Protecting Water Resources and Managing Stormwater






A BIRD'S EYE VIEW FOR NEW HAMPSHIRE COMMUNITIES

Protecting Water Resources and Managing Stormwater:
A Birds Eye View For New Hampshire Communities

Written by:

Julia Peterson, New Hampshire Sea Grant and University of New Hampshire Cooperative Extension

Amanda Stone, University of New Hampshire Cooperative Extension

James Houle, University of New Hampshire Stormwater Center

Design and production by: Tricia Miller, MillerWorks Graphic Design

Cover Photos: Photos.com

This project has been funded through a grant utilizing federal funds from the U.S. Environmental Protection Agency. The views expressed do not necessarily reflect those of the EPA. Mention of trade names, products or services does not convey, and should not be interpreted as conveying, official EPA approval, endorsement or recommendation.

UNIVERSITY *of* NEW HAMPSHIRE
COOPERATIVE EXTENSION

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

Special thanks to the following contributors and reviewers:

Steve Adams, New Hampshire Sea Grant

Cathy Coletti, New Hampshire Department of Environmental Services, Coastal Program

Lori Lavac, New Hampshire Sea Grant

Lisa Loosigian, New Hampshire Department of Environmental Services, former intern

Jillian McCarthy, New Hampshire Department of Environmental Services

Barbara McMillan, New Hampshire Department of Environmental Services

Steve Miller, Great Bay National Estuarine Research Reserve, Coastal Training Program

Robert Roseen, University of New Hampshire Stormwater Center

Derek Sowers, Piscataqua Region Estuaries Partnership

INTRODUCTION

Thou in thy narrow banks art pent:
The stream I love unbounded goes
Through flood and sea and firmament;
Through light, through life, it forward flows.

—Ralph Waldo Emerson, *Two Rivers*

This excerpt from Emerson's poem captures the movement and power of water. It moves through a cycle powered by evaporation, transpiration, condensation, precipitation and infiltration. Each rain or snow storm brings this water cycle to our attention. Water is essential for life, and although it is a renewable resource, water is a finite resource.

Increasing levels of construction and land development are accompanied by an increasing need to manage stormwater in order to protect public health, property and natural resources. There is no silver bullet when it comes to protecting water resources in the face of land development. However, communities that take steps toward preventing problems spend less money managing their infrastructure, increase protection of natural resources, and improve community resiliency to droughts and flooding.

This document is intended to help communities consider the range of strategies available to help protect water resources. It uses a bird's eye view to encourage community boards and municipal departments to consider a variety of options and use an integrated approach to water resource protection. It is designed to help communities recognize and discuss the state of their current water resource management, determine where gaps exist and consider next steps.

An integrated approach, for example, would include strategies that prevent many water resource problems by leaving important, naturally vegetated lands, especially those adjacent to water resources, undisturbed. Natural lands carry out the critical functions of allowing water to infiltrate into the ground and filtering contaminants from stormwater runoff. At this time, no engineered solution can fulfill those roles as efficiently and effectively as healthy plants and soils can.

Where high degrees of development already exist, design and engineered solutions to stormwater management may be the best available options. In those situations, the most effective stormwater management techniques, such as reductions in effective impervious cover and the use of low impact development, promote the infiltration and filtration functions typical of natural lands and reduce burdens on local stormwater infrastructure.

Integrating the multiple strategies outlined in this guide (conserving land, protecting riparian buffers, minimizing impervious cover and using low impact development techniques) provides communities with options that can be tailored to the landscape and offer complementary results when used in tandem. Strategies that focus on preventing problems are likely to be more effective in protecting water supplies, water quality and financial resources. Most communities will need to use several strategies and implement them with a combination of voluntary and regulatory tools.

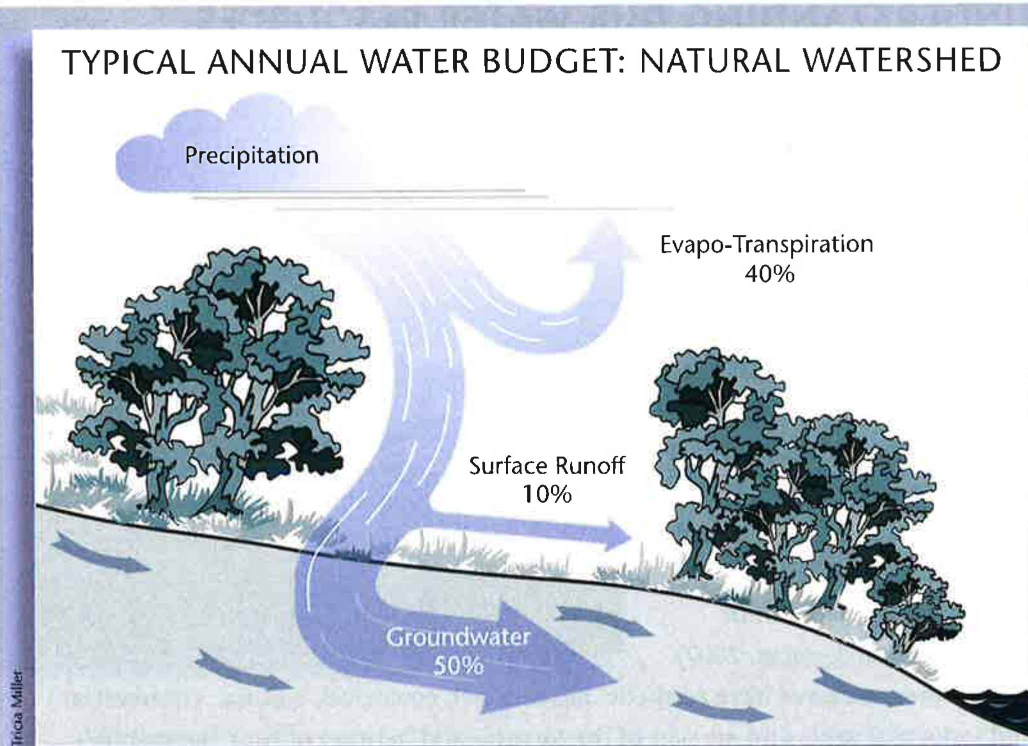
Implementing effective stormwater management requires good information gathering, education, planning, policy-making and practices. Based on regional and national case studies, the most effective implementation is likely to happen where teams of municipal officials, engineers, developers, landscape architects, land and water conservation groups and technical advisors work together on shared goals.

UNDERSTANDING OUR WATER RESOURCES

New Hampshire is considered a water-rich state, especially in comparison to other parts of the country. It is home to 17,000 miles of rivers and streams, nearly 1,000 lakes and large ponds, and 238 miles of ocean and estuarine coastline (*New Hampshire Water Resources Primer,* 2008). Groundwater in New Hampshire supplies household water to 60 percent of the state's population (New Hampshire Department of Environmental Services, 2007). These water resources have aesthetic, recreational, ecological, cultural, commercial and industrial value and are part of the identity and heritage of New Hampshire's communities and residents.

Many of New Hampshire's water resources are relatively clean, healthy and abundant, but threats to clean and adequate waters are unrelenting and evidence of damage is rising. Most direct sources of water pollution from industrial and commercial pipes (*point sources*), are regulated and managed. It is the indirect sources of water pollution (*non-point sources*) that are currently considered the primary threat (U.S. EPA). Non-point source pollution comes from construction site erosion, faulty septic systems, leaking automotive fluids, agricultural and residential fertilizers and pesticides, road salt and other diffuse origins. Nearly all non-point source pollution is associated with human activities on the landscape within a watershed and the accompanying stormwater runoff. As landscapes change from natural conditions (fields and forests) to highly built conditions (buildings, roads, parking lots), water quality and quantity are adversely affected. As water quality and quantity degrade, community vulnerability increases. The following text describes some concepts important for understanding how activities on land affect surface water and groundwater quality and quantity.

Stormwater is water that accumulates on land as a result of rain events. It is sometimes called stormwater runoff. Impervious land cover like driveways, sidewalks, streets and roofs prevent stormwater runoff from naturally soaking into the ground, thereby creating faster and greater volumes of surface flows. Across the U.S., unmanaged stormwater runoff has caused serious damage to property, as well as to streams, lakes and estuaries, particularly where land uses change from rural to urban activities.



Infiltration in the Natural Environment

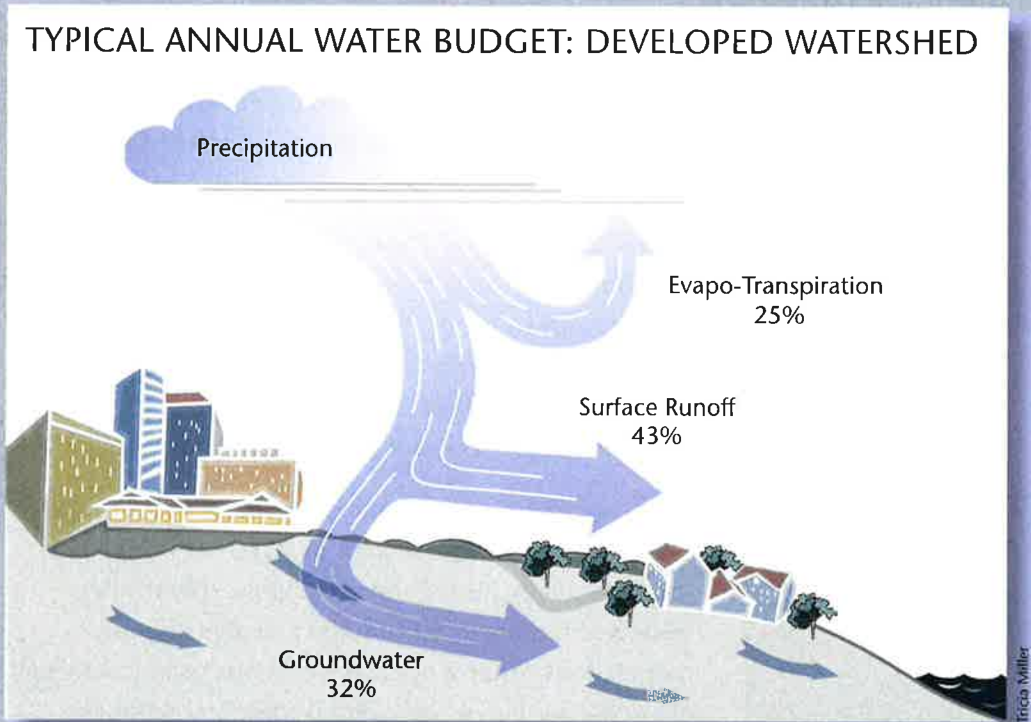
In natural areas like forests, shrublands, fields and wetlands, water from rainfall and snowmelt penetrates the ground surface into soils, or *infiltrates,* where it:

- Remains in the subsurface and is taken up by plants (transpiration) or evaporates.
- Discharges into streams, ponds and bays via bank seepage, helping to maintain stream flows and water levels during drier periods.
- Penetrates more deeply into the ground and accumulates as groundwater.

Natural ecosystems efficiently infiltrate and filter pollutants from water. The closer a community and its development patterns can mimic and take advantage of existing natural ecosystems, the more effective and less costly their water resources protection efforts will be.

Filtration in the Natural Environment

Land cover and water health are intimately connected. Vegetation and soils play important roles in filtering out pollutants from runoff. Where dense vegetation such as shrubs, trees and herbaceous plants exists, water flowing as surface runoff slows down, allowing the sediment and pollutants to settle out. Plants and soil microbes then transform or process some contaminants into less harmful compounds. Vegetation also helps bind the soil and prevent erosion, reducing the amount of sediment that reaches surface waters.



