

Bristol County Source Water Assessment



University of Rhode Island Cooperative
Extension in cooperation with RI Health
Source Water Assessment Program

Acknowledgements

This assessment was conducted in partnership with the Bristol County Water Authority, municipal officials representing watershed communities, staff of RI HEALTH and the RI Department of Environmental Management, nonprofit organizations promoting conservation and environmental stewardship of watershed resources, and many other citizen volunteers. These volunteers made significant contributions to the mapping and assessment work. They reviewed draft maps, commented on preliminary assessment results, offered valuable insights on local water quality concerns, and offered practical suggestions to better protect source waters. Special thanks goes to Pasquale Delise and Susan Andrade of the Bristol County Water Authority, who shared background reports and current data and participated in the assessment. Angelo Liberti of the RIDEM Division of Water Resources and Christine Stuart of the Southern Rhode Island Conservation Service also shared information and assisted in the assessment workshops. While we have tried to incorporate local comments to the extent possible, any errors or omissions are the sole responsibility of the authors. The findings and recommendations were developed based on discussions with the assessment volunteers but represent the best professional judgment of the authors based on available data, modeled assessment results and supporting scientific literature, and do not necessarily reflect municipal, URI or RI HEALTH policies.

As the State SWAP Program Coordinator and project manager, Clay Commons provided essential support throughout this project, which included assistance in developing risk analysis procedures, making RI HEALTH technical reports available, organizing public outreach, and participating in the assessment process. Debra LaFleur made public well monitoring data readily available and helped us interpret this rich database. June Swallow, Chief Office of Drinking Water Quality and EPA Region 1 project officer, Buddy Souza, provided support and direction throughout the project.

Dr. Arthur Gold, Professor in the Natural Resources Science Department and Extension Water Quality Program served as scientific advisor on this project. Dr. Gold oversaw development of the assessment approach and provided guidance in evaluating pollution risks and interpreting modeled results. Other key URI staff who contributed to the assessments include James Lucht who assisted with initial GIS database development and assessment. Dorothy Q. Kellogg provided support in modifying the MANAGE nutrient loading spreadsheet for SWAP assessments. Holly Burdett and Alyson McCann assisted in public outreach and trained volunteers to update land use maps used in the assessment. Kaytee Manchester, URI Coastal Fellowship Program intern, assisted in GIS mapping and well data analysis. Emmanuel Falck also assisted in final well data analysis and report editing. The URI Environmental Data Center provided direct access to the RIGIS database and the Center's knowledgeable staff generously provided technical support in GIS database development and mapping.

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April 2003

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This report and a fact sheet summarizing results are available to view or download through the URI Cooperative Extension and RI HEALTH websites. Large format maps of the water supply areas developed to inventory natural features and map potential pollution sources are available for review at municipal offices.

For more information about the RI Source Water Assessment Program or this report contact:

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Funding for this report was provided by the RI HEALTH Office of Drinking Water Quality through a grant from the U.S. Environmental Protection Agency under the Source Water Assessment Program, established by the 1996 amendments to the federal Safe Drinking Water Act.

This is Technical Report #03-05, Contribution 3987 of the University of Rhode Island College of Environment and Life Sciences and Rhode Island Cooperative Extension. URI Cooperative Extension provides equal program opportunities without regard to race, age, sex or preference, creed or disability.

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Bristol County Source Water Assessment

1. INTRODUCTION

This report summarizes the results of the Rhode Island Source Water Assessment Program for Bristol County Water Authority (BCWA) drinking water supply areas. The study areas include the two large watersheds surrounding BCWA's four surface water reservoirs and the wellhead protection area and aquifer recharge area for its two wellfields in Barrington, Rhode Island.

The goal of Rhode Island's Source Water Assessment Program is to better protect drinking water supplies at their source by evaluating threats to future water quality and making this information available to water suppliers, town officials, and landowners. Because the vast majority of land in reservoir watersheds and groundwater recharge areas is privately owned, the assessment is designed to generate information municipal officials can use to support local planning and regulation of land use in drinking water supply watersheds and aquifers. The assessment provides a consistent framework for identifying and ranking threats to all Rhode Island public water supplies following three basic steps:

- Inventory and map potential sources of pollution within wellhead protection areas or reservoir watersheds;
- Assess the risk associated with these potential sources of contamination and rank the susceptibility of the water supply;
- Identify practical steps town officials and residents can take to reduce pollution risks and make results available.

This assessment was conducted by the University of Rhode Island Cooperative Extension in cooperation with the Rhode Island Department of Health and numerous water suppliers, municipal officials and local volunteers dedicated to protecting local drinking water supplies. Participants in the mapping and assessment phases of the program attended a series of workshops to help identify potential sources of contamination within the study areas. Assessment volunteers reviewed draft products and helped to identify alternative management options for better protection of local drinking water supplies.

What is Source Water?

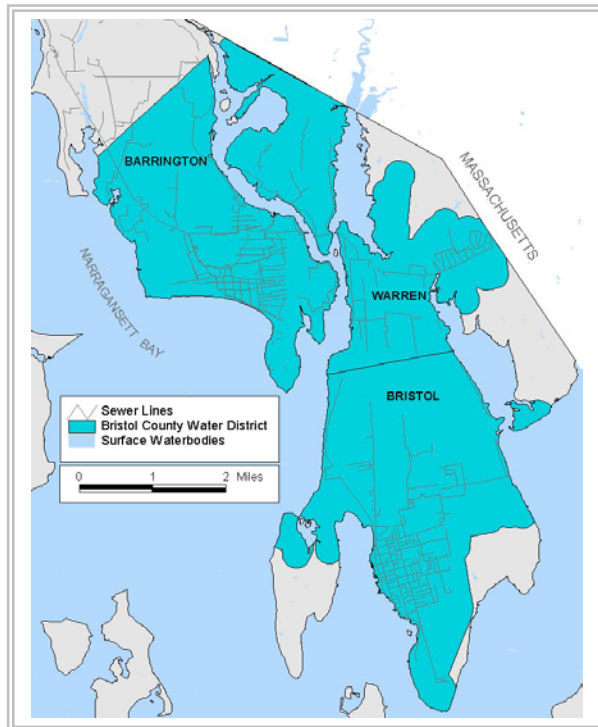
Source water is untreated water from streams, lakes, and interconnected underground aquifers that recharge public and private wells and replenish drinking water supply reservoirs.

While some treatment is usually necessary for public drinking water supplies, preventing drinking water contamination at the source makes good sense. Keeping headwater streams and groundwater recharge areas free of pollution:

- *Safeguards public health,*
- *Reduces treatment costs, and*
- *Protects environmental quality.*

U.S. Environmental Protection Agency Source Water Protection Program

Map 1: Public Water and Sewer Utilities



The Bristol County Water Authority Source Water Assessment

The BCWA provides public water to residents and businesses in Barrington, Bristol, and Warren, Rhode Island. The BCWA currently maintains 15,700 service contracts, providing public water to an estimated 55,000 people. The BCWA water supply system is comprised of two distinct production and distribution systems: the Bristol-Warren system, which receives water from four surface water reservoirs located in both Rhode Island and Massachusetts; and the Bristol system, which is supplied primarily by the Barrington wellfield. The BCWA also maintains a connection to the Providence Water supply through the East Bay Pipeline. The BCWA provides an average 4.0 million gallons a day (mgd) to its customers.

The Source Water Assessment study areas for the BCWA include the watershed for the Shad Factory and Anawan reservoirs both located in Rehoboth, Massachusetts, the watershed for the Kickemuit and Swansea reservoirs located in Swansea, Massachusetts and Warren, Rhode Island, and the wellhead protection area for the Barrington, Rhode Island wellfields. The larger Barrington Aquifer recharge area was also included in the assessment to enhance municipal ground-water protection efforts.

The BCWA is currently meeting all state and federal drinking water standards. Raw water from the Barrington wellfield is treated at the Nyatt Road Well Station through an iron-manganese removal plant employing aeration, oxidation, filtration, and pH adjustment. Source water from the four surface water reservoirs is combined in the Kickemuit Reservoir and treated with chlorine dioxide at the Child Street Filter Plant prior to distribution.

Land use activity in the watersheds for BCWA's four surface water reservoirs has led to serious water quality impairments. A number of Water Quality Restoration Plans are currently underway in both Rhode Island and Massachusetts to address elevated levels of pathogens and nutrients in the Kickemuit Reservoir, the Kickemuit River, and the Palmer River, including the Shad Factory Reservoir (MA). Maintaining high water quality on a watershed basis is critical in these areas as raw water from the four reservoirs is eventually mixed in the Kickemuit Reservoir prior to treatment. Furthermore, both the Shad Factory Reservoir and the Kickemuit Reservoir are

impoundments along major rivers. Protecting source water in the impoundments also requires monitoring and protection efforts for the rivers and their watersheds.

