-1974

Project Name	Water Protection/ Planning / Education Project Description Color Key: Groundwater Projects (Blue), Surface Water (Black), Both (Green). Coastal (Orange) Both coastal & freshwater (purple)	Date Completed	Project Status	Contact Information
Best Management Practices Guidance Document to Prevent Groundwater Contamination from Activities Associated with Rock Blasting	Provides technical and regulatory information to communities and the regulated communities to address potential water quality impacts associated with rock blasting.	2009	Draft document is complete and being reviewed by the public.	Brandon Kernen NHDES 271-0660
Land Use and Groundwater Quantity Management Document for Communities	Developing a document that describes how communities shape groundwater use and land development through local land use planning.	2009	Draft of the document has been completed and is being reviewed by the Groundwater Commission	Brandon Kernen NHDES 271-0660
Rivers Management and Protection Program/ River Corridor Management Plans	Pursuant to RSA 483, the Rivers Management and Protection Program was established to formally recognize New Hampshire rivers characterized by outstanding natural, historic, cultural, and economic resources. The intent of the program is to complement and reinforce existing state and federal water quality laws while simultaneously respecting reasonable on-water and off-water uses of the resources associated with designated rivers. The program includes significant interaction with local communities through the development and implementation of river corridor management plans. Fourteen rivers have been designated to date, eleven river corridor management plans have been created, and two management plans are in progress. For more information go to http://des.nh.gov/organization/divisions/water/wmb/rivers/index.htm	Ongoing	Ongoing	Steve Couture NHDES 271-8801
Instream Flow Protection Pilot Program	Under RSA 483 and Chapter 278, laws of 2002, An Instream Flow Protection Pilot Program is in progress to establish protected instream flows on the Souhegan and Lamprey Rivers, and to develop Water Management Plans for these watersheds. The Souhegan pilot began 9/2003, and the Lamprey pilot began in 2004. For more information go to http://des.nh.gov/organization/divisions/water/wmb/rivers/instream/	Ongoing	To be completed by 10/2009	Wayne Ives NHDES, 271-3548

Project Name	Water Protection/ Planning / Education Project Description **Color Key: Groundwater Projects (Blue), Surface Water (Black), Both (Green). Coastal (Orange) Both coastal & freshwater (purple)**	Date Completed	Project Status	Contact Information
New Hampshire Stream Team	The NH Stream Team is an ad hoc group comprising representatives from state and federal agencies, as well as university and private entities. The NHST's primary goal is to advance the use of science in channel restoration and streambank stabilization efforts, and provide a venue for communication among river management stakeholders. This includes developing regional hydraulic reference curves which will enable river managers to properly evaluate and design river channel restoration projects based on regression analyses of fluvial geomorphic data collected at reference sites. It also includes developing a guidelines document for natural stream channel design and streambank stabilization. For more information go to http://des.nh.gov/organization/commissioner/pip/publications/wd/documents/r-wd-06-37.pdf and http://des.nh.gov/organization/commissioner/pip/publications/wd/documents/r-wd-06-27.pdf	Ongoing	Ongoing	Steve Couture NHDES 271-8801
River Basin Planning & Assessment Program Report	Chapter 217 of the Laws of 1993 directed DES to design a river basin planning and resource assessment program and present it to the Governor, Senate President and House Speaker. The purpose of this act was to "further the state's efforts toward meeting its responsibility to protect public trust interests and to authorize coordinated long-range planning and water management to enable the state to balance various demands for water and increase the likelihood that existing and future water-use demands will be met." A progress report was presented in 1994, and with Chapter 208 of the Laws of 1995 DES was authorized and directed to continue and complete the design of such a program.	1996	Report completed	Paul Currier NHDES 271-3289
River Restoration – Dam Removal and Alteration	DES has coordinated the removal of unsafe or unwanted dams in the state, which are no longer needed for water management, to restore rivers to a healthier, free flowing condition, remove public safety hazards, improve water quality, and eliminate barriers to fish and other aquatic species. The work has been done in cooperation with the New Hampshire River Restoration Task Force.	Ongoing	Ongoing	Deb Loiselle NHDES 271-8870