Reduced Infiltration and Filtration in the Built Environment

In built areas, infiltration of water from rainwater and snowmelt is limited. The majority of precipitation moves across the land surface as *runoff*. The impervious cover (roads, roofs, parking lots) that accompanies development diminishes both infiltration of water into the ground and filtration of pollutants through soils.

The bottom line is that managing stormwater in built areas is necessary to prevent flooding, reduce erosion and water pollution, and protect public safety and aquatic habitats.

Impervious cover changes the distribution of stormwater by diverting what may have infiltrated through soils directly into surface waters. This results in an increase in stormwater volume and velocity as well as an increased potential for erosion and flooding.

Impervious cover prevents infiltration while magnifying the volume and velocity of stormwater runoff over land. The result is decreased groundwater recharge, diminished stream flow during dry spells and increased surface runoff.

Impervious cover also collects contaminants common to developed areas such as oils, sediments, nutrients and trash that fast-moving stormwater transports to receiving waters. Impervious cover prevents filtration of water by plants and soil and shuttles contaminants with stormwater into the nearest catch basin or surface water. The result is degraded water quality.

Major Contaminants

In New Hampshire, water pollution is typically described in terms of major categories: excess nutrients, sediments, pathogens, toxic contaminants, chloride and thermal stress. All of these contaminants can be found in high concentrations in stormwater that enters surface waters.

Groundwater contamination sites are typically localized (except for salt), and contamination originates from some of the same sources that contribute to surface water contamination. Groundwater contaminants can come from naturally occurring sources, such as radon in bedrock, or from certain land uses that cause contaminants to leach through soils. See the *New Hampshire Water Resources Primer* (N.H. DES, 2008) for more information about contaminants of concern in surface and groundwater.

- **Excess nutrients** include phosphorus and nitrogen. Excess nutrients lead to algal blooms in lakes, bays and ponds that eventually die-off and decompose, diminishing dissolved oxygen levels in water and affecting fish populations. Sources of excess nutrients include fertilizer, wastewater effluent, agricultural waste and sediments. Phosphorus levels control rates of algal growth in fresh water, and nitrogen levels control rates of algal growth in marine and estuarine waters. Nitrogen in drinking water is a health hazard for infants. (U.S. EPA)
- **Excess sediments** include sand and silt that erode from soil or are carried with stormwater flows. Many contaminants attach to sediments and contribute to excess pollution in receiving waters. Excess sediments reduce water clarity and smother aquatic habitat. Sources of sediments include erosion from disturbed

Julia Peterson

areas and construction sites, freshly plowed agricultural fields and road sand.

- **Pathogens** are disease-causing organisms, typically bacteria and viruses. Sources of pathogens include agricultural waste, pet waste, wastewater effluent and faulty septic systems. The presence of pathogens beyond specific levels limits water use for drinking, fish and shellfish consumption and some forms of recreation.
- **Toxic contaminants** include heavy metals, polycyclic aromatic hydrocarbons (PAHs) and volatile organic compounds (VOCs). They are generally poisonous to living organisms and are often persistent in the environment. Sources of toxic contaminants include petroleum products, paints, solvents, herbicides, pesticides and other household, commercial and industrial chemicals.
- **Excess chloride** creates mineral imbalances for plants and animals living in freshwater aquatic systems. The main source of chloride is de-icing salts from winter road maintenance operations. Backwash from water softeners may also contribute, but to a lesser degree. Salt is very difficult to filter out and is a growing concern in New England waters.
- **Temperature stress** is created when heated water enters a natural aquatic system. Cold water environments can hold more dissolved oxygen and are therefore able to support greater biological diversity. Heated water comes from some manufacturing process waters and from runoff that has flowed over warm surfaces, such as parking lots and roadways. The warmer water reduces the amount of dissolved oxygen, affecting fish and other aquatic populations.

Barbara McMillan

MUNICIPAL ROLES IN WATER RESOURCE PROTECTION

Who is responsible for keeping surface water and groundwater clean and abundant in our communities? There's a role for everyone—homeowners, landowners, businesses, developers, volunteer board members, municipal staff members, environmental organizations, state and federal agencies and many others. Stormwater management is a shared task that spans rural to urban settings, single lot to watershed-wide scales, and voluntary to regulatory approaches. Nonetheless, much of the regulatory responsibility and power lies with local communities.

New Hampshire's towns and cities can reduce threats to water resource quality and quantity from stormwater by managing activities on the landscape within their boundaries. Municipal boards and staff members have a powerful influence because of the hands-on roles they play in crafting community plans and visions, shaping community policies, projecting community attitudes and determining which development plans are accepted. The price for ignoring stormwater effects is that excess and polluted runoff threatens drinking water supplies, taxes community budgets and stresses municipal infrastructure. The benefits of improved stormwater management are reduced pressure on municipal infrastructure, greater resilience to droughts and flooding, healthier and more abundant water resources and better regulatory compliance.

While change is difficult in any community, the evidence is quite clear that current stormwater management techniques are not adequately protecting water quality (UNH Stormwater Center, 2007) or municipal infrastructure (Antioch New England Graduate School, 2005). In order to address these pressures, community boards and municipal staff members may need to increase their knowledge of stormwater management techniques, change attitudes about development and rethink strategies for protection.

Generally, in order to improve stormwater management, communities will need to:

- gather information about their existing water resources, policies and programs;
- educate their boards, staffs, development professionals and residents;
- encourage voluntary adoption of appropriate strategies;
- include various strategies in plans i.e. master plans and local watershed plans;
- create, comply with and enforce policies that include sound strategies; and
- implement practices and policies backed by sound science, technology and engineering in municipal, commercial, industrial and residential properties.

New Hampshire is fortunate to have many sources of information about natural resources, including reports, maps, publications and websites. Three publications containing helpful information for communities were released in 2008 from New Hampshire Department of Environmental Services (N.H. DES): The *DES Stormwater Manual, DES Innovative Land Use Planning Techniques* handbook and *DES Water Resources Primer*. New Hampshire is also home to the University of New Hampshire Stormwater Center, a field site for the evaluation of stormwater treatments and center for technical expertise.

There are also many organizations and agencies that provide education and outreach for communities (see *References and Resources*, page 43). Board members have varying degrees of comfort and expertise with each topic they confront and there is often turnover on boards, so ongoing education is a regular need.

The New Hampshire Natural Resource Outreach Coalition (NROC) provides education, technical assistance and facilitation to coastal communities in New Hampshire by working with communities on natural resource protection goals of their choice. NROC is a member of the National NEMO (Nonpoint Education for Municipal Officials) Network. For more information see: http://extension.unh.edu/CommDev/NROC/CANROC.cfm.

Planning for better stormwater management is challenging because water resources are not confined to municipal boundaries and watershed plans are not always integrated into master plans. In addition, the visions supported by master plans are not always borne out through regulation. Sound planning should help communities (and their neighbors) set the groundwork for sound policies, better parcel-based decisions and ultimately better stormwater management.

UNHSC

While most communities have master or comprehensive plans outlining a vision for the community overall, many land use decisions are made on a parcel-by-parcel basis according to existing policies. These parcel-by-parcel decisions add up to create cumulative impacts on water resources, stormwater infrastructure and municipal budgets. Sometimes the cumulative impacts are overlooked during the development review process, but are ultimately what a community will face.

Overcoming Barriers to Better Stormwater Management

Municipalities have unique challenges and opportunities with regard to stormwater management. Both formal and informal assessments of barriers to innovative stormwater management underscore the important role that local decision makers play (Nowacek et al., 2003; Godwin et al., 2008). Development professionals wishing to use more innovative techniques are frustrated when local policies do not permit more environmentally friendly development or when approval of innovative projects takes significantly more time than conventional projects. On the other hand, local decision makers are frustrated with the limited number of alternative designs that are presented to them and the shortage of good local examples that can help them address questions about the environmental and economic performance of various stormwater treatment methods. (N.H. Low Impact Development Conference, 2008). The State of New Hampshire requires comprehensive stormwater management plans for the largest development sites, but protective standards that address stormwater pollution at smaller development sites are left to municipalities. The irony is that while conventional stormwater management systems are familiar, they are failing. Scientific data are growing and show that stormwater management designs need to be improved dramatically in order to adequately protect local water resources (UNH Stormwater Center, 2007).

A growing trend is emerging where municipalities are updating local regulations and development guidelines to reflect the higher treatment standards of today. This is being accomplished through:

1. **Protection of Critical Resource Areas.** The most permanent and assured protection of sensitive resource areas is achieved through the use of conservation easements and conservation land acquisitions. Sensitive areas can also be effectively protected or buffered from development impacts by establishing conservation overlay districts that prohibit or restrict development in drinking water or wellhead source areas, wetlands, shoreland buffers, wildlife corridors, cold water streams, and other critical natural resource areas.
2. **Adoption of Innovative Land Use Ordinances.** Land use ordinances can be used to help protect water resources by incorporating environmental characteristics zoning, requiring or providing incentives for cluster or

conservation developments, and establishing environmental protection performance standards that development proposals must meet. The N.H. DES *Innovative Land Use Planning Techniques* handbook provides model ordinances that can be adopted at the municipal level for improved environmental management, including better stormwater management and erosion and sediment control. As this handbook points out, stormwater management requirements are best addressed through a performance-based zoning ordinance. A performance-based approach (authorized under RSA 674:21) allows the community to specify the desired outcome or performance required by any development activity without being overly prescriptive regarding the specific techniques or approaches used.

A zoning ordinance can be the most comprehensive means for addressing issues affecting stormwater management, such as lot usage, density, location of buildings, and vegetative cover. Zoning ordinances are especially helpful when projects do not require site plan or subdivision regulations review. In the absence of a formal review, developers rely on ordinances to know what is or is not allowable.

3. **Updating Site Plan and Subdivision Review Regulations.** More effective stormwater management strategies and performance requirements need to be outlined in town regulations and considered by developers and municipal staff early in the development planning process. Promoting the latest state and federal standards such as water quality treatment and infiltration is the best way to prevent problems before they happen. If not already detailed in a land use ordinance, these regulations should specify the standards developers need to meet for demonstrating how they applied low impact development principles to their site design and stormwater management approach. Developers should submit designs that meet performance standards, and have requirements for inspections and financial sureties that stormwater and erosion and sediment control measures will be built and maintained as proposed.

4. **Updating Municipal Master Plans.** How and where development happens in a community should be guided by the "big picture" vision established in a municipality's master plan. Among other things, the plan should make it clear what the municipality values, how it intends to guide growth and development, and the primary strategies that it will utilize to protect natural resources. This guiding document sets policy directions for the municipality to pursue through the implementation of specific ordinances and regulations. Effective stormwater management is part of a comprehensive approach and commitment to sustainable development that should be articulated in the municipal master plan and consistently reflected in the community's ordinances and regulations.

5. **Supporting Innovative Stormwater Management Projects.** Examples of innovative stormwater management are slowly starting to appear in New Hampshire despite an overall lag in community policies to require them. Most local development projects that include innovative stormwater management are being driven by either a critical natural resource, a multi-purpose mission (education/research/restoration) or a trailblazing team of property owners, engineers, architects, and landscape designers wishing to create a more environmentally sustainable project. Innovation is often a bumpy road and conditions that encourage decision makers, engineers, planners and builders to learn about more effective stormwater management together with help from technical experts and tools are the most successful (Nowacek et al., 2003). Supporting development proposals that voluntarily include innovative stormwater management can help move a community forward more smoothly as they consider their own policies.