1.1 Assessment Study Areas

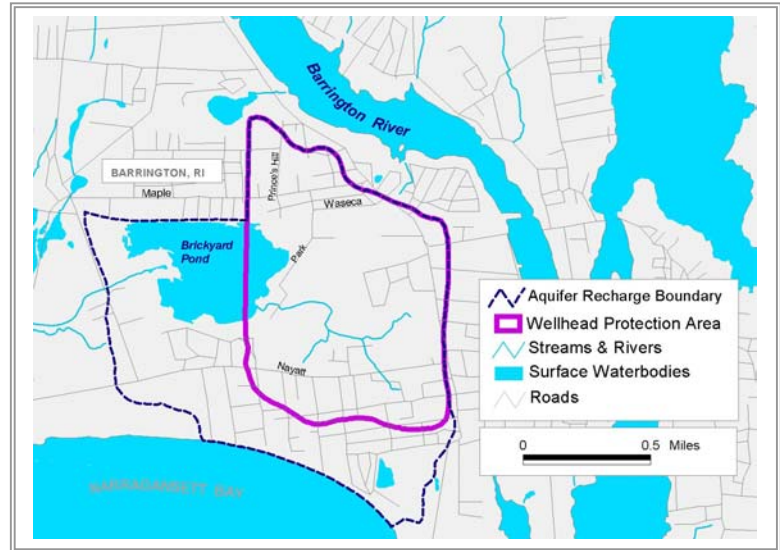
Barrington Wellhead Protection Area

The 482-acre wellhead protection area for the Barrington well is located in downtown Barrington, Rhode Island, between the Barrington River and the Narragansett Bay. Barrington well water quality is very good, although, elevated levels of sodium have been detected. Land use activity in the wellhead protection area is a mix of commercial and higher density residential development. The area is almost entirely sewered, which significantly reduces the likelihood of groundwater contamination from wastewater discharges. There are, however, a number of old landfills and leaking underground storage tanks within the wellhead protection area. The Town of Barrington has not adopted a wellhead protection plan or an aquifer protection overlay zone to restrict hazardous materials and underground storage tanks in the town's groundwater supply area.

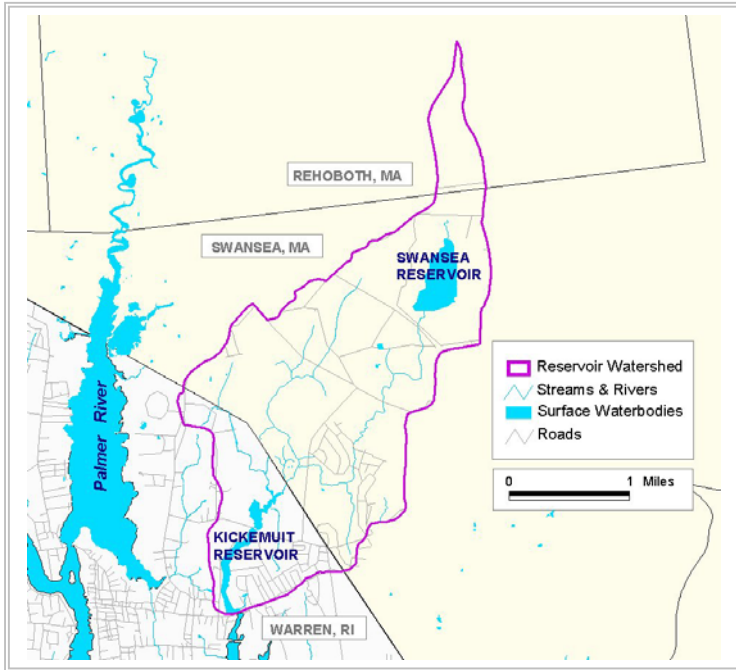
Barrington Aquifer Recharge Area

The groundwater recharge area for the Barrington Aquifer is approximately 889 acres in size, and encompasses the wellhead protection area for the Barrington wells. Brickyard Pond, an 85-acre freshwater pond, is also located within the recharge area. Local water quality monitoring data has detected high levels of chlorophyll and low levels of dissolved oxygen in the pond, particularly during summer months (URI Watershed Watch, 2000). Land use activity in the area is a mix of commercial, residential, and recreational development. The recharge area, including the wellhead protection area, is almost entirely developed. Most of the remaining forested land is permanently protected as open space or for recreational land uses.

Map 2: The Barrington Wellhead Protection Area & Aquifer Recharge Area



Map 3: The Kickemuit Reservoir & Swansea Reservoir



The Kickemuit Reservoir and Swansea Reservoir Watershed

The Kickemuit Reservoir and Swansea Reservoir watershed encompasses 3,310 acres in the towns of Warren, Rhode Island, and Swansea and Rehoboth, Massachusetts. The Kickemuit Reservoir is an impoundment on the Kickemuit River in Warren, Rhode Island. The reservoir is fairly shallow and provides only a small portion of the BCWA's total supply. Water from the Swansea Reservoir, which lies just north of the Kickemuit in Swansea, Massachusetts, is released when needed and flows to the Kickemuit Reservoir through a 3.5-mile long natural stream.

Although the raw water quality in the Swansea Reservoir is good, as it flows to the Kickemuit Reservoir, it passes through a dense, unsewered

residential development. The BCWA is considering installing a pipeline between the two reservoirs as a safer means of conveyance. Water quality in the Kickemuit Reservoir and River has not been meeting RIDEM water quality standards due to elevated levels of bacteria. A nonpoint source pollution assessment study (TMDL) recently conducted by RIDEM concluded that septic systems, urban land uses, stormwater outfalls, and agriculture have all had a significant impact on the bacteria and nutrient levels in the reservoir. The study also concluded that a significant proportion of the contaminant load in the reservoir is being discharged from the river into the impoundment.

Land use activity in the watershed is a mix of agriculture and higher density residential development, with some commercial development along major highways. Much of the agricultural land in the watershed occurs in the Town of Warren, Rhode Island. The Town of Warren has adopted a Kickemuit Reservoir Watershed Overlay District to protect the potable surface water supply within town. The town also provides sewer services to the more densely developed area of the watershed. Failing septic systems in the Swansea, Massachusetts portion of the watershed is an ongoing concern. To address this problem, Save The Bay and MA DEP are both working with municipal officials in Swansea, Massachusetts.

The Shad Factory Reservoir and Anawan Reservoir Watershed

The watershed for the two reservoirs is approximately 20,092 acres in size, and extends into four Massachusetts towns: Attleboro, Dighton, Rehoboth, and Seekonk. The reservoirs are both located in Rehoboth, Massachusetts. The Shad Factory Reservoir is an impoundment on the Palmer River, and is the primary water supply for the Warren-Bristol distribution system. Water from the Shad Factory Reservoir is conveyed to the Kickemuit Reservoir through a pipeline owned and operated by the BCWA. The Palmer River is one of only three rivers in Massachusetts that supports a significant American Shad population. The State of Massachusetts has classified the waters of the Palmer River and the Shad Factory Reservoir as Class B, Cold Water Fishery (MADEP, 2002). In 1998, the Palmer River was placed on Massachusetts' 303(d) list of impaired waters for nutrients, flow alteration, and pathogens (MA DEP, 1999). MA DEP is currently conducting a nonpoint source pollution assessment (TMDL) and Water Quality Restoration Plan for the Palmer River Watershed.

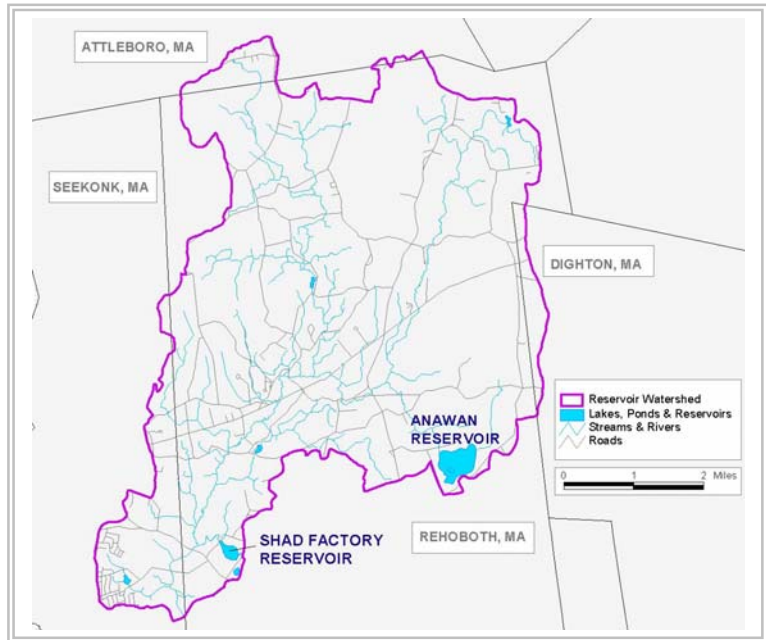
The Anawan Reservoir is approximately 135 acres in size, and is used by the BCWA as a back-up supply for the Shad Factory Reservoir. When required, water is released from the Anawan Reservoir into the natural channels of Bad Luck Brook and the Palmer River where it discharges into the Shad Factory Reservoir. Water withdrawal from the Shad Factory Reservoir is currently at capacity. Over 50 percent of this large watershed is forested. Land use activity in the watershed is a mix of suburban development (3,783 acres) and agriculture (2,126 acres). There are also four large golf courses in the watershed.