Project Name	Water Protection/ Planning / Education Project Description Color Key: Groundwater Projects (Blue), Surface Water (Black), Both (Green). Coastal (Orange) Both coastal & freshwater (purple)	Date Completed	Project Status	Contact Information
Merrimack River Initiative	The overall goal of the Merrimack River Initiative (MRI) was to develop and implement a Watershed Management Plan that would help restore and maintain the physical, chemical, and biological integrity of the Merrimack River and its watershed to meet existing and future multiple uses and to protect natural resources. New England Interstate Water Pollution Control Commission (NEIWPCC) was involved with the MRI since its inception in 1988 when an agreement to protect the watershed was signed by EPA, NH, MA, and NEIWPCC. With a grant from EPA, NEIWPCC served as coordinator for MRI activities. NEIWPCC worked with NH DES staff to prepare outreach materials, develop the management plan, and cultivate local watershed action through small local involvement grants.	2000	Complete	Beth Card NEIWPCC 978-323-7929
Merrimack River Combined Sewer Overflow and Watershed Assessment Study	The 5 cities on the Lower Merrimack River with combined sewer overflows (CSO) (Manchester, Nashua, Lowell MA, Greater Lawrence MA, Haverhill MA) received a U.S. Army Corps of Engineers grant in 2001 for a Watershed Assessment Study of the lower Merrimack. The study's purpose was to develop a comprehensive Watershed Management Plan for the lower Merrimack that will guide financial investment in water quality improvements, integrating the requirement for CSO abatement with other water quality issues. Camp, Dresser and McKee, under contract to the Corps, conducted the $2M study which consists of water quality monitoring and modeling from Manchester to the sea.	2006	Complete	Paul Currier NHDES 271-3289
Connecticut River Forum	Connecticut River Forum: Comprising New England Interstate Water Pollution Control Commission, CT, MA, VT, and NH, the CT River Forum has been working since 1993 to restore water quality in the CT River Watershed. During FY-97, the Forum compiled a draft report entitled The Health of the Watershed: A Report of the Connecticut River Forum, which summarized the organization's work over the prior four years. The document provided a snapshot of water quality in the Connecticut River basin, and made recommendations for the protection and enhancement of the river and its tributaries. The report encouraged the establishment of a watershed-wide management approach which will consider the cumulative impacts of all activities affecting the river-basin. The Connecticut River Fish Tissue Study was a collaborative effort that resulted from the research and assessments of the CT River Forum. Data collected as part of the fish tissue study is currently being validated.	2001	Complete	Paul Currier NHDES 271-3289 Beth Card NEIWPCC 978-323-7929

Project Name	Water Protection/ Planning / Education Project Description Color Key: Groundwater Projects (Blue), Surface Water (Black), Both (Green). Coastal (Orange) Both coastal & freshwater (purple)	Date Completed	Project Status	Contact Information
Winnipesaukee River Basin – Enhanced Septage Capacity Project	The state-owned, DES-operated Franklin Wastewater Treatment Plant (WWTP), which was built to address wastewater disposal needs of the Winnipesaukee River Basin, has increasingly become a regional treatment resource for septage processing. In FY '03, more than half of the septage treated at the Franklin facility originated from communities outside of the Winnipesaukee River Basin Program's service area. To enable the WWTP to continue to provide these much-needed septage treatment services, the plant's solids handling capacity was upgraded with high efficiency dewatering equipment. This $5 million project was completed in 2007 and replaced the plant's existing, 25-year old dewatering system with high efficiency centrifuges. Septage, along with the wastewater sludge produced at the WWTP, is treated to become biosolids and is recycled to area farms for use as a high nitrate fertilizer for animal feed crops. Additional evaluations including improving the septage and wastewater sludge handling capabilities at the Franklin WWTP and augmenting septage capacity at alternate regional WWTP locations are currently underway. Recommended improvements will be implemented as funding becomes available.	Ongoing	Phase I Dewatering Project completed in 2007, septage and WWTP residuals handling evaluations are ongoing	Sharon McMillin NHDES 934-4032
Winnipesaukee River Basin – Phase II WWTP Improvements Project	This project is designed to prioritize and then implement recommended upgrades to the 30-year old Franklin WWTP in a phased approach that minimizes disruption to ongoing operations and best utilizes available funding. Priority projects include: updating the UV disinfection system for the WWTP discharge to the Merrimack River; modernizing the monitoring/control/communications system that links the treatment plant's operational processes and the sewer collection system remote pumping facilities; and maximizing the energy efficiency of operations.	Ongoing	Ongoing	Sharon McMillin NHDES 934-4032