6. **Anticipating the Costs of Development on Stormwater Infrastructure.** When reviewing development proposals, long term and cumulative costs for municipal stormwater infrastructure should be on the reviewer's mind. Communities pay for maintaining, repairing, replacing, adding and upgrading aging infrastructure. Some communities are addressing costs by implementing stormwater utilities. The stormwater utility is a fee similar to those paid for electricity or drinking water that is based on usage and supports stormwater infrastructure and management. The funds are dedicated exclusively to stormwater needs. Fees are typically based on lot characteristics, and reductions in the fee are often offered for practices that reduce damaging impacts from stormwater. These fee reductions can serve as an incentive to encourage more innovative and effective stormwater management. Stormwater utility fees are commonly based on an equivalent residential unit (ERU) that represents the average impervious area of a single family lot, usually several thousand square feet. Presently, fees fall around $3-$5/ERU per month for residential properties and $60-$90 per month for commercial properties.

   Communities that are considering implementing a stormwater utility fee are encouraged to have a stormwater utility feasibility study done. New Hampshire recently passed enabling legislation for municipal stormwater utilities. Several towns across New England have already or are currently in some phase of implementing a stormwater utility, including Manchester, N.H. Stormwater utilities are being adopted more frequently throughout the nation and are likely to be one of the tools that more New Hampshire towns consider in the future to address challenges to their stormwater infrastructure and management.

Model Ordinances

These provide a framework from which to start the ordinance development process.

- Center for Watershed Protection:
  www.cwp.org/Resource_Library/Model_Ordinances/index.htm
- *DES Innovative Land Use Planning Techniques: A Handbook for Sustainable Development.* 2008. N.H.Department of Environmental Services, Report #WD-08-19:
  http://des.nh.gov/organization/divisions/water/wmb/repp/innovative_land_use.htm
- *Municipal Guide to Fluvial Erosion Hazard Mitigation* (includes fluvial erosion hazard model ordinance): www.anr.state.vt.us/dec//waterq/rivers/docs/rv_municipalguide.pdf
- U.S. Environmental Protection Agency:
  www.epa.gov/owow/nps/ordinance/links.htm

Land Use Regulations and Development Techniques

These provide information about various innovative strategies and tools for sustainable development.

- *Alternatives for Coastal Development,* NOAA Coastal Services Center:
  www.csc.noaa.gov/alternatives
- *Conservation Development Manual,* Office of Sustainable Watersheds, Rhode Island Department of Environmental Management:
  www.dem.ri.gov/programs/bpoladm/suswshed/pubs.htm
- *Local Tools for Smart Growth: Practical Strategies and Techniques to Improve Our Communities,* National Association of Counties:
  www.naco.org/Content/ContentGroups/Programs_and_Projects/Environmental1/Sources/1528LocalTools.pdf

Regional Planning Commissions (RPC)

RPCs provide professional planning expertise in writing and tailoring municipal regulations to best protect the specific natural resources located within the municipality's jurisdiction and ensuring consistency among their planning strategies.

- Central New Hampshire Regional Planning Commissions: www.cnhrpc.org
- Lakes Region Planning Commission: www.lakesrpc.org
- Nashua Regional Planning Commission: www.nashuarpc.org
- North Country Council: www.nccouncil.org
- Rockingham Planning Commission: www.rpc-nh.org
- Southern New Hampshire Planning Commission: www.snhpc.org
- Southwest Region Planning Commission: www.swrpc.org
- Strafford Regional Planning Commission: www.strafford.org
- Upper Valley Lake Sunapee Regional Planning Commission: www.uvlsrpc.org

State and Federal Roles in Water Resources Protection

In New England, most land use decisions are made at the town or city level, which provides for a large degree of local control. However, there are also layers of state and federal regulations to take into consideration. State level regulations in New Hampshire are designed to make sure that projects with federal permits do not violate state water quality standards, that large development projects prevent erosion and manage stormwater, and that certain land use activities are restricted within shoreland areas (DES, 2008). Federal and state regulations represent the minimum that communities can use to protect water resources. Community regulations and policies can meet or exceed those.

> Stormwater is regulated by the US EPA under the Clean Water Act. Since March 2003, municipalities and developers have been subject to new requirements dealing with stormwater management. The requirements are called Phase II Stormwater Regulations because they are the second round of stormwater rules implemented by EPA. It is likely that stormwater will continue to be regulated far into the future.

For many communities, the EPA National Pollutant Discharge Elimination System (NPDES) Phase II regulations have heightened attention to stormwater. Phase II regulations require communities to begin to manage stormwater flowing through their municipality. Many communities are actively doing what they can, assessing what else they can do and building the human, informational, regulatory and financial resources necessary to do so.

Each surface water body in the nation falling under the federal Clean Water Act is assigned a designated use. Designated uses provide for the protection and propagation of a balanced population of shellfish, fish and wildlife, and allow

Julia Peterson

recreational activities in and on the water (*New Hampshire Water Resources Primer*, 2008). The designations are Drinking Water, Recreation, Shellfish and Aquatic Life Use. State governments help to identify water body impairments related to those designated uses, and to monitor and report them in the 305b report. While the Clean Water Act has done a great deal since its inception to clean up the country's water bodies, especially from point sources of pollution, the number of impairments is on the rise and many of them are linked to ineffective stormwater management and non-point source pollution. The goal of the Clean Water Act is to remove water bodies from the list of impaired waters (303d list) and to prevent additional listings.

Because federal activities can greatly impact a state's coastal resources, the national Coastal Zone Management Act (CZMA) established a formal review process called federal consistency. This process allows states to manage coastal uses and resources and to facilitate cooperation and coordination with federal agencies through states' coastal management programs. Per the CZMA, federal activities proposed in the 17 communities in the New Hampshire coastal zone require federal consistency determination by the New Hampshire Coastal Program. Find more information at http://des.nh.gov/organization/divisions/water/wmb/coastal/federal_consistency.htm.

The Comprehensive Shoreland Protection Act (CSPA) of New Hampshire recognizes the important role of riparian lands in protecting water resources. The CSPA regulates activities within 250 feet of shorelines for designated public lakes and ponds, large rivers and tidal waters in order to minimize the potential for water resource contamination. The list of water bodies currently affected by the CSPA can be found at http://des.nh.gov/organization/commissioner/pip/publications/wd/documents/r-wrd-91-4.pdf. More details about the Act can be found at the N.H. DES webpage. Helpful information about caring for shoreland property and appropriate landscaping can be found in *Landscaping at the Water's Edge*, a training manual for landscapers available at http://extension.unh.edu/resources/.

WATER RESOURCE CHALLENGES FOR COMMUNITIES

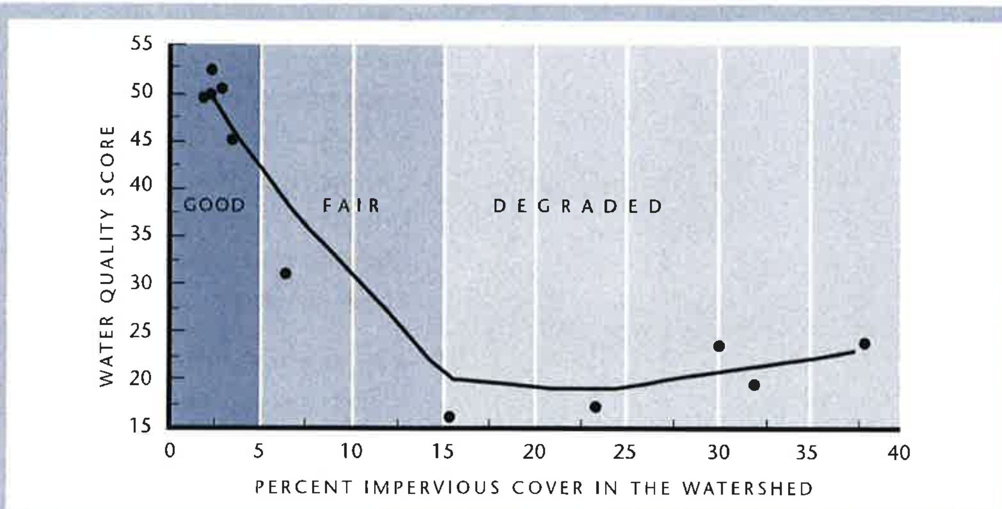
Impervious Cover

Impervious cover is considered one of the biggest challenges to water resource protection because of its effect on the quantity, distribution and quality of water and its association with urbanization. Impervious cover or impervious surface refers to areas that do not allow infiltration of water into the soil. These surfaces include roads, buildings, roofs, decks, patios, driveways, parking areas, compacted soils, walkways and other similar hard surfaces on the landscape. Impervious cover interferes with processes that would naturally occur in undeveloped landscapes, namely the infiltration of water into the ground and filtration of water by plants and soil.

Impervious cover contributes to water quality and quantity problems by accelerating the accumulation, flow and contamination of water over the landscape on its way downhill to receiving waters. Watersheds with high levels of impervious cover are more vulnerable to dramatic shifts in stormwater volume. In heavy storms, large volumes of stormwater flow over impervious areas, accumulate quickly and dump into local storm drains, streams and rivers. They erode shorelines, scour stream banks and stream beds and cause property damage. Impervious cover accelerates both the volume and the rate of flow of stormwater. Impervious cover also robs groundwater systems of recharge, thereby lowering water tables and diminishing base stream flow and aquifer supplies.

The water quality effects of impervious cover can be seen in the graph on the following page. At 5 percent impervious cover within a watershed, a downward trend in water quality begins. At 14 percent it fails to meet common water quality standards (Deacon et al., 2005). Although this particular graph represents a small sample size, other studies have shown similar results where water quality degrades at levels of about 10 percent impervious cover within a watershed and is significantly impaired when greater than 25 percent (Center for Watershed Protection 2003). While the exact percentage of impervious cover associated with water quality degradation may vary according to local conditions for a particular water resource, the basic relationship between increasing amounts of impervious cover and water quality degradation is generally not disputed.

Several studies indicate that streamside forests offer significant protective effect (Deacon et al., 2005); and that brook trout are rarely found in streams within watersheds of greater than 4 percent impervious cover (Stranko, et al., 2008).



Adapted from USGS Report 20055103: *Effects of Urbanization on Stream Quality at Selected Sites in the Seacoast Region in New Hampshire 2001-03.*

The exact percentage of impervious cover associated with degradation of a particular water body is affected by factors such as how degradation is being measured, where the water body is located within the watershed and what the shoreland is like. While there is some variation from site to site, there is a direct relationship between increasing amounts of impervious cover and water quality degradation.

Impervious cover not only presents challenges for clean and adequate water, but also for communities who are responsible for protecting water quality and quantity. Conventional stormwater management depends on impervious cover to convey stormwater away from the built site, across pavement typically to a gutter or drain and into a municipal pipe system that delivers the stormwater to a local water body. From the community perspective, each development project that includes impervious cover and ties into community stormwater infrastructure contributes to water resource impairments and the public infrastructure burden.

Communities can reduce the harmful effects of impervious cover in a number of ways, including avoiding constructing it, disconnecting it from the stormwater infrastructure system, reducing its dimensions and using alternative pavements. More details on these recommendations follow in *Minimizing Impervious Surfaces,* page 30.

The Storm in Stormwater

Another compelling reason for communities to improve stormwater management is the effect of severe storms. Poorly located development, the loss of natural lands, high levels of impervious cover and aged or undersized infrastructure all contribute to increased storm-related flooding, damaged culverts, breached dams and property damage that in turn lead to increased tax burdens, loss of property and threats to public

safety. The stormwater effects from landscape changes that accompany conventional development multiply when storms are severe. If nothing else inspires a community to look for ways to improve stormwater management, these threats should.

According to the Northeast Climate Impacts Assessment report (2007), global climate change is expected to affect stormwater in New England in the following ways:

- With increasing temperatures, more winter precipitation will fall as rain than as snow.
- Rainstorms are likely to increase in frequency and severity.
- An increase in frequency of short-term droughts (one to three months) in summer is likely.
- Sea level will rise between 7 and 24 inches (conservatively) by the end of the 21st century.

The stresses of severe storms, no matter what their origin, have already been experienced in New Hampshire over the past several years.