1.2 SUMMARY OF EXISTING CONDITIONS

As a first step in evaluating potential pollution risks in the assessment study areas, this section summarizes existing, readily available information on water quality concerns, pollution sources, and current management practices. This overview has several purposes:

- To insure that the assessments build on existing information;

Map 4: The Shad Factory Reservoir & Anawan Reservoir Watershed



Monitoring Requirements for Public Drinking Water Supplies	
Rhode Island Department of Health Testing	
Parameter	Testing Requirement
Asbestos.....	Once every ninth year.
Nitrates.....	Quarterly for 1 year; reduce to annually.
Nitrites.....	One sample.
Pesticides/Synthetic Organic Compounds (SOCs).....	Quarterly every 3 years; reduced to twice every third year.
Selected Inorganics.....	Annually.
Unregulated Organics.....	Quarterly every 3 years.
Volatile Organic Compounds (VOCs).....	Quarterly for 1 year; then annually; then reduced to every 3 years.

- To highlight the most valuable or vulnerable water resources;
- To provide a basis for refining water supply system management plans, wellhead protection plans and town water resource protection goals and priorities; and
- To provide a baseline for reviewing progress in water resource protection efforts and for establishing new watershed management strategies.

This summary is drawn from information sources including: water supply system management plans, municipal plans and ordinances, water quality monitoring data; and input from state and municipal officials, water suppliers, and other participants in these assessments. Key features of this water quality status check are summarized below.

Water Quality Goals and Water Resource Protection Strategies

The BCWA has completed a Water Quality Protection Plan as part of its Water Supply System Management Plan. The BCWA’s source water protection areas lie within two states and six municipalities. Under these conditions, protecting drinking water supplies, both now and in the future, will require a high level of communication, interstate coordination, and citizen involvement. The BCWA and Rhode Island regulatory agencies have no jurisdiction to mandate source water protection efforts for Rhode Island drinking water supplies in Massachusetts. However, MA DEP has recently recommended a reclassification of the Anawan, Shad Factory, and Swansea reservoirs as drinking water supplies under its Water Quality Standards (MA DEP 2002).

Moreover, MA DEP is working with non-profit environmental groups in Rhode Island to protect and restore waterbodies in the Narragansett Bay and Mt. Hope Bay watersheds. MA DEP is currently working with Rhode Island’s Save The Bay to study nonpoint source pollution in the Palmer River watershed. In the Kickemuit River watershed, MA DEP is working with Save The Bay and the Kickemuit River Council to identify nonpoint sources of pollution. RIDEM is also conducting nonpoint source pollution assessments for the Kickemuit Reservoir and River. The completion of Total Maximum Daily Load (TMDL) studies and Water Restoration Plans for these waterbodies should direct restoration of these water bodies in coming years.

The Town of Warren, Rhode Island, has taken significant steps to protect the Kickemuit Reservoir. The town adopted a Kickemuit Reservoir Watershed Overlay District to increase regulatory controls on land use. The town also provides public sewers in the more densely developed areas surrounding the reservoir. The Town of Warren and the BCWA own or hold conservation easements on most of the remaining developable land in the watershed. Currently, the Town of Barrington is considering adopting a wellhead protection plan and aquifer overlay district for its groundwater supplies. Most of the Barrington groundwater protection area is sewerage.

2. ASSESSMENT METHOD

This assessment uses a screening-level approach to evaluate pollution risks in water supply watersheds and recharge areas. The focus is on identifying land use and natural features where pollutants are most likely to be generated and move to drinking water supplies. This approach takes advantage of existing information sources, including the extensive computer-mapping database readily available to water supply managers and municipalities through the Rhode Island Geographic Information System (RIGIS). Computer mapping provides the chief tool to identify, analyze, and display potential pollution threats. Assessment results are intended to generate information water suppliers and local officials can use to make land use decisions that reduce pollution risks to water supplies.

This chapter briefly summarizes our approach in assessing the susceptibility of water supply source areas to contamination. It includes:

- A brief overview of the two-level assessment approach used in RI for small and major supplies,
- Background on the challenges of evaluating water quality impacts from land use in source water areas;
- Description of the assessment approach using watershed features to evaluate pollution risk, with outline of data source,
- Methods and assumptions in creating the land use database for current conditions and future projections; and
- Steps in conducting the assessment, and use of assessment products.

This section is designed to provide an overview of assessment issues and our approach. Complete documentation of assumptions and methods are provided in the Appendix to this report.

2.1 Two Levels of Assessment

The RI Source Water Assessment program uses a two-tiered assessment strategy developed by RI HEALTH and URI Cooperative Extension in partnership with an advisory Technical Committee. This provides a consistent review process for all water supplies while ensuring a more thorough assessment of the largest and most productive community supplies.

Basic assessment and ranking - all water supplies

All water supplies were assessed and ranked according to their susceptibility to contamination. The assessment considers potential sources of pollution and natural features that promote movement of pollutants, to include, for example: high intensity land use, number of mapped potential pollution sources such as underground storage tanks, location of potential sources by soil type and proximity to the supply, and existing water quality. A simple scoring system assigns a

MANAGE is the **M**ethod for **A**ssessment, **N**utrient-loading, and **G**eographic **E**valuation of watersheds and groundwater recharge areas. This screening-level pollution risk assessment method uses computerized maps known as Geographic Information Systems (GIS) to compile, analyze, and display watershed and recharge area information.

The assessment incorporates a suite of pollution risk factors including:

- Map analysis locating likely pollution “hot spots.”
- Land use and landscape features summarized as watershed health “indicators”.
- Nutrient loading estimates comparing potential pollution sources associated with different land uses.

This method incorporates a simple mass balance hydrologic spreadsheet but is a collection of assessment techniques rather than a packaged model. MANAGE was developed and is applied by URI Cooperative Extension as a watershed education and decision support tool for use with Rhode Island communities.

For more information go to:

<http://www.uri.edu/ce/wq/mtp/html/manage.html>.

“Rhode Island’s groundwater resources are extremely vulnerable to contamination because of the generally shallow depth to groundwater, aquifer permeability, and the absence of any confining layers. Preventing groundwater pollution must be a priority if the long-term quality of the state’s groundwater resources is to be protected.

The focus of state water pollution concerns has shifted from specific discharges or ‘point’ sources.... Maintaining or restoring state waters requires that non-point sources of pollution be addressed.”
RIDEM 2002

numerical value, which categorizes the water supply’s overall risk of pollution from low to high. Results of this basic ranking for the source water areas are included in the appendix of this report.

Comprehensive assessment - major community supplies

In addition to the basic mapping and ranking of pollution sources, major community water systems supplying more than 50 million gallons per day also receive a more in-depth assessment using the URI Cooperative Extension MANAGE pollution risk assessment method. This makes more extensive use of computer map databases, in order to evaluate land development patterns and landscape features posing the greatest risk to local water resources. The additional analyses may include any or all of the following:

- Calculation of percent impervious area, percent forest and wetland, land use characteristics in shoreline buffers, and other factors.
- Development of a hydrologic and nutrient loading budget estimating average annual nitrogen inputs to surface runoff and groundwater leaching; phosphorus to surface runoff.
- Forecast of potential threats using a “build out” analysis to evaluate future growth based on zoning.
- Comparison of the relative effectiveness of alternative pollution controls in reducing pollutant inputs using nutrient loading estimates.
- Public involvement in the assessment by field checking and updating land use maps; and reviewing and commenting on draft results.

Both the basic and comprehensive assessment are fully consistent with each other as the basic ranking was developed using elements of the MANAGE method. This technical report includes the combined results of both the basic and in-depth assessment.