Project Name	Water Protection/ Planning / Education Project Description **Color Key: Groundwater Projects (Blue), Surface Water (Black), Both (Green). Coastal (Orange) Both coastal & freshwater (purple)**	Date Completed	Project Status	Contact Information
Wastewater Residuals	A legislative study commission was established under Senate Bill 87 to look at setbacks to designated rivers for the land application of biosolids septage and short paper fiber. Water quality impact is just one of the concerns related to wastewater residual treatment and disposal. There have been a number of studies and initiatives addressing this concern. A legislative study commission was established under HB 699 to examine the methods and costs of sewage, sludge and septage disposal.	Final Report submitted 7/1/2004 Final Report submitted 11/1/2008	Resulted in legislation to extend the grandfathering of existing land application sites in designated river corridors.	Patricia Hannon NHDES 271-2758
Stormwater Phase II Assistance	Federal stormwater management requirements took effect in 2003. Urbanized municipalities are required to develop and implement local stormwater management plans, construction sites over one acre require a federal permit, and municipally owned industrial facilities require stormwater permits. While DES is not the permitting authority, it provides needed technical assistance to the regulated community. See our web site for more details: http://des.nh.gov/organization/divisions/water/stormwater/index.htm	Ongoing	Ongoing	Jeff Andrews NHDES 271-2984
Exotic Species Program	The primary purpose of the Exotic Aquatic Species Program is to “prevent the introduction and further dispersal of exotic aquatic weeds and to manage or eradicate exotic aquatic weed infestations in the surface waters of the state” (RSA 487:17, II). The DES program has five focus areas: 1) Prevention of new infestations, 2) Early detection of new infestations, 3) Control of established infestations, 4) Research towards new control methods with the goal of reducing or eliminating infested areas, and 5) Regional and national cooperation.	Ongoing	Ongoing	Amy P. Smagula NHDES 271-2248

Project Name	Water Protection/ Planning / Education Project Description Color Key: Groundwater Projects (Blue), Surface Water (Black), Both (Green). Coastal (Orange) Both coastal & freshwater (purple)	Date Completed	Project Status	Contact Information
Water Related Public Outreach and Youth Education Initiatives	There are a variety of water related programs and initiatives throughout the state dedicated to public outreach and youth education. At DES there is a public information office that routinely distributes information. There is also a speaker's bureau and a variety of annual outreach events. There are many other key players dedicated to water related public outreach including UNH Cooperative Extension and a myriad of river, lake and watershed groups. In terms of youth education, DES sponsors Project WET (Water Education for Teachers) which trains teachers in a water-centered curriculum. There are also a number of water fairs and teacher workshops that DES and others hold annually to target New Hampshire's youth. The other key players mentioned above are also very involved in youth education efforts. For more information go to http://des.nh.gov/organization/divisions/water/dwgb/dwspp/educ.htm	Ongoing	Ongoing	Public Information Tim Drew NHDES 271-3503 Youth Education Alicia Carlson NHDES 271-4071
Water Conservation Initiative	This initiative involved developing and promoting four water conservation case studies and other outreach materials including a pamphlet and multiple fact sheets. These materials are available in hard copy or electronically via the DES website and have been used in partnership with WasteCap at workshops. For more information go to http://des.nh.gov/organization/divisions/water/dwgb/water_conservation/index.htm	2005	Completed	Derek Bennett NHDES 271-6685
Drought Management Plan Revision	In 2009 DES will coordinate the update of the state's Drought Management Plan. The existing Plan was created in 1991. Given the state's experience in recent years with droughts, it is prudent to evaluate and improve the existing process for responding to droughts.	2009	Initial planning stage	Jim Gallagher NHDES 271-3505
Regional Environmental Planning Program	DES provides funds annually to each of the nine Regional Planning Agencies to implement environmental planning programs. Under the REPP, DES released Innovative Land Use Techniques: A Handbook for Sustainable Development in 2008. REPP funds are used to work with municipalities implementing innovative land use techniques as well as other priority environmental planning projects.	Ongoing	Ongoing	Eric Williams NHDES 271-2358