A 2005 study of Keene, N.H., concluded that many of the culverts in the city were inadequately sized for the rainfall intensities predicted under climate change. Undersized culverts cause water to back up and flood roads. The study estimated that while the costs of upgrading the culverts would be high, they would be comparatively low in relation to those resulting from damage to infratructure and public and private property caused by a major storm (Antioch New England Graduate School, October 2005).

Coastal communities often rely on their location for economic vitality through fishing, tourism, water dependent industries and transportation. Coastal wetlands also play a critical role in buffeting storm surges by absorbing wave energy and holding large quantities of water.

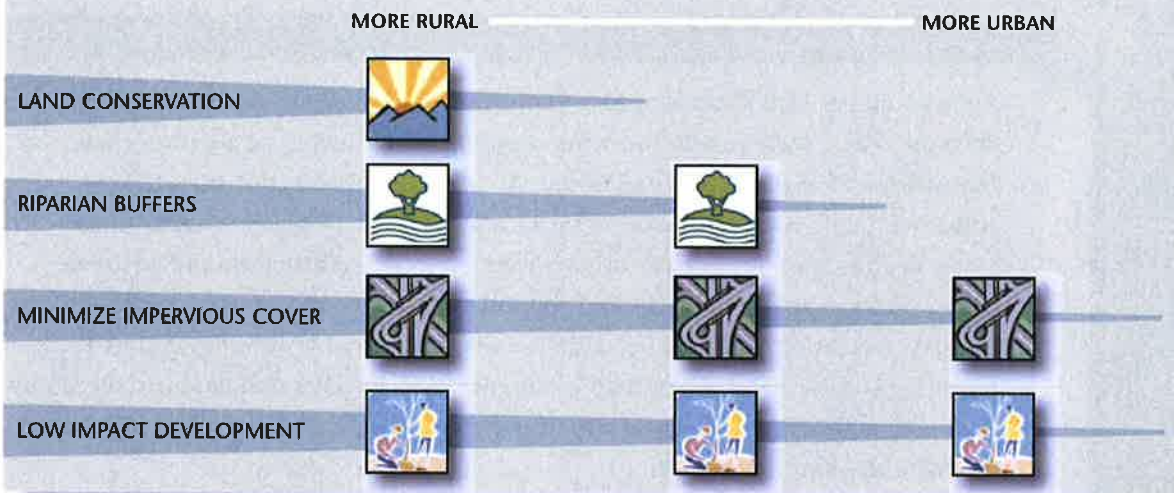
Coastal communities are particularly vulnerable to climate change because of their location at the downstream end of the watershed and the anticipated effects of sea level rise. In New Hampshire, coastal communities also tend to have the highest levels of impervious surface (relative to other parts of the state) which compounds threats from heavy storms and sea level rise (*New Hampshire Water Resources Primer,* 2008). Although any community can benefit from improving stormwater management, it is imperative that coastal communities use integrated approaches to stormwater management because of the degree of harm that storm effects can do to public health, property and wildlife.

OPPORTUNITIES FOR COMMUNITIES

There is no single strategy for water resources protection that is appropriate for every situation, landscape or waterbody. The strategies outlined in this guide focus on preventing water problems from the start. The more natural the landscape, the more numerous, inexpensive and effective the options are for water resources protection. However, as shown in the graphic below, as an area becomes more developed, the range of options for stormwater management decreases, and the effectiveness of each option decreases as well.

> Prudent land conservation and the protection of existing riparian buffers are the most cost effective approaches to water resource protection.

RANGE OF STRATEGY OPTIONS FOR WATER RESOURCE PROTECTION BASED ON LANDSCAPE



Rural and semi-rural communities have more options for protecting high value water resources in addition to an economic incentive to protect rather than have to restore them. In rural areas with substantial forests and fields, prudent land conservation and the protection of existing riparian buffers are likely to be the most cost effective approaches to water resource protection. An ounce of prevention in this case may be well worth a pound of cure.

In highly developed areas, options for improving stormwater management exist, but are more limited and less likely to result in high quality water (Schueler, 2008). In urban areas, opportunities to conserve remaining undeveloped land and protect riparian buffers are important for many reasons, but options are usually not as frequently available due to high development density. Urban communities typically need to rely more on creative ways to reduce and disconnect impervious cover from water resources and stormwater systems and to encourage more low impact designs for existing and new development. For all communities, it is a matter of reviewing what is already being done to protect surface and groundwater resources and taking advantage of opportunities to do more. The results usually benefit not only the natural resources, but also the municipal resources.

From a community perspective, effective stormwater management decreases municipal expenditures over time and can include many of the activities a community does that:

- Preserve natural areas through **land conservation;**
- Protect or enhance **riparian buffers;**
- Minimize **impervious cover** and;
- Use **low impact development (LID)** approaches when developing or redeveloping land.

A description of each of these strategies follows, presented in their order of effectiveness.

Land Conservation

Approximately 15,000 acres of New Hampshire's open space are converted to developed uses each year to meet the demands of a growing population (*New Hampshire's Changing Landscape*, 2005). As New Hampshire continues to grow, conserving land is an increasingly significant priority for many communities. Many of the state's lands have been conserved to maintain clean and adequate water, preserve wildlife habitat and support the rural economy through agriculture, forestry, recreation and tourism. When open land is lost to development, the hydrology of the natural landscape changes. Densely vegetated land is replaced by land uses with a high proportion of impervious surfaces and the associated water quality and quantity impacts.

There are many options available to conserve land permanently. Two of the most popular options used by communities are fee acquisition (outright purchase or donation to a conservation organization) and voluntary conservation easements (a legal agreement between a landowner and conservation organization or government agency that permanently limits uses of the land by extinguishing its development rights).

Primary Benefits of Land Conservation

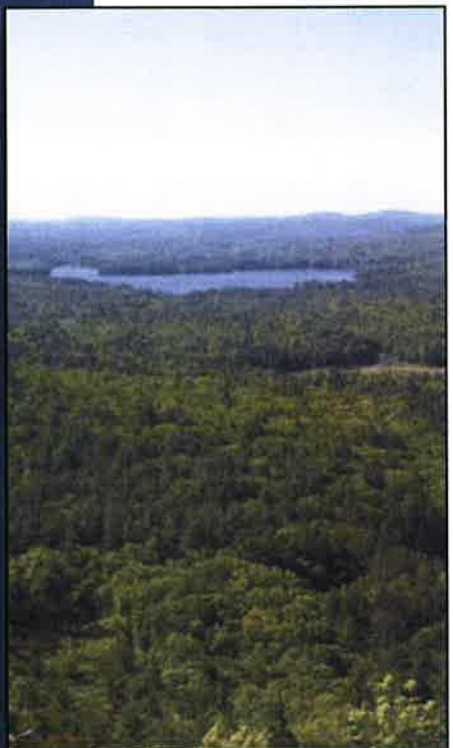
Intact natural systems moderate water quantity by slowing surface runoff and allowing much of the water to infiltrate into the soil and percolate down to the rock layers, recharging ground water supplies. By protecting important water supply lands, communities can realize many cost benefits, such as reduced flood loss and damage, and less need to treat impaired waters. The following are some primary benefits that result from conserving large tracts of naturally vegetated land:

- **Flood Control.** The natural landscape reduces flood-producing flows, resulting in less downstream damage. New Hampshire communities have seen a tremendous increase in the frequency and severity of flooding in recent years. In addition to other factors, this has been in large part due to increasing urbanization of the landscape. As open space lands disappear, the frequency and severity of flooding increases, resulting in increases in downstream property damage and loss. Conserving large tracts of land has the potential to significantly reduce the frequency and severity of flooding.
- **Water Quality Protection.** Maintaining the natural hydrology of an area reduces the amount of pollutants that would enter receiving waters. This helps to maintain high quality drinking water supplies and aquatic habitat and to preserve recreational uses (fishing, swimming, etc.). Changes to water quality resulting from loss of vegetative cover and increased impervious surface cover can degrade fisheries, inhibit recreational uses such as swimming and increase treatment costs for public water supplies. Maintaining large acreages of conserved land helps to maintain high quality water supplies, especially in sensitive water supply lands.

Economic Benefits of Land Conservation

Several towns in New Hampshire have conducted Cost of Community Services studies, which look at the costs of different land uses in individual communities. In each of these towns, it was found that open space pays more in taxes than the cost of the services it requires. In the majority of towns studied, residential properties required more in services than they provided in tax revenues. In other words, it makes economic sense to preserve open space lands, and as an added benefit they will provide a relatively low-cost element to a community's stormwater management strategy.

Many New Hampshire communities have already lost significant portions of open space and, recognizing the benefits of the natural landscape for stormwater management, wildlife habitat and community character, are working to conserve remaining open spaces to maintain their natural functions and reduce economic costs to the community. By protecting lands near to receiving waters (lakes, ponds, rivers and streams), communities are benefiting from a low-maintenance stormwater management strategy.



Recognizing the importance of maintaining high quality water supplies, communities are focusing on protecting significant water supply lands, including wellhead areas, lands overlying high yield aquifers and reservoir watersheds. Communities have the option of permanently protecting these critical lands from development by acquiring the land or working with landowners to place voluntary conservation easements on this land. This ensures both stable and high quality water supplies, and reduces flood-producing flows.

Limitations of Land Conservation

Land conservation projects can take some time to complete, from several months to several years. They also involve significant sums of money. In order to conserve lands via acquisition or easements, the town's conservation fund is usually not enough to finance some of the larger conservation projects. Many towns have used a combination of funds from federal, state and local sources, as well as grants and donations from private individuals. Many of these funding sources require grant applications and can take some time to accumulate. However, despite the time and funds required for conservation projects, the long-term benefits are undeveloped land that is permanently protected and reduced economic costs.

Best Use of Land Conservation

In the more rural and semi-rural communities that still have a lot of undeveloped land, this is an appropriate strategy. The larger the acreage of conserved land, the greater the opportunity for using land conservation as a stormwater management tool. Larger, multiparcel conservation areas provide a large acreage of undisturbed land, allowing natural functioning of the hydrologic cycle.

- Review your community's natural resources inventory maps and associated data, and its conservation plan if available. Are there opportunities to add new lands to existing conservation parcels, enlarging the conserved areas?
- Review the natural resources inventory water resources map and associated data. This map should include surface water resources, groundwater aquifers, wellhead protection radii, wetland resources and sources of known and potential contaminants. Identify those lands that are adjacent to surface waters (lakes, ponds, streams, rivers) or over aquifers. Ensure your community's land conservation plan includes a focus on conserving lands that protect these water resources.

Community Use of Land Conservation

Land can be conserved via outright purchase or donation, or by using a conservation easement. When land is conserved through outright purchase or donation, the landowner sells or grants all rights, title and interest in the property to a conservation organization. The organization owns the land and may grant conservation easements on land it owns in fee to another conservation organization, agency or town. The organization also is responsible for stewardship and management of the land in perpetuity.

A conservation easement is a voluntary legal agreement between a landowner and a conservation organization or government agency that permanently limits uses of the land (by extinguishing the development rights) in order to protect its conservation values. It allows the landowner to continue to own and use the land and to sell it or pass it on to heirs. A landowner may sell a conservation easement to the holding organization, but most often easements are donated.

Examples of Land Conservation Projects

Many towns have conserved land in their community for a variety of purposes: protection of water resources, preservation of wildlife habitat, etc. Below are a few examples of community conservation efforts that have focused on protection of water resources. By maintaining the land in a vegetated undeveloped condition and covering large acreages, these parcels all contribute to stormwater management.