2.2 Background on assessing water quality impacts

Pollutants most likely to contaminate drinking water

According to the RI Department of Environmental Management’s report to congress on the state’s water quality, pollution from routine land use activities is the greatest threat to water quality outside of urban areas (RIDEM 2002). Stormwater runoff, septic systems and erosion are the number one threat to the State’s drinking water supplies and other high quality fishable and swimmable waters. Bacteria, nutrients and sediment associated with these sources have adversely affected drinking water reservoirs, inland lakes and ponds, and coastal shell fishing waters. In fact, pollutants from land use activities are the main cause of new shellfish closures (RIDEM 2002).

Land use activities are also the primary threat to groundwater. The most frequently detected contaminants in RI public wells, excluding

naturally occurring compounds, are MTBE, a highly soluble gasoline additive, and the widely used chemical solvents such as trichloroethene and tetrachloroethane. According to RIDEM's 2002 report on the state's waters, between 15 and 30 percent of all RI public wells have been found to contain low levels of these volatile organic solvents (VOCs). Petroleum products from leaking underground storage tanks are the leading cause of new groundwater contaminant incidents. Nitrate is also a concern as it is often detected at concentrations far above natural background levels. Annually, almost 90 percent of wells have nitrate concentrations less than 3 mg/l, with only five wells slightly exceeding the 10 mg/l nitrate standard. Because even 3 mg/l is more than 10 times the naturally occurring level, this is a serious concern in coastal areas where shellfishing habitat can be impaired at total nitrogen levels as low as 0.35 mg/l (Howes et.al.1999). This low level is near the natural background concentration of groundwater in undeveloped areas of Rhode Island.

Because most land in a reservoir watershed or overlying a well head protection area is often privately owned and not controlled by the water supplier, source water areas are just as susceptible to land use pollutants unless local watershed protection regulations are adopted and enforced. With Rhode Island's population moving out of urban centers to new homes in outlying suburbs and rural source water areas, the potential for water quality impacts to drinking water supplies is greater than ever.

Challenges of measuring land use impacts

Field monitoring and modeling are two basic approaches, often used hand-in-hand to evaluate effects of land use activities on water quality. Field monitoring data provides the most solid information to assess water quality conditions and identify pollution sources. However, field studies of even small watersheds is complex and time consuming, especially when compared to traditional sampling of discharge pipes. Pollutants from multiple sources such as over fertilized lawns, storm drains, and septic systems enter streams and groundwater at many locations scattered throughout a watershed, making it difficult to accurately evaluate impacts. In addition, any one sample represents only a snap shot in time. Regular sampling is needed to separate variations due to weather or season and to establish trends.

To complicate matters, mounting evidence points to basic changes in hydrology brought about by development as a root cause of water quality problems. Increased runoff with construction – almost impossible to avoid unless strictly controlled, prevents rainwater from naturally infiltrating into the ground. Water running off the ground surface escapes treatment that would have occurred through slow

Threats to lakes and ponds

22% of RI lakes and ponds are not clean enough for healthy aquatic life or swimming due to bacteria, nutrients, low oxygen or metals.

The major sources are:

- *Runoff*
- *Septic systems*
- *Agricultural fertilizers*
- *Water withdrawals and other changes in flow.*

RIDEM's assessment of lakes and ponds includes 42 drinking water supply reservoirs. Of these reservoirs, 99 percent are meeting drinking water standards. In most areas, however, this assessment does not include information on upstream tributaries due to lack of data.

RIDEM 2002

“It is generally recognized that protecting the quality of drinking water is cheaper than treating water after it has been contaminated, and more certain than seeking new sources.”

RI HEALTH Source Water Assessment Plan, 1999.

movement through soil. The combined result is reduced groundwater recharge and degraded surface water quality. Monitoring is a challenge given the wide range of physical, chemical and biological impacts that are possible. Finally, even where significant resources are devoted to field studies, results are often inconclusive. For example, DEM scientists have conducted extensive field studies of impaired surface waters only to conclude that “in the majority of cases there is not enough data to link the causes of non-support to actual sources of pollution” (RIDEM 2002).

Watershed scale models provide an alternative or supplement to field sampling. Modeling uses information regarding specific features of a study area, such as soil types and water flow patterns, with research data about pollutant interactions. It then makes simplifying assumptions to apply these facts to the whole study area, creating a picture of how a study area functions. Modeling is frequently used to estimate sources of pollutants, especially when sparse or inconclusive field data indicates the amount of pollutant present without leading to a verified source. Modeling is used to extrapolate from known data points to make assumptions about the larger study area, thus gaining a “big picture” perspective needed to evaluate cumulative impacts. And modeling is a valuable tool in testing.

It is important to remember that all models generate results that are only as good as the input values. Results of both simple and sophisticated models are estimates. Complex models may not generate more useful data for management, especially when comparing relative differences is adequate for choosing pollution controls (Center for Watershed Protection 1998). For both simple and complex models alike, great uncertainty surrounds the fate and transport of pollutants in the environment. Because of these data gaps, quantifying a direct response between pollution sources and resulting water quality in a down gradient well or surface reservoir is extremely complex and filled with uncertainty. In the Waquoit Bay watershed in Cape Cod, Massachusetts, for example, researchers modeling watershed nutrient dynamics concluded that even in heavily studied watersheds with an extensive field monitoring database, the relationship between pollution sources and resulting water quality was the most difficult to estimate (Weiskel, 2001). These unknowns currently preclude researchers from setting up a direct relationship between pollution sources in a watershed and resulting impact of those pollutants in receiving waters.

2.3 Approach: Linking landscape features to pollution risks

Given the difficulties in assessing land use impacts through field monitoring and conventional water quality models, the RI Source

Water Assessment Program relies on accepted pollution risk factors established by the U.S Environmental Protection Agency (EPA) and other scientific organizations to identify and rate pollution threats (EPA, 1996; Chesapeake Bay Foundation, 2001; Maryland Department of Environmental Protection, 2002; Nolan et.al., 1997). Given that water quality is a reflection of the land use activities and physical features of a watershed or recharge area, this approach relates the characteristics of the watershed to potential sources of pollution that may lead to impaired water quality through “cumulative” effects of increased pollutant inputs and hydrologic stresses with increased impervious and surface water runoff. These indices couple high quality spatial data on a suite of landscape features with our current understanding of land use impacts to evaluate and compare risks to water supplies. Our focus is on identification of high risk situations that could lead to impaired water quality and identification of appropriate management options to prevent degradation.

The relationship between watershed characteristics and water quality is grounded on basic, widely accepted concepts about movement of water and pollutants applicable to both surface stormwater flow and leaching to groundwater (Dunne and Leopold, 1978; National Academy of Sciences, 1993). These principles include:

- Most water pollution comes from the way we use and develop land.
- Intensive land use activities are known to generate pollutants through for example, accidental leaks and spills, septic system discharges, fertilizer leaching, or runoff from impervious areas.
- Forest, wetlands, and naturally vegetated shoreline buffers have documented ability to retain, transform, or treat pollutants.
- Natural landscape features such as soil types and shoreline buffers determine water flow and pollutant pathways to surface waters and groundwater.

Land use pollutants are therefore not completely diffuse across a landscape but are associated with recognizable patterns of intense land use in combination with hydrologically active sites, such as areas of high water table and excessively permeable soils, where pollutant movement is more likely given soil type and proximity to receiving waters. Recent findings by the U.S. Geological Survey document the validity of using this approach to assess pollution risk. In an extensive national review comparing water quality of streams and aquifers with watershed characteristics, USGS researchers (Nolan et.al., 1997) concluded that water quality is the result of multiple variables, not pollutant inputs alone. This study demonstrated that a combination of land use and landscape characteristics were highly reliable in identifying settings at greatest risk of contamination.

Threats to Groundwater

Ninety percent of Rhode Island groundwater is suitable for drinking but low-level organic contaminants have been found in 15 – 30% of wells tested. The most common contaminants are petroleum products, organic solvents, nitrates and pesticides.

The major sources are:

- *Underground storage tanks*
- *Hazardous and industrial disposal sites*
- *Spills*
- *Landfills*
- *Septic systems*
- *Road salt*
- *Fertilizers and pesticides*

RIDEM 2002

Using these accepted concepts, areas of high pollution risk can be mapped to provide a rapid, first-cut assessment to screen pollution risks and set a direction for additional analysis or management. The indicators used in this source water assessment are standard measures commonly used in similar watershed analyses to evaluate a waterbody's susceptibility to degradation. These indicators include for example, the factors listed below.