Project Name	Water Protection/ Planning / Education Project Description Color Key: Groundwater Projects (Blue), Surface Water (Black), Both (Green). Coastal (Orange) Both coastal & freshwater (purple)	Date Completed	Project Status	Contact Information
Regional Water Supply	RSA 485 charges DES with evaluating regional water supply needs. Since the 1950s a number of regional water supply studies have been performed. The most recent is dated 1988: Southern New Hampshire Water Supply Study by Roy Weston Engineers. Under legislation passed in 2001, DES and the PUC undertook a study to examine barriers to regional sharing of drinking water. Subsequent legislation passed in 2003 established a state grant program providing 25 percent reimbursement of costs related to planning, design and construction of facilities for public water system interconnections. In addition, with federal funds from the EPA security grant program, DES has supported several studies examining means of interconnecting public water systems. This program has funded a study of 10 Seacoast communities, communities in the Nashua/Manchester region, and an interconnection between Milford and Wilton, among others. A study of interconnections in the Concord area is ongoing. For more information go to http://des.nh.gov/organization/divisions/water/dwgb/capacity/pwsg.htm	Ongoing	Legislation passed in 2001 Interconnection Grants currently being awarded	Bob Mann NHDES 271-2953
Groundwater and Drinking Water Protection Strategy	This strategy was developed to identify what more DES and partners should be doing to protect these resources. Currently, DES and partners are working on the second major update of the plan to improve protection. The plan consists of a number of action items under three broad headings: prevention, education, and resource assessment. The latest progress report on the strategy can be viewed at http://des.nh.gov/organization/divisions/water/dwgb/dwspp/strategy.htm	Second update due for completion in 2009.	Ongoing	Paul Susca NHDES 271-7061

Project Name	Water Protection/ Planning / Education Project Description Color Key: Groundwater Projects (Blue), Surface Water (Black), Both (Green). Coastal (Orange) Both coastal & freshwater (purple)	Date Completed	Project Status	Contact Information
Drinking Water and Wastewater System Security	Drinking Water System Security: Since the terrorist attacks on 9/11, DES has been involved in increasing security at public water systems. This includes training operators in assessing and addressing water system vulnerability, improving internal and external emergency readiness, and providing grants for source security. NH is also involved in piloting a program to involve local distributors of security equipment in providing low cost supplies to water systems. NH and New England Interstate Water Pollution Control Commission (NEIWPCC) have also been involved in a pilot in Manchester to install and test a state of the art drinking water security monitoring system. http://www.des.state.nh.us/wseb/EmergencyPlanning/index.asp Wastewater Treatment Facility Security: With EPA funding, NEIWPCC contracted with a security and wastewater operations firm to assist 13 communities in NH (Nashua, Franklin, Exeter, Manchester, Concord, Keene, Durham, Portsmouth, Merrimack, Rochester, Milford, Claremont, and Lebanon) with a Vulnerability Assessment of their wastewater treatment facility. This was done through three phases of funding from EPA. The contractors reviewed the plants' assets, identified vulnerabilities, and made recommendations for security improvements to protect the facilities from intentional or unintentional threats. Four of the first five selected treatment plants were chosen due to their location within the Merrimack River watershed (a public water supply system). Additional facilities were selected based on size, potential threat, or recommendation of DES staff. A statewide workshop was held after each round of visits to discuss findings and to instruct other facilities on the process. Workshops were held in May 2003, June 2004, and June 2005 to share benefits with other WWTFs and discuss other free EPA-funded tools available for them to conduct these assessments themselves.	Ongoing Ongoing	Ongoing Ongoing	Johnna McKenna NHDES 271-7016 Tom Groves NEIWPCC 978-323-7929