- **Barrington, N.H. Samuel J. Tamposi Water Supply Reserve.** Barrington is a source of drinking water for several downstream communities, including Portsmouth, Dover, Durham and the University of New Hampshire. In the early 1990s, Barrington worked to conserve the 1400-acre Samuel A. Tamposi Water Supply Reserve (SATWaSR), which harbors the headwaters of the Oyster and Bellamy rivers, both critically important water supplies for the seacoast. The land is owned by the town of Barrington and protected by an easement held by the Society for the Protection of N.H. Forests. The Reserve includes a variety of habitats, including many vernal pools and globally rare Atlantic white cedar swamps. The large size of this tract of conserved land makes it important for maintaining high water quality and stable flow volumes downstream.
- **Manchester, N.H.** Manchester Water Works has used Lake Massabesic as its water supply source since 1874 and now owns 8,000 acres of land, including 95 percent of the Lake's 28-mile shoreline. This effort recognizes the importance of protecting high quality water supplies. This very large acreage is critical for maintaining water quality and controlling the amount and timing of stormflows. www.manchesternh.gov/website/Departments/WaterWorks/LakeMassabesicWatershed/tabid/422/Default.aspx

See *References and Resources* (page 44) for more information on Land Conservation.

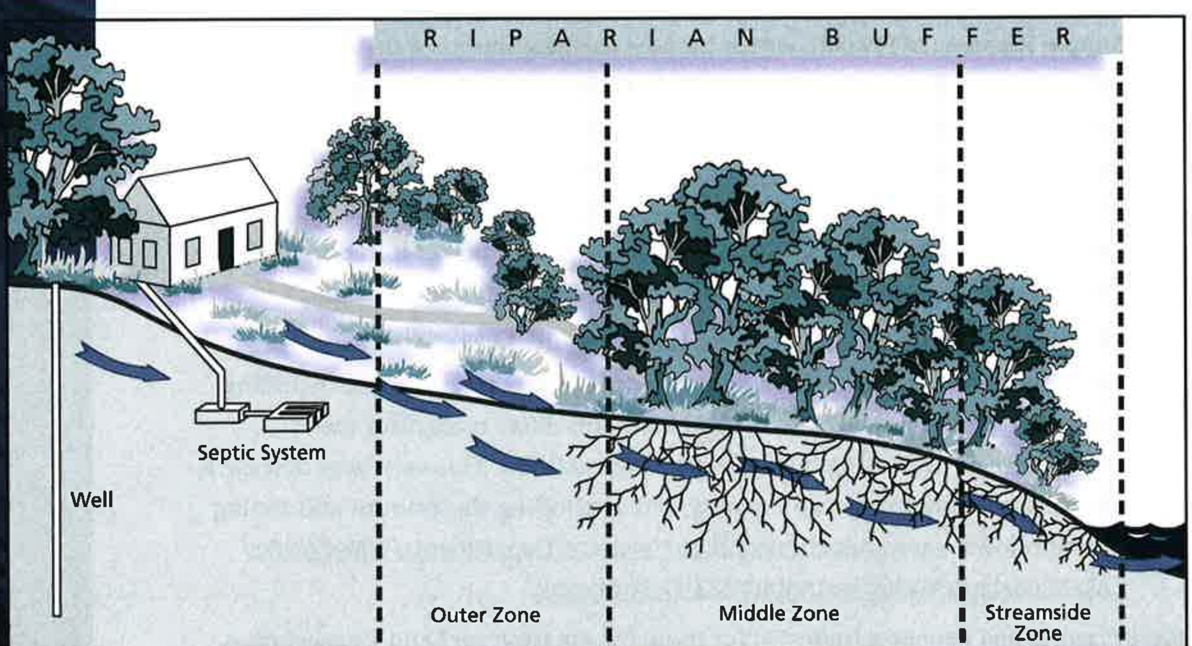
Riparian Buffers

Riparian buffers are vegetated areas along the shores of surface waters (lakes, ponds, streams, rivers) and wetlands. The primary function of a buffer is to physically protect and separate a stream, lake or wetland from the impacts of adjacent land use. Riparian buffers are considered to be the single most effective protection for our water resources.

Buffers are typically vegetated with trees, shrubs, groundcovers and herbaceous plants. This vegetation helps to slow the flow of surface runoff and capture nutrients, sediments and other pollutants before they reach the water body.

Riparian buffers can be densely forested and shrubby upland areas or floodplain areas that provide a transition zone between developed upland and adjacent surface waters. While most buffers are naturally vegetated, some buffers are purposely planted and maintained to provide water quality and quantity benefits. Many natural riparian buffers have been lost as land use has changed in recent years. Restoring these buffers by planting appropriate vegetation is an important step forward for protecting water quality and reducing the effects of surface runoff.

The recommended buffer width to adequately protect water resources is 100 feet. Studies have found that the majority of water quality improvements occur in the first 100 feet of a vegetated buffer (*Buffers for Wetlands and Surface Waters*, N.H. Audubon, 1997). One hundred feet is sufficient to allow flood flows to slow down and deposit their sediment and pollutant loads before entering the receiving water.



Primary Benefits of Riparian Buffers

Buffers adjacent to surface waters and wetlands help to minimize the impacts of impervious surfaces, reducing the amount and velocity of surface runoff, sediments and pollutants that may otherwise enter the surface water or wetland. Buffers adjacent to surface waters and wetlands provide a variety of benefits:

- **Flood Control:** Vegetation in the buffer area allows surface water flow from rain storms to spread out, slow down and infiltrate the soil and/or be intercepted and transpired by plants as it moves across the land to a water body. This substantially reduces downstream flooding and regulates streamflows. Conversely, in areas with impervious surfaces and little natural vegetation adjacent to surface water, stormwater moves very rapidly across the landscape, resulting in rapid storm surges downstream that can cause flooding.

- **Water Quality Protection:** Buffers also provide critical water quality protection. Because the flow of water is slowed down, this allows sediments and pollutants transported in the storm water to settle out and filter through the soil. Plant root systems in the buffer can take up excess dissolved nutrients from fertilizers, animal waste, sewage waste water and erosion that would otherwise pollute surface waters and wetlands. These excess nutrients are stored in the leaves, stems and roots of buffer vegetation, preventing the nutrients from reaching the water.

- **Bank Stabilization:** Riparian buffers stabilize streambanks and protect them from erosion. Roots hold the bank soil together, and roots and stems together protect the shore by deflecting the cutting action of currents, waves and stormwater.

Economic Benefits of Riparian Buffers

Riparian buffers provide a low-cost protective strategy to manage stormwater on-site without the need for costly structures. Because buffers are at the hydrologic interface between the upland and shoreline, they are regarded as one of the more effective mechanisms for protecting water resources. In the long term, the cost of protecting buffers through regulation (buffers ordinances) or land protection is minimal compared with the cost of providing stormwater structures in the absence of riparian buffers.

Limitations on Buffer Use

With the high value of shoreland property, there are increasingly few undeveloped shorelines, especially along lakes and some of the larger ponds. Some buffer areas may be degraded and require costly restoration. However, the costs of restoration are usually offset by the long-term benefits of a vegetated buffer. Actual buffer widths may vary significantly from town to town. Some towns have successfully passed ordinances specifying widths of more than 25 feet, but others have had difficulty getting a buffer of 25 feet or less passed. Education of town residents and board members about the reasons for protecting buffers is critical to build support for passing adequate buffer ordinances.

Best Use of Riparian Buffers

This strategy can be used where there are undeveloped shorelines along lakes, ponds, rivers, streams and wetlands. Recognizing this, the Manchester Water Works has protected 95 percent of the 28-mile shoreline of Lake Massabesic, the primary water source for Manchester and environs since 1874. This buffer, together with 8,000 acres of protected land around the lake, is critical to maintaining a high quality water resource and controlling the timing and volume of water entering the lake.

When using riparian buffers, careful choices must be made about which kinds of buffers are needed and how wide they must be. In many cases, a new buffer ordinance may need to be adopted or an old one may need to be revised to establish a more effective buffer network. When designing a buffer protection strategy, some issues that should be addressed include the following:

- Is buffer restoration or better stewardship possible along an aquatic corridor that has already been developed?
- Will the buffer network be managed as a recreational greenway or as a conservation area?
- Who will maintain the buffer and how will maintenance be paid for?
- How much pollutant removal can realistically be expected from the buffer network?
- What is the appropriate buffer width? (Refer to *References and Resources* for buffer width recommendations.)

Community Use of Riparian Buffers

A variety of options are available to protect buffers for wetlands and surface waters, including: wetland/surface water buffer overlay zoning district, shoreland and riparian protection ordinance, amendments to subdivision and site plan review regulations, or land acquisition as a measure for protecting wetlands/ surface water buffers. Refer to *Buffers for Surface Waters and Wetlands* and *Innovative Land Use Planning Techniques* for more information on these mechanisms.

GRANIT is the New Hampshire Geographically Referenced Analysis and Information Transfer System and the statewide Geographic Information Systems (GIS) clearinghouse located at the University of New Hampshire in Durham.

New Hampshire municipalities may elect to adopt regulations that extend protection to streams and surface waters that are not covered by the Comprehensive Shoreland Protection Act, and they may also decide to adopt more stringent regulations than the minimum standards of the CSPA. Review the N.H. DES model shoreland buffer ordinance chapter "Shoreland Protection: The Importance of Riparian Buffers" in the publication *Innovative Land Use Planning Techniques*. (See *References and Resources* for more information.)

The UNH Complex Systems Research Center has developed a shoreline buffer data layer for the GRANIT Data Mapper (mapper.granit.unh.edu/viewer.jsp), an online data viewing and query tool. Maps can be made displaying shoreline buffers in increments that include 50, 100, 150, 200, 250 and 300 feet. This helps the user to see how different widths of buffers would look in their community.

Examples of Riparian Buffer Projects

Reviewing examples of buffer projects and ordinances can be helpful in determining what would work in your community. Below are a few examples.

- **Town of Exeter.** The Norris Brook Stream Buffer Demonstration Project in Exeter provides an example of a restored, planted buffer area. Exeter created a vegetated streamside buffer along a 500′ section of Norris Brook, located in Swazey Park, a public park in the town. The site is in an urbanized area where, prior to the project, very little natural buffer vegetation remained. The stream buffer was designed to filter polluted runoff, provide a transition zone between the stream and human land use, and improve fish habitat. The town consulted with local buffer specialists to select and place native plantings that have high wildlife habitat values and bank stabilization properties. An educational kiosk on the importance of vegetated buffers is located near the site. For more information or for directions to the site, contact project staff from the Town of Exeter at 603-773-6157 or N.H. DES at 603-559-0032.
- **City of Portsmouth Inland Wetlands Protection District and Buffer Zone.** Portsmouth used this ordinance to protect wetlands and buffers around wetlands and other water bodies. The Inland Wetlands Protection District Buffer Zone includes all land within 100 feet of the Inland Wetlands Protection District. The purpose of the buffer zone is *"to reduce sedimentation of wetlands and water*

bodies, to aid in control of non-point source pollution, to provide a vegetative cover for filtration of runoff, to provide for the protection of wildlife habitat and help preserve ecological balance." www.cityofportsmouth.com/planning/application/zoningord-art-VI.pdf

- **Town of Amherst Rules and Ordinances for the Wetlands Conservation District.** The purpose of this ordinance is *"to prevent unnecessary or excessive expenses to the Town to provide and maintain essential services and utilities which arise because of inharmonious use of wetlands, to encourage those uses that can be appropriately and safely located in the wetland area, and to protect water supplies, aquifers and aquifer recharge areas."* www.amherstnh.gov/Regulations/conservation.html

See *References and Resources* (page 47) for more information on Riparian Buffers.

Minimizing Impervious Surfaces

Photos.com

Impervious land cover or impervious surface refers to areas that do not allow water to infiltrate into the soil. As described in the section *Impervious Cover* on page 18, the greater the amount of impervious cover within a watershed, the greater the potential for degraded waters.