Type of Pollution Risk Indicators

The presence of likely pollution sources and stressors.	<ul style="list-style-type: none"> ▪ Percent high intensity land use ▪ Percent impervious cover ▪ Estimated average annual runoff and nutrient loading
Landscape features promoting pollutant movement to surface or ground waters.	<ul style="list-style-type: none"> ▪ Location and extent of highly permeable soils ▪ Location and extent of shallow water table networks. ▪ Developed shoreline buffers
Waterbody features that amplify vulnerability to contaminants.	<ul style="list-style-type: none"> ▪ Aquifer type ▪ Reservoir depth and flushing rate ▪ Existing water quality condition.

More detailed information about pollution risk indicators and mass balance modeling methods used in this assessment are provided in the results section of this report, with more extensive information also provided in the appendix.

Data Sources and Outputs

The assessment results are based on five types of information either used or generated by the risk analysis.

- Review of existing water supply management plans, municipal plans and ordinances, state reports, Rhode Island Department of Health water quality monitoring data.
- Local input from municipal officials, water supply representatives and assessment volunteers for important information on existing conditions and concerns.
- Map analysis of land use, soils, known pollution sources and other watershed features to systematically locate probable pollution “hotspots” using the RI Geographic Information System (RIGIS) database. Data derived from the RIGIS database is intended for planning-level analysis only.
- Land use and soils acreages extracted from the RIGIS map database, compiled using a separate spreadsheet and summarized as averages for each study area.
- Modeled estimates of average annual runoff, groundwater recharge, and nutrient loading as measures of cumulative pollution risk. This is a standard mass balance method similar to

those widely used in comparable applications elsewhere including Cape Cod and the New Jersey Pine Barrens.

Database Development

The land use data for this analysis was derived from the 1995 RIGIS coverage, using twenty-one land use categories consolidated from 32 mapped categories based on similar use, intensity, and pollution risk. Land use maps were updated with major changes and corrections identified by assessment mapping volunteers based on their knowledge of the area and windshield surveys. The number of dwelling units was estimated from the RIGIS residential land use categories. Population was based on 2.4 persons per dwelling unit, unless otherwise determined. The town sewer service district was updated when possible using sewer line information provided by the towns. Without parcel level data on the number of homes actually connected to the sewer line, we assumed homes within 500 feet are reasonably likely to take advantage of public sewers. Based on the land area outside the sewer district, we estimated the number of houses with septic systems per acre based on RIGIS residential land use categories.

Complete documentation of methods used to create a land use database, and detailed results for each study area, is included in appendices to this report. This includes a land use breakdown by soil type for each study area, land use characteristics of shoreline zones, and estimated future land use based on buildout projections.

2.4 Assessment Steps

The following steps briefly outline the process used to involve the public and conduct the assessment.

1. **Organize an assessment group.** In each study area, RI Health and URI Cooperative Extension worked with the water supplier and municipal officials to coordinate and schedule the assessment, identify key organizations to be involved, and recruit local volunteers to participate in the assessment. *Mapping volunteers* were trained to field check land use maps and inventory potential sources of pollution. A small group of *Assessment volunteers* – primarily town staff and board members – reviewed draft results, provided input on local resource issues, and made suggestions for management controls.
2. **Create land use and natural resource inventory maps for display and analysis.** The study area boundaries were selected in cooperation with the water supplier and/or town officials. At a minimum this included the water supply watershed or wellhead protection area but in some cases was expanded to include other areas for future planning purposes. In cooperation with local volunteers, RIGIS land use maps were updated with major land use changes and known or suspected pollution sources. A future land use/zoning map was created using town coverages or digitized from zoning boundaries provided by the town. The basic coverages used in the assessment include land use, soils, sewer lines (buffered to create an area coverage) and surface water buffers (200 feet).
3. **Briefly summarize existing conditions.** This is a brief overview, based on available plans, monitoring data, and water quality issues identified by water suppliers, municipal officials and assessment volunteers. In addition, the RI HEALTH public well database was analyzed and results for the past five years were summarized and ranked using the RI Source Water Assessment ranking.
4. **Identify and rank pollution risks based on current land use.** Using land use, soils, and other mapped data, the MANAGE model uses a spreadsheet to generate summary statistics, or “indicators” such as percent impervious area. The same spreadsheet calculates a hydrologic budget and nutrient-loading estimate as an additional indicator of pollution risk. Basic land use characteristics, number of potential pollution sources, and monitored data are factored into a pollution risk rating for each source water area.

5. **Map high-risk pollution “hot-spots” for the whole wellhead protection area or reservoir watershed.** Mapped hot spots help to target the location of potential pollution sources by combining high intensity land uses that are known pollution sources with soil features where pollution movement is most likely.
6. **Predict future land use and population change through a “build-out” analysis for each study area.** This map-based analysis, projects the type and location of growth assuming all unprotected land is eventually developed based on municipal zoning and future land use maps created in step 2.
7. **Forecast future land use impacts to water resources using the “build-out” analysis.** Pollution risk indicators and a hydrologic budget/ nutrient loading for future land use are estimated by re-running the spreadsheet analysis (Step 4) using the future land use map.
8. **Summarize and rank pollution risks.** The RI Source Water Assessment Ranking was used to summarize and rate pollution risks for each water source, with results averaged as one ranking for suppliers having more than one source of supply. This basic rating is used for all public water supplies in Rhode Island. For major community supplies additional risk factors, such as impervious estimates, nutrient loading and build out results, were also identified and rated.
9. **Evaluate effectiveness of management options to reduce pollution risk.** Using the MANAGE spreadsheet, we estimated the relative change in runoff and nutrient loading that could be expected under different pollution control practices. Because this analysis is limited to change in nutrient loading only, a wide range of management options were identified based on accepted current best pollution prevention practices.
10. **Make results available to water suppliers, local decision makers and the public.** Final results are summarized as a technical report and a 4-page full color fact sheet. These are available through the RI HEALTH and URI Cooperative Extension web sites. Fact sheets are suitable for direct mail to watershed residents by water suppliers or municipalities. Although it is beyond the scope of the source water assessment program to develop detailed action plans, reports include recommendations focusing on pollution prevention. Map analyses are made available as large-format maps. In cooperation with RI HEALTH, final summary results will be presented to town officials, with presentations scheduled at the convenience of town councils and planning/zoning boards.

Source Water Protection Savings

Rhode Island public water suppliers are estimated to have saved **\$2,755,180** in a three-year period through “monitoring waivers” granted by US EPA based on source water protection plans.

Where a supplier has a source water protection plan in place, where certain pesticides and organic chemicals are not used in a source area or state, and where sampling data also confirms the supply is not vulnerable, water suppliers may reduce monitoring. This means money saved can be better spent protecting against actual threats.

Source: Technical and Economic Capacity of States and Public Water Systems to Implement Drinking Water Regulations, Report to Congress, September 1993, as reported by New England Interstate Water Pollution Control Commission, 1996.

Applying Results

In addition to meeting EPA requirements, source water assessments have many practical applications. One key benefit for water suppliers is to support monitoring flexibility. Based on assessment results, RI HEALTH may grant monitoring waivers to a supplier for specific contaminants that are not found within the source area. This can amount to savings of several hundred dollars per year for each system that receives waivers. The actual amount depends on the specific testing requirements that may be waived. The state can also use assessment results to require additional monitoring for supplies at risk or to earmark grant money for pollution prevention programs for the systems at highest risk (RI Health 1999).

Assessment results can also provide a basis for future watershed assessment. The GIS map inventory of land use risk factors and mapped pollution sources establish a database that can be used to update watershed protection plans. In source water areas where field monitoring data is limited, assessment results may be used to locate high risk areas for additional field monitoring, to support design of expanded field monitoring, or identify areas where specialized field studies or modeling is warranted.

Because the assessment focuses on potential land use impacts, assessment results have been used to strengthen local land use planning and regulation. The following are, for instance, a few ways RI communities have used assessment results:

- Update town water quality goals and priorities for action. Towns have incorporated assessment findings and recommendations into town comprehensive plans, water supply or wastewater management plans, and other watershed plans.
- Support adoption of wastewater inspection and upgrade ordinances, and develop standards for performance of onsite systems through zoning overlay districts. Information generated on pollution risks and suitability for onsite wastewater treatment has been used to build support for better wastewater management and to determine level of improvement needed.
- Create and distribute public information materials, incorporating assessment results and maps, targeting high risk areas.
- Use map products generated in routine town planning and project review.

Assessment recommendations incorporate current accepted management practices focusing on pollution prevention. Although these were developed with local input, recommendations in this report are not truly town priorities unless incorporated into town plans, capitol improvement budgets, and ordinances. The next step is for local officials to review assessment results in light of current policies and management practices, and develop their own list of protection priorities with implementation plan.