Project Name	Water Protection/ Planning / Education Project Description Color Key: Groundwater Projects (Blue), Surface Water (Black), Both (Green). Coastal (Orange) Both coastal & freshwater (purple)	Date Completed	Project Status	Contact Information
Funding Local Water Protection Initiatives	There are a number of established grant and loan programs at DES that annually make money available for local water protection planning and implementation projects. Examples include the clean water and safe drinking water state revolving loan funds, and grants for watershed assistance and restoration, drinking water source protection, water supply land protection, and exotic aquatic plant control. More information on any of these loan or grant programs can be found at http://des.nh.gov/organization/commissioner/pip/categories/grants.htm	Ongoing	Ongoing	NHDES 271-3503
Electronic Permitting Project	A project is underway to introduce electronic permitting to DES. This project will be piloted in the Subsurface Disposal System Permitting Program and will then be expanded to include the Alteration of Terrain and Wetlands Permitting Programs. The purpose is to increase efficiency and reduce costs associated with permitting.	Ongoing	Ongoing	William E. Evans, P.E. NHDES 271-3304
Unused Medicine Disposal Policy	Work with stakeholders to develop a unified approach to properly disposing unused medicines in the state to protect New Hampshire's water resources. Focus areas include disposal practices at long-term health care facilities and at private residences. A background document summarizing medicine use trends, current disposal practices and regulatory considerations has been developed.	2009	A background document has been developed.	Brandon Kernen NHDES 271-0660
NH Estuaries Project, State of the Estuaries Report	The NH Estuaries Project has prepared a "State of the Estuaries" report based on environmental indicators. The report is produced every three years. The NHEP holds a day-long conference to present the report and related research.	Ongoing	Ongoing	Phil Trowbridge NHDES, 271-8872
Coastal Regional Outfall Sewer System Project	Senate Bill 70, effective July 7, 2003 established a commission to study, among other things, the feasibility of collecting the effluent from all coastal municipal wastewater treatment facilities discharging the effluent in the ocean.	Completed	Report available	Steve Roberts NHDES 271-2980

Summary of Statutory and Regulatory Authorities for New Hampshire Water Protection Activities

	PROGRAM TYPE ACTIVITY OR PROGRAM	STATE STATUTORY AUTHORITY TITLE & RSA NUMBER		STATE RULES TITLE & NUMBER		RELATED FEDERAL AUTHORITY[1]
Assessment	DES[1] -Water Division					
	Water Use Registration and Reporting	Water Management	488	Water Use Registration and Reporting	Env-Wq 2102	-----
	Well Registration Program	NH Water Well Board	482-B	Water Well Board Rules	We 100-1000	-----
Prevention	DES – Water Division					
	Ambient Groundwater Quality Standards	Groundwater Protection Act	485-C	Groundwater Discharge Permit & Registration Rules	Env-Wq 402	SDWA
	Beach Inspection Program	Water Pollution and Waste Disposal	485-A:26	Public Bathing Places	Env-Wq 1100	BEACH
	Clean Vessel Act Program	Control of Marine Pollution & Aquatic Growth	487			CVA
	Chemical Monitoring Waivers	Safe Drinking Water Act	485	Protocol for Monitoring Waiver	Env-Dw 712*	SWDA
	Coastal Program	Multiple Authorities[2]		Multiple Regulations[3]		CZMA Sec. 307
	Dams Program	Dams, Mills, and Flowage	482	Dam Rules	Env-Wr 100-700	-----
	Drinking Water Revolving Fund	Aid to Public Water Systems	486-A	Drinking Water State Revolving Loan Fund Program	Env-Dw 1100	SDWA
	Drought Management	Emergency Management Act (Repealed)	107	n/a	n/a	-----
	Exotic Species Program	Control of Marine Pollution and Aquatic Growth	487	New Hampshire Clean Lakes Program	Env-Wq 1300	-----
	Groundwater Reclassification Program	Groundwater Protection Act	485-C	Groundwater Reclassification Rules	Env-Dw 901	SDWA
	Groundwater Discharge Permits Program	Groundwater Protection Act	485-C	Groundwater Discharge Permit & Registration Rules	Env-Wq 402	SDWA
	Instream Flow Program / Protected Rivers	Rivers Management and Protection Program	483:9-c	Rules for the Protection of Instream Flow	Env-Wq 1900	-----
	Laboratory Accreditation	Safe Drinking Water Act	485	Laboratory Accreditation	Env-C 300	SDWA
	Large Groundwater Withdrawal Program	Groundwater Protection Act and Safe Drinking Water Act	485-C 485	Large Groundwater Withdrawal Rules	Env-Wq 403*	SDWA
	New Community Well Siting Program	Groundwater Protection Act	485	Small and Large Production Wells Rules	Env-Dw 301 & 302	SDWA
	Bottled Water Source Siting Program	Groundwater Protection Act	485	Groundwater Sources of Bottled Water Rules	Env-Dw 303	SDWA
	Public Drinking Water Program (monitor, engineer, mgt.)	Safe Drinking Water Act	485	Public Water Supply Rules	Env-Ws 300-394 Env-Dw 100-1100* Env-Wq 300-2100*	SDWA
	Residuals Management Section	Water Pollution and Waste Disposal	485-A	Sludge Management & Septage Management	Env-Wq 800 & 1600	CWA
	Rivers Management and Protection Program	Rivers Management and Protection Program	483:11	Rivers Management & Protection Program Rules	Env-Wq 1800	-----
	Section 401 Water Quality Certification Program	Water Pollution and Waste Disposal	485-A	Surface Water Quality Regulations and Water Quality Certification Rules	Env-Wq 1700 Env-Wq 302*	CWA CWA
	Alteration of Terrain Program	Water Pollution and Waste Disposal	485-A:17	Alteration of Terrain	Env-Wq 1500	CWA
	Shoreland Protection Program	Comprehensive Shoreland Protection Act	483-B:17	Shoreland Protection Rules	Env-Wq 1400	-----
	State Water Pollution Control Revolving Loan Fund	Aid to Municipalities for Water Pollution	486:14	State Water Pollution Control Revolving Loan Fund	Env-Wq 500	CWA
	Stormwater Program					CWA
	Subsurface Program (septic & subdivisions)	Water Pollution and Waste Disposal	485-A: 29-44	Subdivision and Individual Sewage Disposal System Design Rules	Env-Wq 1000	CWA
	Surface Water Discharges (NPDES[1])	Water Pollution and Waste Disposal	485-A:13	State Surface Water Discharge Permits	Env-Wq 301*	CWA
	Surface Water Diversion	Compliance with Water Quality Standards	485-A:12	Surface Water Quality Regulations	Env-Wq 1700	-----
	Underground Injection Control (UIC) Program	Safe Drinking Water Act	485	Groundwater Discharge Permit & Registration Rules & Underground Injection Control Rule	Env-Wq 402 Env-Wq 404*	SDWA