Impervious cover can be minimized through a variety of strategies, including:

- Avoiding constructing it by maintaining natural landscapes wherever possible on building sites.
- Disconnecting impervious cover from stormwater systems by draining impervious surfaces to vegetated areas where water will infiltrate and be filtered by plants and soil.
- Reducing the dimensions of paved surfaces for roadways, parking lots and driveways and building footprints through voluntary or regulatory means (e.g. impervious limits).
- Concentrating development on a site to allow for relatively greater amounts of natural land with an equivalent number of built units.
- Where hardscapes are necessary, using porous pavements such as porous asphalt, concrete or pavers.

The importance of maintaining forests, fields, wetlands and other natural landscapes is outlined in the *Land Conservation* and *Riparian Buffer* sections of this guide (see pages 22 and 26). Loss of forests and fields and their ecological functions compound the damaging effects of impervious cover. As landscapes become more urbanized, the attention to impervious cover amounts becomes more critical.

An important distinction should be made between *Effective* and *Total* Impervious Cover. Effective impervious cover is the portion of the total amount of impervious cover in a development area that is directly connected to the storm drain system. Impervious cover that drains to vegetated areas where stormwater can infiltrate, or be filtered and stored, is not considered part of the effective impervious cover.

Another mechanism for reducing effective impervious cover is the use of *porous pavement*. This is a hard surface that allows stormwater to infiltrate into the sub-base below, thereby disconnecting it from the drainage system. An additional benefit of porous pavements is that they typically require much less road salt than conventional pavements for de-icing in winter (UNHSC, 2008). This is a considerable benefit to water quality in New Hampshire, where chloride levels in many surface waters are rising, and to municipal and commercial managers seeking to reduce property maintenance costs.

New Hampshire's new antidegradation requirements propose a maximum target of 10 percent effective impervious cover (EIC) and a minimum of 65 percent undisturbed cover for developed sites. The "1065" rule means that there should be no greater than 10 percent effective impervious cover and no less than 65 percent undisturbed cover within the property boundary of a site (N.H. *Stormwater Manual*, 2008). There is a misconception that EIC is a limit on development practices in general; however, the rule allows for up to 35 percent of a site to be developed and treated through stormwater management systems. If more land surface is proposed for development, pollution calculations are required to demonstrate effective treatment of the pollution from the increased impervious cover.

Primary Benefits of Minimizing Impervious Surfaces

The benefit of limiting impervious cover is that it should prevent or minimize additional runoff in developed or developing areas. The connection between increasing amounts of impervious cover within a watershed and water quality degradation is strong. Impervious cover limits should help to limit water quality degradation and reduce stormwater volume and velocity. Impervious cover limits are also a preventative strategy that can actually reduce a builder's project costs versus stormwater treatment strategies that might increase project costs.

Economic Benefits of Minimizing Impervious Surfaces

Minimizing effective impervious cover can save significant project costs by reducing:

- the amount of paving and curb and gutter material,
- the need to construct large centralized conventional stormwater drainage infrastructure (pipes and catchbasins) and,
- the need for drainage pipes to tie into stormwater system. (EPA publication 841-F-07-006, December 2007).

The town of Stafford, New Jersey reduced the amount of costly dredging needed by preventing silt from entering waterways.

The same town was recognized by FEMA for its stormwater management ordinance, open space preservation, watershed management and other programs as valid processes for controlling flooding. Because of these efforts, residents received discounts in flood insurance premiums.

http://marine.rutgers.edu/pt/coastal_training/toolkit/storm/case-study.html.

Municipalities can save money by:

- Requiring that developers be responsible for runoff produced when developing a site, decreasing the impact to the surrounding community and property owners.
- Reducing need for new or expanded stormwater infrastructure, including drains, pipes, bridges and culverts.

The Limitations of Minimizing Impervious Surfaces

The effectiveness of impervious cover limits are naturally challenging in urban or intensely developed areas where water infiltration and filtration have already been lost with forests, fields and wetlands. In urban zones, it can be difficult to truly recover green space, so redevelopment has to include the best available options, including reducing the amount of effective impervious cover through retrofitting of better stormwater treatments (see *Low Impact Development*, page 34) in place of conventional pavement, curb and gutter.

An added challenge exists for critical resource areas such as drinking water sources or wetlands. In general, these areas require higher levels of protection, including land conservation and riparian buffer controls.

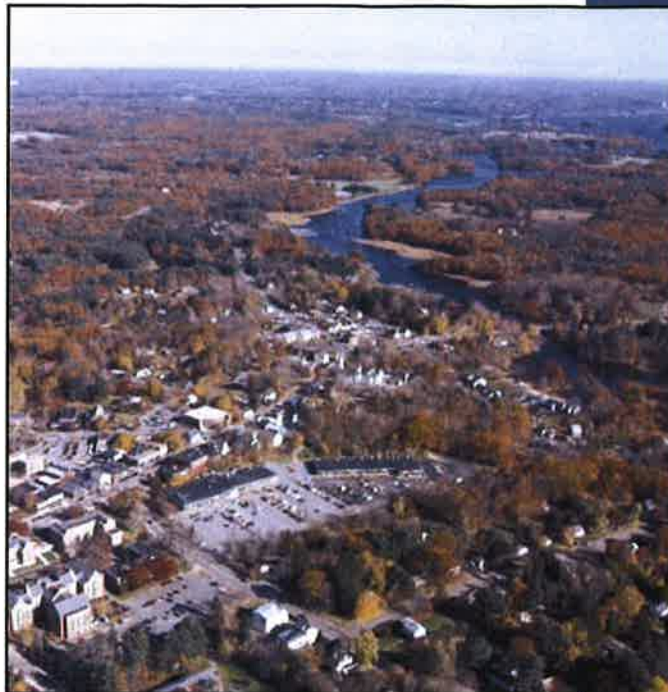
Best Use of Minimizing Impervious Surfaces

Minimizing impervious cover is best used where development and redevelopment are occurring or likely to occur. In some cases, communities can prevent impervious surface beyond a certain threshold. In other cases, communities can require that impervious surfaces be disconnected from waterbodies and the stormdrain system. In still other cases, builders can use stormwater management devices such as porous pavements that provide an equivalent surface for vehicles, but still allow water to infiltrate into soil.

How Your Community Can Minimize Impervious Surfaces

Many communities start their discussions about impervious cover limits by looking at geographic information system (GIS) maps. Some towns have information about the percentages of imperviousness by watershed, and most have maps of their major water resources and watersheds. A growing number of towns also have information about the current percentages of impervious cover within their town boundaries (see Piscataqua Region Estuaries Partnership, formerly New Hampshire Estuaries

Project, maps in resources list). New research indicates that images from high resolution aerial photographs are even more accurate than satellite imagery for detecting impervious cover (Stranko, et al., 2008). It is important to be careful when stating upper thresholds for land cover because different imagery methods may produce different results.



Communities can limit impervious surfaces through careful planning of roads, parking lots and building sites (Center for Watershed Protection, 1998). Impervious cover limits can be incorporated into standards for street widths and lengths, cul-de-sacs, frontages and setbacks, building footprints and parking lots. Effective impervious cover can be limited by requiring new or existing impervious cover to be hydraulically disconnected from municipal stormwater drainages.

As the technology for and information about porous pavements grows, many community decision makers are learning about alternatives to traditional impervious cover materials. Current research indicates that the most widely available porous pavements are best suited for parking lots, sidewalks and other light traffic uses. The UNH Stormwater Center provides information about the effectiveness of various porous pavements.

Examples of Projects Minimizing Impervious Surfaces

- New Hampshire's new Alteration of Terrain permit program uses effective impervious cover limits on building sites to help protect natural resources. (*N.H. Stormwater Manual, Volume 1,* 2008)
- The State of Connecticut recently used an impervious cover target for establishing a Total Maximum Daily Loads (TMDL) in a small stream where contaminants transported in stormwater were considered the probable cause of impairment. www.ct.gov/dep/lib/dep/water/tmdl/tmdl_final/eaglevillefinal.pdf
- The Great Bay Discovery Center at Sandy Point in Greenland has on-site examples of porous concrete, porous asphalt and a rain garden that receives runoff from impervious asphalt.

See page 45 for more information on Minimizing Impervious Surfaces.

Low Impact Development

Low impact development (LID) is a way of encouraging more infiltration, filtration and storage of water at a development site so that the water cycle functions as it would in a natural or undeveloped condition. Often in the past, stormwater was managed as a nuisance or a threat to most developments and was collected and removed from the site as quickly and efficiently as possible, usually through drains, pipes and other structures. Today more people view stormwater as an asset that, when infiltrated into the ground, recharges drinking water supplies, maintains minimum stream flow and sustains surrounding vegetation. Innovative stormwater management in the built environment creates as many opportunities as possible for water to infiltrate into the ground, be filtered through the soil and to be used by nearby plants. Under these circumstances, there is no need to convey large amounts of water off the site and into stressed municipal drainage infrastructure.

The challenges with water are having it where we want it, when we want it and in the condition we want it. LID directly addresses these issues in two primary ways.

1. **Better Site Design.** Incorporating the following techniques results in the reduction of stormwater volume and, consequently, the need for additional treatment.
   - Minimize disturbed areas
   - Maintain natural buffers
   - Minimize impervious cover
   - Disconnect impervious cover
   - Minimize soil compaction
   - Use alternative pavement (*N.H. Stormwater Manual*–Chapter 6, 2008)
2. **Structural LID Techniques.** Landscape features or devices are deliberately designed and constructed to allow water to infiltrate soil, be filtered by soil and plants, and be stored and treated on the site. Examples of structural LID techniques include:
   - Rain gardens (bioretention)
   - Gravel wetlands
   - Porous pavements
   - Tree filters
   - Vegetated swales (for curbless roads)

Primary Benefits of LID

LID's emphasis on infiltration and filtration benefits communities by recharging groundwater supplies and reducing contamination to receiving waters. It also benefits communities by dispersing rather than concentrating large amounts of stormwater, reducing the burden on existing infrastructure or avoiding the need for new structures and costly repairs. LID features are also usually more attractive in appearance than conventional stormwater systems and often less expensive.

Much of the burden of resisting and recovering from regularly occurring storms and hurricanes falls on communities because they are responsible for local infrastructure. Climate change is expected to compound the municipal burden as storms become more frequent and intense. LID approaches help to reduce demands on local infrastructure (stormdrains, pipes, culverts and dams) and strengthen community resiliency for impacts from climate change.

Economic Benefits of LID

Low impact development can bring economic benefits to developers, property owners and municipalities. It is important for cost analyses to take stormwater management design, installation and maintenance costs into account as well as savings incurred from not having to treat water, restore water resources or build and replace infrastructure.

In a report that describes 17 low impact development case studies, EPA found that LID practices were both fiscally and environmentally beneficial to communities. In a few cases, initial design costs were higher; however, significant savings were achieved through lower costs for site grading and preparation, stormwater infrastructure, site paving and landscaping. (EPA publication 841-F-07-006, December 2007)

LID can benefit communities by:

- Reduced flooding costs
- Reduced combined sewer overflow control costs
- Reduced filtration costs

For the last 50 years, the primary purpose of stormwater management was to provide for public safety through the prevention of flooding. This resulted in drainage designs that provided quick and efficient drainage for all storms except the largest, most infrequent events. Today, however, many of our problems with water quality reflect the lack of protection resulting from a focus on *quantity* concerns. Today's drainage designs now require water *quality* systems that target more effective treatment of smaller and more frequent rain events, in addition to flood control. Water quality management broadens the goals of drainage design. It focuses on controlling the sources of runoff, then intercepts, infiltrates, filters, and evaporates to the maximum extent practicable. The results are cleaner runoff, a reduction in runoff volume and smaller and less frequent use of flood controls.