3. POLLUTION RISK RESULTS

This chapter summarizes the primary results of the assessment using land use and landscape characteristics of each study area and modeled estimates of nutrient sources based on these local features. Summary statistics generated are used as “indicators” of watershed health and potential risk to water quality. Findings are organized as follows:

- Background on the relationship between watershed characteristics and water quality explains our assumptions about indicators, their appropriate use, and how to interpret results.
- Each indicator is briefly described and results for the study areas presented in chart form with brief narrative. Although each study area is assessed separately, results are reported for the study areas as one group, using a summary chart and brief narrative. A ranking is assigned to frame results in terms of low to high risk.
- Runoff and nutrient loading estimates, which are additional indicators modeled using a simple mass balance approach, are described and results summarized in a similar way.

Results are typically presented for current conditions. In some cases the potential effect of alternative management practices may be tested by adjusting input values to represent various pollution control practices, such as reduced fertilizer application or use of nitrogen-reducing on-site wastewater treatment systems. Alternative management scenarios are generally explored using nutrient loading estimates but other indicators may be used as well depending on the type of change expected.

Results presented in this chapter are key findings from a relatively small number of indicators most appropriate for the local study areas. These were selected considering the particular pollutants and stresses of concern to local water resources, current land use risks, and type of growth expected. Complete summary statistics for each study area and in some cases, results of additional analyses not shown here, are included in the appendix to this report. Supporting documentation on selection, use and ranking of indicators is also included in appendices.

3.1 Linking Land Use to Water Quality

The quality of ground and surface water is the product of multiple variables. Although land use is an extremely useful gauge of pollutant inputs, other factors, such as depth to water table, forested buffers, and characteristics of a reservoir or aquifer, also influence contaminant movement at different scales. Extensive comparison of water-shed and aquifer features with monitored water quality show that the combination of natural features and human influences are the most reliable predictors of impaired water quality (Nolan et.al., 1997).

Rhode Island's Drinking Water

Public Water Suppliers

have at least 15 service connections, or serve at least 25 people per day for at least 60 days of the year. Rhode Island has about 477 public water suppliers serving more than 1,055,000 people. These fall into four categories:

Types of water supplies

17 Large community water suppliers provide at least 50 million gallons per year.

About 70 Small community water suppliers serve residential customers such as clusters of homes, trailer parks and nursing homes, but pump less than 50 million gallons per year.

74 Non-transient non-community suppliers serve at least 25 of the same people for at least 60 days a year, such as schools or businesses.

330 Transient non-community suppliers serve at least 25 different people at least 60 days of the year. These include for example, hotels, campgrounds and restaurants

Surface or Groundwater

74% of Rhode Islander's drink water from surface water supplies – the Scituate Reservoir alone provides water for 60% of the state's population.

22 water companies, mostly large suppliers, use surface water. The other 455 water systems use groundwater.

26% of Rhode Islanders rely on groundwater for water supply, about 100,000 of these have private wells.

Vulnerability of Public Wells

In a recent U.S. Geological Survey study conducted in Rhode Island, researchers verified that public groundwater supplies are more likely to show elevated levels of toxic contaminants and nitrogen when high intensity uses are located within the wellhead protection areas.

Solvents and other toxics were clearly associated with industrial land uses. They also found that elevated nitrogen (>1 mg/l nitrate-N) in groundwater was associated with urban land uses whether or not the area was sewerred, due to leaking sewers and fertilizers from home lawns, parks, golf courses, and schools.

(DeSimone and Ostiguy, 1999).

Taking advantage of these established relationships, this assessment uses selected characteristics of the study areas as watershed “health” indicators. These indicators are ranked to evaluate the degree to which water resources in each study area are susceptible to pollution. Results reported in this section highlight situations where pollutants are more likely to be generated and transported to surface or groundwater. The potential for pollutant movement considers the most likely immediate water flow pathway, based on soils and proximity to receiving waters to evaluate whether surface or ground waters are more susceptible to contamination.

Indicators used in this assessment provide estimates of potential threats to water quality based on established but generalized relationships between landscape features and water quality. It is important to emphasize that results indicate potential, not verified pollution problem areas. These estimates may not hold true in every case due to wide variation and inherent unpredictability of natural systems. Given this uncertainty, risk factors provide useful information to identify key threats most likely to affect drinking water quality and to rank those threats based on trends observed in other water bodies. Results are designed to direct pollution prevention actions to high-risk locations threatening high value resources.

Understanding and Interpreting Results

Assessment results are best used to compare relative differences in risk among study areas or between different land use scenarios. Sub-watersheds or recharge areas representing a range of land use types and densities provide the most useful comparative results. Undeveloped study areas with extensive forest and undisturbed shorelines are particularly valuable as “reference” sites representing natural, low-risk conditions. At the other end of the spectrum, densely developed or disturbed study areas, where water quality is highly susceptible to impact, represent “high risk” circumstances. In each case reference watersheds provide more realistic benchmarks when monitored water quality data corresponds to estimated risk levels based on mapped features or modeled nutrient loading estimates.

Future pollution risk estimates developed from the build out analysis are approximate projections intended to highlight potential future pollution risks and should not be viewed as absolute values. Because current and future values were created using consistent methods, both can be compared directly. This generates useful information in determining whether water resources are at greater risk from current activities or future development. Perhaps most importantly, results can support selection of appropriate management actions to address areas of greatest risk, focusing for instance on mitigating existing threats, controlling impacts of new development or avoiding future impacts by modifying town land use goals and zoning standards. In

some cases the potential effects of improved pollution control practices may be tested by adjusting input values to represent various pollution control options, such as reduced fertilizer application or use of nitrogen-reducing on-site wastewater treatment systems.

In evaluating assessment results it bears repeating that this is a screening level analysis generating approximate values. At the same time, these estimates are based on current, high-resolution data that is adjusted for the study areas. Input values for basic indicators, such as high intensity land use, were calculated directly from updated local land use maps in combination with other reliable data sources, such as population and housing occupancy derived from U.S. Census data and town records. Nutrient loading inputs to groundwater are based on research conducted in Rhode Island on typical local land uses; values for lawn area and fertilizers rates may also be modified based on local recommendations. Consequently, results are designed to reflect site-specific conditions to the maximum extent possible while still relying on mapped coverages and other readily available data sources. As a follow-up to this assessment, we recommend that results, especially mapped locations of potential high-risk pollution sources, be verified based on local knowledge and field investigations.

Ranking Pollution Risks

To make the assessment more useful for management decisions, indicator results are generally ranked along a scale from low to high or extreme risk. These thresholds are general guidelines serving as a frame of reference in interpreting results. They should be considered points along a continuum, not rigid categories with distinct boundaries. In setting pollution ratings for the various watershed indicators, risk thresholds are generally set low as an early warning of potentially hazardous conditions before adverse impacts occur. For example, in drinking water supply watersheds the presence of any high intensity land use within 200 feet of surface waters automatically rates a moderate risk to water quality. This is based on the assumption that *any* high-risk land use within this critical buffer zone is a possible threat and should be investigated. Low risk thresholds are designed to help prevent degradation of high quality waters, including drinking water supplies that may be un-treated, coastal waters that are sensitive to low level increases in nitrogen, and unique natural habitats that may also be sensitive to small fluctuations in sediment levels, temperature or phosphorus. Identifying risks in early stages also provides an opportunity to take pollution prevention actions as the most cost effective approach to protecting local water quality rather than relying on clean up actions after degradation occurs. In general, restoring a polluted water body is much more costly and technically challenging than pollution prevention.

Interpreting results of indicators

Establishes relationship between watershed condition and potential water quality condition based on trends observed in other water bodies.

Estimates derived from GIS databases should be verified using local maps or field data. Actual water quality condition should be verified through field measurements.

Estimates are best used to compare relative differences among study areas or between different land use / pollution management scenarios.

Ranking thresholds are not sharp breakpoints but points along a continuum.

Results are intended to identify key threats most likely to affect drinking water quality, and to direct pollution prevention actions to high risk locations threatening high value resources.

While ranking systems are useful in organizing and distilling results it is important to recognize that any ranking system can easily mask or over-simplify results. For instance, when indicator risk levels are near the edge of one risk category, a change in only a few points causing a shift to the next risk level may represent only a minor increase in actual threats. At the same time, greater increases occurring within a category may represent real threats that go unnoticed. Likewise, low summary rankings created by averaging results of several variables can easily obscure localized but extreme risks, giving a false sense of confidence in existing protection measures. Because all watershed indicators represent averages for a study area or shoreline zone, we recommend careful review of land use and hot spot maps to identify site-specific locations for pollutant movement. When interpreting indicator results we have tried to emphasize areas of greatest risk, major differences among different study areas or development scenarios, and general trends. We have chosen not to evaluate results using statistical measures, partly because doing so may imply results are solid data points rather than estimates of potential risk. Rather than focusing on exact values generated, we believe results are best used to compare actual conditions and trends, to stimulate discussion of acceptable risks, and to support selection of appropriate management practices.