*New rule designation once rule is readopted.

	PROGRAM TYPE ACTIVITY OR PROGRAM	STATE STATUTORY AUTHORITY TITLE & RSA NUMBER		STATE RULES TITLE & NUMBER		RELATED FEDERAL AUTHORITY[1]
Prevention (cont'd)	Wastewater Treatment Program	Water Pollution and Waste Disposal	485-A	Wastewater Treatment Rules	Env-Wq700,305,303*	CWA
	Water Conservation Program	Safe Drinking Water Act	485:61	Water Conservation Rules	Env-Wq 2101	-----
	Water Council	Department of Environmental Services	21-O:7	Water Council Procedural Rules	Env-WC 100 & 200	-----
	Watershed Rules (PWS[1] with surface water sources)	Safe Drinking Water Act	485	Rules to Protect Purity of Regulated Watersheds	Env-Dw 902*	-----
	Water Supply Land Grant Program	Aid to Public Water Systems	486-A	Water Supply Land Grant Program	Env-Dw 1002*	-----
	Water System Regionalization/Contamination Investigation	Aid to Public Water Systems	486-A	Public Water Supply Grants	Env-Dw 1001*	-----
	Water System Security – Emergency Plans	Safe Drinking Water Act	485	Emergency Plan for Community Water Systems	Env-Dw 360.15*	SDWA
	Well Drillers	NH Water Well Board	482-B	Water Well Board Rules	We 100-1000	-----
	Wellhead Protection Program	Groundwater Protection Act	485-C	Best Management Practices for Groundwater Protect.	Env-Wq 401	SDWA
	Wetlands Council	Department of Environmental Services	21-O:5-a	Wetlands Council Procedural Rules	Env-WtC 200	-----
	Wetlands Program	Fill and Dredge in Wetlands	482-A	NH Wetlands Programs Rules	Env-Wt 100-800	CWA, RHA
	Winnipesaukee River Basin Program	Water Pollution and Waste Disposal	485-A:45 - 54	Winnipesaukee River Basin Program Rules	Env-Wq 1200	CWA
	DES – Waste Management Division					
	Hazardous Waste Compliance Program	Hazardous Waste Management Act	147-A	Hazardous Waste Rules	Env-Hw 100-1100*	RCRA, SARA, & CERCLA
	Solid Waste Regulation	Solid Waste Management Act	149-M	Solid Waste Rules	Env-Sw 100-2100	RCRA
	Aboveground Storage Tank (AST) and Underground	Oil Discharge or Spillage in Surface Water	146-A:11-c	Aboveground Petroleum Facilities Rules	Env-Or 300* &	RCRA
	Storage Tank (UST) Programs	Underground Storage Facilities	146-C:9	Underground Storage Facilities Rules	Env-Or 400*	RCRA
	Motor Vehicle Salvage Operations	Solid Waste Management Act	149-M:59, 60	Pending	Pending	-----
	Municipal Government Statutory Authority					
	Drought-Water Use Restrictions	Restricting the Watering of Lawns	41:11:d	n/a	n/a	-----
	Water Protection Assistance Program	Local Water Resources Management and Protection Plans	4-C:22 & 674	n/a	n/a	-----
	Water Protection Assistance Program	Regional Water Resources Management and Protection Plans	4-C:23 & 53-A	n/a	n/a	-----
	Municipal Land Use Regulation	Regulation of Subdivision of Land	674:36	n/a	n/a	-----
		Site Plan Review Regulations	674:44	n/a	n/a	-----
		Zoning Ordinances	674 – 676	n/a	n/a	-----
		Nuisances; Toilets; Drains, Expectoration; Rubbish and Waste	147	n/a	n/a	-----
	Motor Vehicle Recycling Yards and Junk Yards	Auto Salvage Yard License	236:111-117	n/a	n/a	-----
	Public Utilities Commission					
	Public Utilities	Water Companies, When Public Utilities	362:4	Rules for Water Service	Puc 600	-----
	Department of Safety					
	Homeland Security and Emergency Management	Flood, Drought, and Water Supply Disruption	21-P, 34-47	n/a	n/a	-----
	Office of Energy and Planning					
	Water Protection Assistance Program	Technical Assistance Program	4-C:19	n/a	n/a	-----
	Department of Agriculture					
	Division of Pesticide Control	Insect Pests & Plant Disease	430:28-48	Pesticide Control Rules	Pes 100-1000	FIFRA