- Reduced cooling costs
- Increased amenity values (MacMullan, 2007 National LID conference)

LID can benefit developers through:

- Increased number of buildable lots
- Grassy swales, no curbs or gutters
- Green streets that increase property values
- Reduced permitting fees (MacMullan, 2007 National LID conference)

Limitations of LID

While the goal of low impact development is to mimic the hydrology of natural systems in the built environment, it is nearly impossible to replace all of the ecological functions of a natural system with human-engineered solutions. The performance of specific LID features will vary and treat contaminants differently. Ultimately, any end of pipe treatment strategy works best when used in sequence in a treatment train (UNH Stormwater Center, 2007). As with any conventional stormwater treatment system, low impact development features need to be correctly installed and maintained in order to function properly. However, low impact development features consistently outperform conventional stormwater treatments when evaluated for managing stormwater volume and quality (UNH Stormwater Center, 2007).

Best Use of LID

LID is used where building and development have already happened or are going to happen. This could be in rural or urban settings and at small or large scales. Soil type, slope, water table characteristics and the amount of impervious cover will all influence exactly which techniques should be used. It is very important to make sure the correct LID approaches are selected for each site. Some LID features such as rain gardens, curb cuts and tree filter boxes can be retrofitted into existing developments. Details about suitability and maintenance of select LID features are included in the fact sheets that follow and the 2007.

Because LID is incorporated into building, construction and reconstruction, town planners and boards play an important role in encouraging its use. Communities can encourage LID by:

- Removing barriers to its use, such as minimum parking lot size and road widths, within existing ordinances.
- Promoting it through zoning ordinances.
- Incorporating it into site plan and subdivision regulations.

LID can also be promoted in non-regulatory ways:

- Participating in education for municipal staff, board members and development professionals.
- Showcasing good examples
- Incorporating it into municipal properties and practices.

Examples of LID Projects

- **The Great Bay Discovery Center.** The educational facility of the Great Bay National Estuarine Research Reserve in Greenland, N.H., has incorporated a number of LID features into the facility and grounds, including porous pavements and rain gardens.
- **National LID Atlas** (mostly Connecticut, Rhode Island and California). This is a relatively new web-based inventory of LID features that allows users to search based on location or feature. http://clear.uconn.edu/tools/lid/index.htm
- **New England LID Treatment Index.** This is a web-based inventory similar to the National LID Atlas, but covering a smaller geographic area. www.erg.unh.edu/stormwater/index.asp
- **UNH Stormwater Center.** This property hosts multiple stormwater treatments and provides an active research field site to assess their performance. UNH Campus West Edge Parking Lot, Durham, N.H. www.unh.edu/erg/cstev

See *References and Resources* (page 45) for more information on LID.

FACT SHEETS

The following fact sheets have been developed as an introduction to various LID stormwater management strategies commonly in practice today. The sheets contain a basic description of each technology in addition to general effectiveness with respect to water quality and water quantity treatment. Information is also provided on cost and maintenance sensitivity. More detailed information can be found in the UNH Stormwater Center's annual reports, which can be downloaded at www.unh.edu/erg/cstev/.

LOW IMPACT DEVELOPMENT SYSTEM: POROUS PAVEMENT

Porous asphalt (top) and dense mix asphalt (bottom) during a heavy rain event.

Porous pavement systems are an extremely effective approach to stormwater management. Their design serves two distinct purposes: providing parking or transportation surfaces, and treating stormwater quality and quantity volumes without taking up any additional space. Rainfall drains through pavement and directly infiltrates the subsurface. This significantly reduces runoff volume, decreases its temperature, improves water quality and essentially eliminates impervious surface. It also speeds snow and ice melt, dramatically reducing the salt required for winter maintenance. The porous asphalt design tested at the UNH Stormwater Center (UNHSC) is distinctive in its use of coarse sand for a reservoir base and filter course—a refinement that enhances its effectiveness in treating water quality.

BMP type:	Porous Pavement, Infiltration system
Design Source:	UNHSC
BMP Cost:	Porous asphalt average: $2.80/square foot (UNHSC) Pervious concrete average: $4.60/square foot (NNCPA) Costs include materials and installation
Water Quality Treatment:	Excellent, except for nitrogen
Water Quantity Management:	Excellent. Is sufficient for quantity and quality control.
Maintenance Sensitivity:	Medium, requires minimum two to four cleanings per year with a vacuum truck.

LOW IMPACT DEVELOPMENT SYSTEM: GRAVEL WETLAND


Gravel wetland operation in a rain event.

The subsurface gravel wetland is a recent innovation in Low Impact Development (LID) stormwater design. It approximates the look and function of a natural wetland, effectively removing sediments and other pollutants commonly found in runoff, while enhancing the visual appeal of the landscape. The subsurface wetland evaluated at the UNH Stormwater Center is a horizontal-flow filtration system that should not be confused with other stormwater wetlands that function more like ponds. Instead, it relies on a dense root mat, crushed stone and a microbe-rich environment to treat water quality. Like other filtration systems, it demonstrates a tremendous capacity to reduce peak flow and improve water quality.

BMP Type:	Stormwater Wetland, Filtration
Design Source:	UNHSC
BMP Cost Per Acre Treatment:	$22,500
Water Quality Treatment:	Excellent
Water Quantity Management:	Excellent; however, it is suitable for water quality volume sizing only.
Maintenance Sensitivity:	Medium, requires periodic cutting of vegetation to prevent nutrient cycling. Pretreatment should be free draining, open structures stabilized with grass.

LOW IMPACT DEVELOPMENT SYSTEM: BIORETENTION/RAINGARDEN

Bioretention systems are among the most common low impact development (LID) stormwater approaches. Runoff flows into landscaped depressions, where it ponds and infiltrates the soil. The engineered soil mix and vegetation provide water quality treatment and infiltration similar to undeveloped areas. UNHSC has evaluated a number of such systems. Of key importance is engineering an appropriate soil with just the right proportion of sands and silts. Too many fine materials like silts may clog the system, too few and there may be issues with vegetation establishment and nutrient removal. There are many designs, both good and bad, available for bioretention systems. It is important that any design be refined for targeted pollutants, regional climate and general aesthetic qualities.

BMP Type:	Raingarden/Bioretention system
Design Source:	Low Impact Development Center 2006
BMP Cost Per Acre Treatment:	$18,000
Water Quality Treatment:	Excellent
Water Quantity Management:	Excellent. However it is suitable for water quality volume sizing only. May be most effectively used as a source control strategy reducing the overall percentages of effective impervious cover (EIC) and minimizing size of end of pipe structures.
Maintenance Sensitivity:	Medium, requires periodic pruning of vegetation to prevent nutrient cycling and maintain aesthetic appearance. Periodic inspections for clogged surface areas, water routing and rodent burrowing are also important.

LOW IMPACT DEVELOPMENT SYSTEM: TREE BOX FILTERS

Tree box filters are mini bioretention systems that combine the versatility of catch basins with the water quality treatment of vegetated systems. They serve as attractive landscaping and drainage catchbasins. Unlike many other forms of urban landscaping, they are not isolated behind curbs or deprived of water and nutrients in runoff. Their water quality treatment performance is high, often equivalent to other bioretention systems, particularly when well distributed throughout a site.

BMP Type:	Filtration, Infiltration, Urban Retrofit
Design Source:	UNHSC
BMP Cost Per Acre Treatment:	$25,000/2,500 per unit.
Water Quality Treatment:	Excellent
Water Quantity Management:	This system is suitable for effective impervious cover (EIC) reduction only. Reduction of EIC will result in significantly lower water quantity management efforts (N.H. DES 2008).
Maintenance Sensitivity:	Low, requires periodic replacement of vegetation (every five to ten years) and periodic inspection for trash accumulation and infiltration capacity.

Amanda Stone

LOOKING FORWARD

The work of community board members and municipal staffers in New England's small towns is critically important for shaping community character and protecting local natural, cultural and economic resources. It can be tempting for decision makers to latch on to what may seem like quick and easy solutions, although none truly exist. It is hoped that the information provided in this guide will help local board and staff members manage their stormwater in a more integrated way with support from the locally relevant resources and examples provided. In time, New Hampshire will have more examples of innovative stormwater management in communities that integrate their use of land conservation, riparian buffers, minimized impervious cover, low impact development and other strategies to protect their water and ultimately their community's natural, social and economic resources.

REFERENCES AND RESOURCES

General

Godwin, D., B. Parry, F. Burris, S. Chan, A. Punton. *Barriers and Opportunities for Low Impact Development: Case Studies from Three Oregon Communities*. 2008. Oregon Sea Grant ORESU-W-06-002.

New Hampshire Department of Environmental Services. *Innovative Land Use Techniques Handbook*. 2008. http://des.nh.gov/organization/divisions/water/wmb/repp/innovative_land_use.htm

New Hampshire Department of Environmental Services. *Stormwater Manual*. 2008. http://des.nh.gov/organization/divisions/water/stormwater/manual.htm

New Hampshire Department of Environmental Services. *New Hampshire Water Resources Primer*. 2008. http://des.nh.gov/organization/divisions/water/dwgb/wrpp/primer.htm

Nowacek, D., E. Nelson, J. Petchenik. *Social and Institutional Barriers to Stormwater Infiltration* – A Report to EPA/NSF/USDA. 2003. Wisconsin.

University of New Hampshire Stormwater Center Annual Report 2007. www.unh.edu/erg/cstev/2007_stormwater_annual_report.pdf

U.S. Environmental Protection Agency Nonpoint Source Pollution website: www.epa.gov/owow/nps/qa.html

U.S. Environmental Protection Agency list of drinking water contaminants, potential sources and effects: www.epa.gov/safewater/contaminants/index.html

Weathering the Storm: Managing Stormwater with LID in Northern New England Conference Summary (unpublished report) of event held in Somersworth NH on June 12, 2008. www.fbenvironmental.com/presentations.html

Impervious Cover

Center for Watershed Protection. *Impacts of Impervious Cover on Aquatic Systems* – Watershed Protection Research Monograph #1. 2003

Deacon, J., S. Soule, T. Smith. *Effects of Urbanization on Stream Quality at Selected Sites in the Seacoast Region in New Hampshire, 2001-2003*. USGS Scientific Investigations Report 2005-5103. http://pubs.usgs.gov/sir/2005/5103/

Stranko, S., R. Hildebrand, R. Morgan II, M. Staley, A. Becker, A. Roseberry-Lincoln, E. Perry, P. Jacobson. "Brook Trout Declines with Land Cover and Temperature Changes in Maryland," *North American Journal of Fisheries Management* 28:1223-1232. 2008.