3.2 Land Use / Landscape Risk Indicators

HIGH INTENSITY LAND USE

High intensity land use activities use, store or generate pollutants that have the potential to contaminate nearby water resources. Both sewerred and unsewerred areas are included in this indicator based on evidence that densely developed areas generate high levels of pollutants regardless of the presence of public sewers. The water quality risks associated with intense land use activities cover a broad range of pollutants and hydrologic stresses, generated from a wide variety of sources. These include for example:

- Fuel products from leaking underground storage tanks.
- Solvents and other toxic materials from accidental spills or improper disposal, especially at industrial sites.
- Hydrologic impacts and polluted runoff from roads, parking lots and other impervious surfaces.
- Nutrient, bacteria and increased runoff from subsurface drains used to intercept groundwater on house lots and in agricultural fields.
- Nutrients and pesticides applied to tilled cropland, home lawns, parks and golf courses; also bacteria and nutrients from animal waste storage sites and where livestock have access to water.
- Nutrient and bacteria from leaking sewer lines or malfunctioning pump stations, and from septic systems in dense unsewerred areas (Pitt et al. 1994).

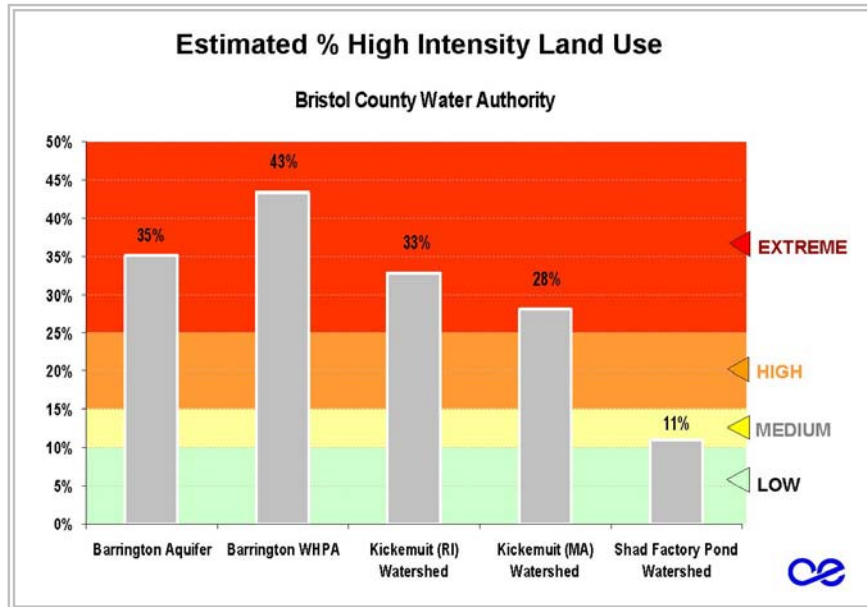
At the site level, ranking the intensity of development or its potential to pollute surface and groundwater resources must also take into consideration the suitability of the land to accommodate development as well as the proximity of the development to shoreline zones. For ex-ample, although medium density residential development on one acre size lots is not considered a high intensity land use, it could have a potentially serious impact on water resources depending on soil conditions, slope or hydrology of the land. Other indicators designed to evaluate these site features include: percent high intensity land use within shoreline zones, on high water table, and on excessively permeable soils. Results are presented in this chapter and/or in the appendices to this report. In addition, co-occurrence of high intensity land use with problem soils and shoreline areas was mapped to identify potential high-risk pollution “hot spots”.

We identify six high intensity land use categories. A complete list is included in the Manage Technical Documentation, an appendix to this report. The ranking system used assigns a low risk to watershed areas having 10 percent or less land in high intensity uses. Water quality is considered to be at extreme risk in study areas with greater than 40 percent high intensity land use.

High Intensity Land Uses

- *Commercial and industrial uses.*
 - *Highways, railroads and airports.*
 - *Junk yards.*
 - *High and Medium-high density residential >4 units / acre.*
 - *Schools, hospitals and other institutional uses.*
 - *Tilled cropland such as corn, potatoes, and nursery crops.*
-

Figure 1. Estimated High Intensity Land Use



Results: High Intensity Land Use

- As is evident in Figure 1, four of the five protection areas are in the extreme risk category for this indicator. In the Barrington Aquifer recharge area and the Barrington wellhead protection area, high intensity land use is primarily higher density residential and commercial development. Management efforts to protect groundwater supplies in this area should focus on pollution prevention education for existing businesses and homeowners, stormwater management, and monitoring of known point sources of pollution such as underground storage tanks.
- In the Kickemuit watershed, high intensity land use is primarily agricultural (approximately 500 acres) and higher density residential development. Protection efforts should focus on wastewater management, stormwater management, residential pollution prevention, and agricultural management practices.
- The level of high intensity land use in the Shad Factory Reservoir and Anawan Reservoir watershed as a percentage of total land area is in the low to medium risk category for this indicator. To some extent, this lower rating is due to the larger size of the watershed. It is important to keep in mind that any high intensity land uses in a drinking water supply area poses risks to water quality. There are approximately 2,126 acres of farmland in this watershed, 15 percent of which occurs in riparian buffer zones. There are also four large golf courses in the watershed totaling close to 500 acres.

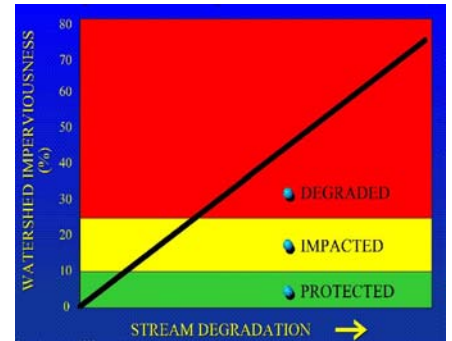
IMPERVIOUS COVER

Impervious cover is a catchall term for pavement, rooftops, and other impermeable material that prevent rainwater from seeping into the ground. Impervious surfaces affect water quality by increasing polluted runoff. Paved areas provide a surface for accumulation of pollutants and create an express route for delivery of pollutants to waterways. Just as importantly, impervious cover alters the natural hydrologic function of the landscape by dramatically increasing the rate and volume of runoff and reducing groundwater recharge.

High levels of impervious surfaces within a watershed lead to “flashier” streams with widely fluctuating water levels, diminished stream flow during critical summer low-flow periods, higher stream temperatures, and increased sedimentation in streambeds, which decreases the capacity of streams to accommodate floods. In streams and wetlands these changes result in loss of habitat, reduced biodiversity, and chemical changes in water quality. Without subsurface water infiltration, natural pollutant removal by filtering and soil microbes is bypassed, compounding pollutant delivery. In groundwater recharge areas, impervious cover reduces recharge to deep groundwater supplies.

Numerous studies have linked the extent of impervious surfaces to declining aquatic habitat quality in streams and wetlands (Schueler 1995; Arnold and Gibbons, 1996; Prince George’s County, 2000). According to these reports, stream and wetland habitat quality is often impaired as watershed impervious levels exceed 10 percent, with as little as 4 to 8 percent affecting sensitive wetlands and trout waters (CWP 2002, Azous and Horner 1997, Hicks 2002). At greater than 25-30 percent imperviousness, the extent of flooding and stream water quality impacts can become severe. Under these conditions, flooding may be controlled but stormwater treatment systems designed to improve the quality of runoff have much lower success rates.

We use standard methods to calculate impervious cover for RIGIS land use categories (USDA 1986). These represent averages for each land use type including local roads. Impervious cover on individual lots is likely to be lower. Assumptions are listed in the Manage Technical Documentation (appendix). Although RIGIS photo-interpreted land use is considered a highly reliable data source for estimating impervious cover, researchers at the University of Connecticut have found that impervious levels for similar land use types can vary considerably by community (Prisloe et.al., 2001). Our estimates are therefore best used to compare relative differences between current and future levels and among watersheds. For greater accuracy, impervious estimates could be refined by either direct measurement of aerial photographs and subdivision plans or by local knowledge of typical house, driveway, road, and parking areas for local neighborhoods.



Increasing impervious cover results in declining stream health.