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	PROGRAM TYPE ACTIVITY OR PROGRAM	STATE STATUTORY AUTHORITY TITLE & RSA NUMBER		STATE RULES TITLE & NUMBER		RELATED FEDERAL AUTHORITY[1]
Corrective	Department of Transportation					
	Well Replacement Program	Administration of Transportation Laws	228:34	None	------	------
		Private Water Supplies				
	DES – Water Division					
	Shellfish Program	Sanitary Production & Distribution of Food	143:21,21-a,63	n/a	n/a	-----
		Fish, Shellfish, Lobster and Crabs	211: 63-a	n/a	n/a	-----
		Water Pollution & Waste Disposal	485-A:8	n/a	n/a	-----
	Total Maximum Daily Load Program	n/a		n/a	n/a	CWA
	DES – Waste Management Division					
	Fuel Oil Discharge Cleanup Fund	Fuel Oil Discharge Cleanup Fund	146-E	Petroleum Release Compensation Rules	Odb 100-400	-----
	Groundwater Remediation Permitting	Groundwater Protection Act	485-C:13	Groundwater Release Detection Permit Rules	Env-Or 700	SDWA
		Brownfields Program	147-F	Brownfields Program Under RSA 147-F	Env-Or 800	-----
				Contaminated Site Management	Env-Or 600	SDWA
	Hazardous Waste Emergency Response	Hazardous Waste Management	147-A	Hazardous Waste Rules	Env-Hw 100-1100*	RCRA, SARA, & CERCLA
		Hazardous Waste Cleanup Fund	147-B			
	Leaking Petroleum Storage Tanks	Oil Discharge and Disposal Cleanup Fund	146-D	Petroleum Release Compensation Rules	Odb 100-400	-----
		Oil Spillage & Discharge in Public Waters	146-A,C,& D			OPA-1990, CWA
	Municipal Solid Waste Landfill Closures	Solid Waste Management	149-M	Solid Waste Rules	Env-Sw 100-2100	RCRA
	Oil Spill Emergency Response	Oil Discharge or Spillage in Surface Water or Groundwater	146-A			OPA-1990, & CWA
	RCRA C (Hazardous Waste) Corrective Actions	Hazardous Waste Cleanup Fund	147-B	Hazardous Waste Rules	Env-Hw 100-1100*	RCRA
		Hazardous Waste Management	147-A			
	Superfund Corrective Action Program	Hazardous Waste Cleanup Fund	147-B	Hazardous Waste Rules	Env-Hw 100-1100*	SARA, & CERCLA

See footnotes on the following page.