Land Conservation

American Farmland Trust, 2002. *Making the Case for Land Conservation: Fifteen Years of Cost of Community Services Studies.* www.farmland.org

Coastal and Estuarine Land Conservation Program. http://des.nh.gov/organization/divisions/water/wmb/coastal/celcp/index.htm

Lind, Brenda, 2005. *Conserving Your Land: Options for NH Landowners.* Center for Land Conservation Assistance / Society for the Protection of N.H. Forests. http://clca.forestsociety.org/publications/

N.H. Department of Environmental Services, 2008. *Innovative Land Use Planning Techniques – A Handbook for Sustainable Development.* Report #WD-08-19. http://des.nh.gov/organization/divisions/water/wmb/repp/innovative_land_use.htm

N.H. Department of Environmental Services, 2008. *New Hampshire Stormwater Manual.* http://des.nh.gov/organization/divisions/water/stormwater/manual.htm

N.H. Department of Environmental Services Water Supply Land Grant Program: The N.H. DES Water Supply Land Protection Grant Program provides 25 percent matching grants to municipal water suppliers for the purchase of land or conservation easements critical to their water quality. These water supply lands must be currently unprotected and within the wellhead protection area for a groundwater source or within the source water protection area and within five miles of the intake of a surface water source. (NHDES, 2009). http://des.nh.gov/organization/divisions/water/dwgb/dwspp/land_acqui/index.htm

Society for the Protection of NH Forests, 2009. *Funding Sources for Land Conservation.* Center for Land Conservation Assistance. http://clca.forestsociety.org/pdf/funding-sources.pdf

Taylor, Dorothy Tripp, 2000. *Open Space for New Hampshire: A Toolbook of Techniques for the New Millennium.* New Hampshire Wildlife Trust. http://clca.forestsociety.org/publications

Thorne, Sarah, 1997. *Permanently Protecting Water Supply Lands with Conservation Easements.* Society for the Protection of N.H. Forests. www.spnhf.org/pdf/watersupply.pdf

Tidelines: Land Protection Issue. Includes a summary of The Land Conservation Plan for New Hampshire's Coastal Watersheds, examples of land protection success stories in our coastal watershed and a panel of experts on why land protection is important. http://des.nh.gov/organization/commissioner/pip/newsletters/coastal/document/tl_08_land_protection.pdf

Low Impact Development

EPA. *Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices* – Publication Number EPA 841-F-07-006, December 2007

Evaluation of Best Management Practices for Highway Runoff Control: Transportation Research Board. www.trb.org/news/blurb_detail.asp?id7184

Jordan Cove Annual Report. This report describes a 10-year paired watershed study of a conventional and a low impact development subdivision in Connecticut. www.csc.noaa.gov/alternatives/conserve_info.html.

Low Impact Development Center, Beltsville, Md: www.lowimpactdevelopment.org

Prince Georges County Maryland LID website: www.co.pg.md.us/government/agencyindex/DER/ESD/low-impact.asp

UNH Stormwater Center: www.unh.edu/erg/cstev/

UNH Stormwater Center 2007 Annual Report: www.unh.edu/erg/cstev/2007_stormwater_annual_report.pdf

U.S. Environmental Protection Agency Low Impact Development Center: www.epa.gov/nps/lid

Minimizing Impervious Surfaces

Center for Watershed Protection. *Better Site Design: A Handbook for Changing Development Rules in Your Community.* 1998.

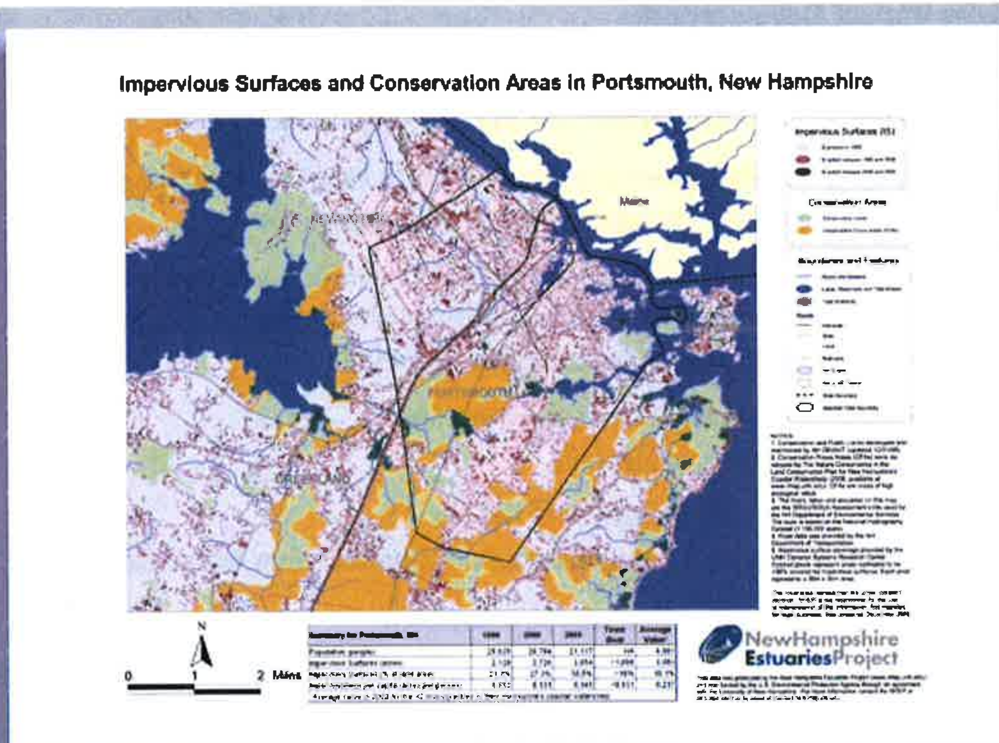
Center for Watershed Protection – Watershed Protection Research Monograph #1 *Impacts of Impervious Cover on Aquatic Systems.* 2003. www.cwp.org/Resource_Library/Center_Docs/IC/Impacts_IC_Aq_Systems.pdf

Connecticut Department of Environmental Protection. *A Total Maximum Daily Load Analysis for Eagleville Brook, Mansfield, CT.* 2007

EPA. *Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices* – Publication Number EPA 841-F-07-006, December 2007

Deacon, J., S. Soule, T. Smith. *Effects of Urbanization on Stream Quality at Selected Sites in the Seacoast Region in New Hampshire, 2001-2003.* USGS Scientific Investigations Report 2005-5103. http://pubs.usgs.gov/sir/2005/5103/

Impervious Surface Analysis for Durham Under Current and Build-Out Conditions In Support of Stormwater Management. 2007. A report to N.H. Estuaries Project. www.nhep.unh.edu/resources/pdf/impervious_surface_analysis-stone-07.pdf



Example of impervious cover map of a developed area produced by the N.H. Estuaries Project; see listing below for web access to this resource.

Impervious Surface Mapping in Coastal New Hampshire 2005: A Final Report to N.H. Estuaries Project. www.nhep.unh.edu/resources/pdf/impervious_surface_mapping-unh-06.pdf

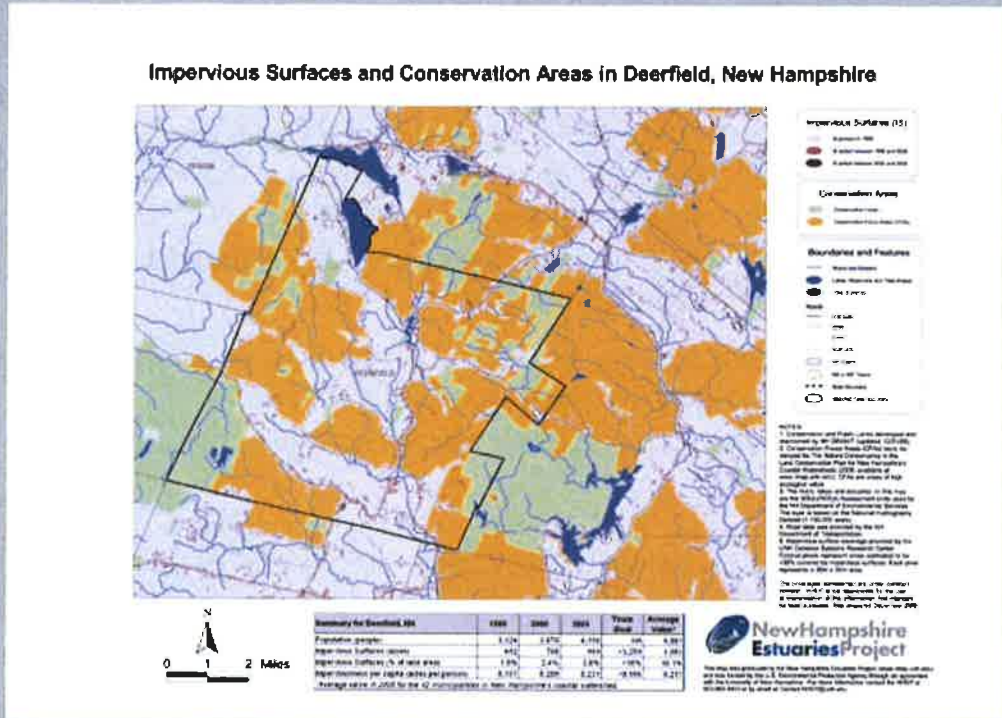
Nonpoint Education for Municipal Officials (NEMO) Impervious Surface website: http://nemo.uconn.edu/tools/impervious_surfaces/index.htm

N.H. Estuaries Project: Impervious Cover Maps for 42 Coastal New Hampshire Towns. www.nhep.unh.edu/resources/maps.htm.

N.H. Department of Environmental Services. *Innovative Land Use Planning Techniques: A Handbook for Sustainable Development.* 2008. Report #WD-08-19 – chapter "Protection of Groundwater and Surface Water Resources."

Schueler, T. *The Impervious Cover Model: Stream Classification, Urban Subwatershed Management and Permitting*, 2008. Chesapeake Stormwater Network. www.cwp.org/Our_Work/Training/Institutes/icm_and_watershed_mgmt.pdf

UNHSC Student Thesis, Kristopher M. Houle. Winter Performance Assessment of Permeable Pavements: A Comparative Study of Porous Asphalt, Pervious Concrete, and Conventional Asphalt in a Northern Climate. September 2008. www.unh.edu/erg/cstev/pubs_specs_info/unhsc_houle_thesis_9_08.pdf



Example of impervious cover map of a rural area produced by the N.H. Estuaries Project; see listing on page 46 for web access to this resource.

Riparian Buffers

Chase, V. et al., *Buffers for Wetlands and Surface Waters: A Guidebook for New Hampshire Municipalities,* NH Audubon Society, revised 1997. http://extension.unh.edu/CommDev/Buffers.pdf

Connecticut River Joint Commission, 2000. *Riparian Buffers Fact Sheets* (a series of 10 fact sheets, including information on buffers for forestland and agricultural land). www.crjc.org/riparianbuffers.htm

N.H. Department of Environmental Services, 2008. Comprehensive Shoreland Protection Act.http://des.nh.gov/organization/divisions/water/wetlands/cspa/index.htm

N.H. Department of Environmental Services, 2008. *Innovative Land Use Planning Techniques: A Handbook for Sustainable Development.* Report #WD-08-19 Chapters on "Shoreland and Riparian Areas" and "Stormwater Management". http://des.nh.gov/organization/divisions/water/wmb/repp/innovative_land_use.htm

N.H. Department of Environmental Services, 2008. *New Hampshire Stormwater Manual.* des.nh.gov/organization/divisions/water/stormwater/manual.htm

N.H. Estuaries Project, 2007. Buffers Program. www.nhep.unh.edu/resources/buffers.htm

N.H. Estuaries Project (NHEP) changed its name in early 2009 to the Piscataqua Region Estuaries Partnership (PREP) to reflect a broader geographic area of involvement. Many documents are still found listed under NHEP.

N.H. Estuaries Project, 2007. Shoreland and Riparian Buffers Resources List. www.nhep.unh.edu/resources/temp/buff_resource_list.pdf

UNH Cooperative Extension, 2007. *Landscaping at the Water's Edge: An Ecological Approach.* Chapter 3 "Vegetative Buffers". Order online at: http://extension.unh.edu/news/2007/05/new_landscaping_at_the_waters_1.html

Zankel, M. et al., 2006. *Land Conservation Plan for New Hampshire's Coastal Watersheds* (includes model Conservation Overlay District). www.nhep.unh.edu/resources/pdf/the_land_conservation-tnc-06.pdf

Stormwater

Antioch New England Graduate School. *Climate Change Will Stress Stormwater Drainage Systems.* October 2005 news release. www.eurekalert.org/pub_releases/2005-10/aneg-ccw101105.php

Northeast Climate Impacts Assessment. *Confronting Climate Change in the U.S. Northeast.* 2007. www.climatechoices.org/assets/documents/climatechoices/confronting-climate-change-in-the-u-s-northeast.pdf