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1. Program Type and Federal Acronyms

BEACH – Beaches Environmental Assessment & Coastal Act
CERCLA – Comprehensive Enviornmental Restoration & Compensation Liability Act
CVA – Clean Vessel Act
CWA - Clean Water Act
CZMA – Coastal Management Act of 1972
DES – Department of Environmental Services
FIFRA – Federal Insecticide Fungicide & Rodenticide Act
NPDES – National Pollutant Discharge Elimination System
OPA – Oil Pollution Act
PWS – Public Water Supplies
RCRA – Resource Conservation and Recovery Act
RHA – Rivers & Harbors Act of 1899
SARA – Superfund Amendment and Reauthorization
SDWA – Safe Drinking Water Act

2. Coastal Program State Statutory Authorities

Powers of the Governor and Council in Certain Cases (By Purchase)	RSA 4:29
Department of Resources and Economic Development	RSA 12-A
Mining and Reclamation	RSA 12-E
Pease Development Authority	RSA 12-G
Department of Environmental Services (Wetlands Council)	RSA 21-O:5-a
Forest Conservation and Taxation (Notice of Intent to Cut)	RSA 79:10
Air Pollution Control	RSA 125-C
Acid Rain Control Act	RSA 125-D
Sanitary Production and Distribution of Food (State Shellfish Sanitation Control Authorities)	RSA143:21-a
Oil Discharge or Spillage in Surface Water or Groundwater	RSA 146-A
Nuisances; Toilets; Drains; Expectorant; Rubbish and Waste (Removal Notice)	RSA 147:4
Hazardous Waste Management Program	RSA 147-A
Council on Resources and Development	RSA 162-C
Energy Facility Evaluation, Siting, Construction and Operation	RSA 162-H
Fish and Game Commission	RSA 206
General Provisions as to Fish and Game (Enforcement of Laws)	RSA 207:54
Endangered Species Conservation Act	RSA 212-A
Fish, Shellfish, Lobsters, and Crabs	RSA 211
Licenses (State Migratory Waterfowl License Required)	RSA 214:1-d
Expansion of State Park System	RSA 216-A
NH Native Plant Protection	RSA 217-A
Historic Preservation	RSA 227-C
Policy, Definitions, and Administration	RSA 227-G
Public Forest Lands: Management, Acquisition and Lost Taxes	RSA 227-H
Forest Resources, Education, Promotion and Planning	RSA 227-I
Timber Harvesting	RSA 227-J
Forest Health	RSA 227-K
Woodland Fire Control	RSA 227-L
State Highways	RSA 230
Access to Public Waters	RSA 233-A
Supervision of Navigation; Registration of Boats and Motors; Common Carriers by Water (Toilet Facilities Required)	RSA 270:72-a
Boating and Water Safety on NH Public Water	RSA 270-D
Pilots, Harbor Masters, and Public Waters	RSA 271
Insect Pests and Plant Diseases	RSA 430
Soil Conditioners	RSA 431
Soil Conservation and Farmland Preservation (Nuisance Liability of Agricultural Operations)	RSA 432:34
Fill and Dredge in Wetlands	RSA 482-A
New Hampshire Rivers Mgmt & Protection Program	RSA 483
Comprehensive Shoreland Protection Act	RSA 483-B
NH Safe Drinking Water Act	RSA 485
Water Pollution & Waste Disposal	RSA 485-A
Groundwater Protection Act	RSA 485-C
Control of Marine Pollution and Aquatic Growth	RSA 487
Local and Land Use Planning and Regulatory Powers	RSA 674

3. Coastal Program State Regulations

NH Drinking Water Rules	Env-Dw 300-1100*
Alteration of Terrain	Env-Wq 1500
Groundwater Reclassification	Env-Dw 901
Best Management Practices	Env-Wq 401
Subdivision & Individual Sewage Disposal System Design Rules	Env-Wq 1000
NH Wetlands Programs Rules	Env-Wt 100-800
Administrative Fines	Env-C 600
Dumping of Fish	Fis 602.04
Pesticide Control Rules	Pes 100-1000
Pease Development Authority Administrative Rules	Pda 100-700
Wood Processing Rules	Res 5200-5800
Natural Heritage Inventory Program	Res 1100

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