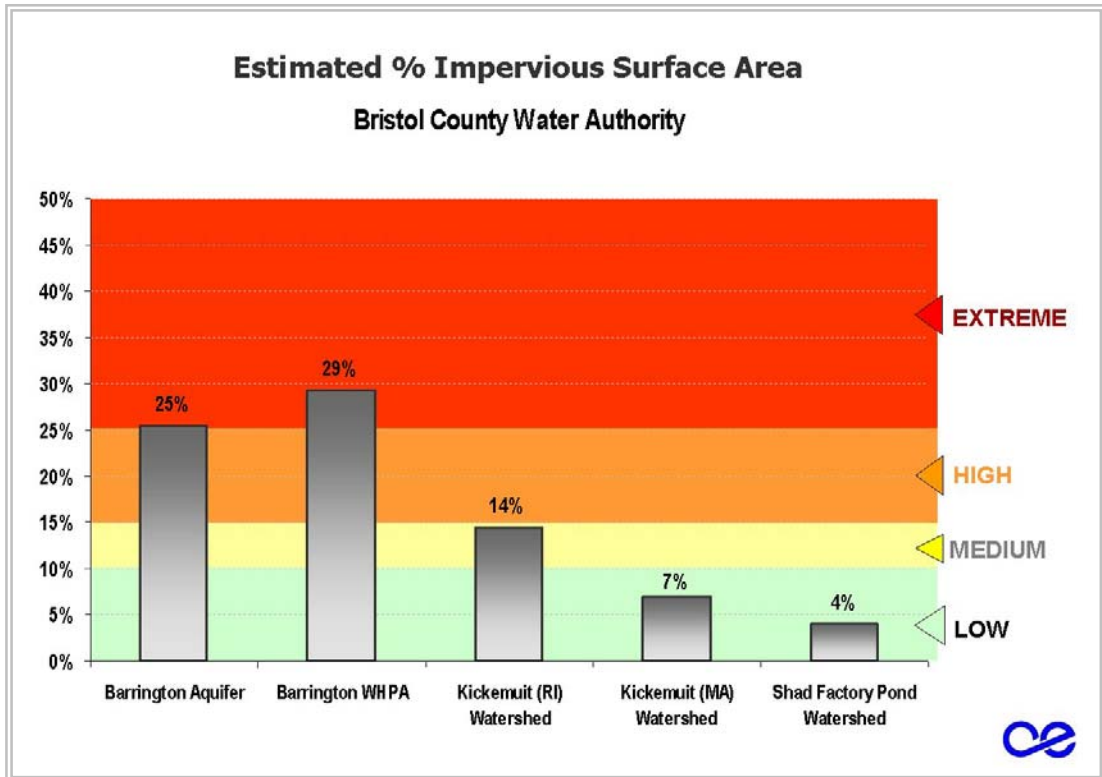
Adapted from Schueler, et. al. 1992

The Relationship Between Percent Impervious Cover and Water Quality

The connection between impervious cover and water quality applies to wetlands, streams and small rivers (1st, 2nd and 3rd order) and has not been validated for other waters such as lakes, reservoirs and aquifers (Center for Watershed Protection, 2002; Hicks, 1997). Increasing impervious cover with urbanization has been shown to lower groundwater tables, however, the thresholds where the extent of impervious surfaces begins to affect groundwater quality or quantity has not been established.

Recent findings suggest that the relationship between impervious cover and stream quality is weakest for streams in less developed watersheds in the 0-10 percent impervious range. These were found to be most susceptible to other influences such as percent forest cover, continuity of vegetated shoreline buffers, soils, agriculture, historical discharges, and other stressors. As a result, more careful review of forest cover, other factors and field measurements become more important in watersheds with less than 10 percent imperviousness. (Center for Watershed Protection 2002)

Figure 2. Estimated Impervious Surface Area



Results: Impervious Cover

- The Barrington Aquifer recharge area and wellhead protection area are both in the extreme risk category for this indicator. The Barrington wellhead protection area is one of the most highly urbanized groundwater protection areas in the state. High levels of impervious surface area, in addition to increasing pollution risks to surface water and groundwater resources, also significantly reduce recharge to groundwater.
- With impervious surface area at 14 percent, the Rhode Island portion of the Kickemuit Reservoir watershed is approaching the high-risk level for degradation of surface water quality. The actual level of impervious surface area for the whole watershed, including both the Rhode Island and Massachusetts portions, is approximately 10 percent. The Kickemuit Reservoir, as previously mentioned, is currently not meeting state water quality standards. Stormwater runoff has been identified as a significant source of pollution entering the reservoir.
- The level of impervious surface area in the Shad Factory Pond watershed is in the low-risk category for this indicator.

FOREST AND WETLAND

Experts agree that forest and wetlands are directly linked to the health of watershed streams and coastal waters (EPA 1999, CWP 2002). Forest and wetlands serve as ecosystem treatment systems, helping to preserve and maintain watershed health. Unlike the other risk factors presented in this study, there is an *inverse* relationship between the amount of these undeveloped lands and risk to water quality. Although some indices assign separate ratings to forest and wetlands area, we combine them based on the simple observation that in Rhode Island, healthy watersheds often consist of one or the other.

Together, both forest and wetlands help to offset the negative hydrologic impacts of development and corresponding pollution inputs to surface and groundwater. In this assessment we consider wellhead protection areas or watersheds that have a combined forest and wetlands cover of 80 percent or more to be at low risk of pollution. Conversely, study areas with less than 20 percent forest and wetlands cover are considered to have little ability to function as treatment areas, and are ranked as having an extreme risk of pollution.

Forests are highly productive, living filters in the natural hydrologic cycle on which we all depend for clean and plentiful source water. Forested watersheds have the capacity to intercept, store, and infiltrate precipitation, thereby recharging groundwater aquifers and maintaining natural stream flows. Undisturbed forest soils tend to store organic matter and nutrients, including atmospheric pollutants associated with acid rain. Forested wetlands and stream buffers also provide shade to surface waters, stabilize stream banks, and filter sediment. In calculating the percent of forest cover in a wellhead protection area or watershed, we also include brush and unfertilized pasture, which provide similar ecological functions in the hydrologic cycle.

Wetlands are a vital link between land and water. Wetland ecosystems function in significant ways to improve water quality and control flooding. At a watershed scale, the extent of wetlands is a measure of the potential for sediment trapping, stormwater storage, and nutrient transformation. Individual wetland functions are highly variable, however, depending on factors such as seasonal changes, location in the larger watershed, storage capacity and ecological condition with respect to pollutant inputs. Despite this variability, the extent of wetlands within a watershed is strongly correlated with healthy eco-systems (Hicks 1997, Amman and Stone 1991, Azous and Horner 1997). Watersheds with a small amount of wetland area have potentially less opportunity for pollutant treatment, less storage capacity to moderate changes in hydrology brought on by urbanization, and a higher potential for direct pollutant delivery to surface waters.

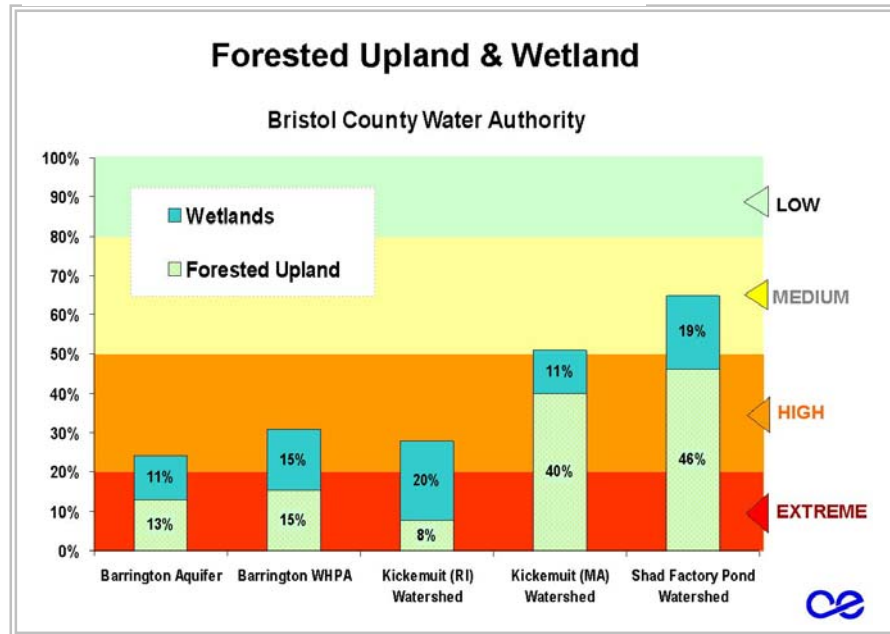
Forests: Watershed Treatment Zones

In New England, field measurements shows that rain and snow contain and deposit nitrogen - about eight pounds per acre each year. When this rain lands on pavement, most, if not all, of the nitrogen can be expected to run off to the nearest culvert and then directly into nearby surface water. However, when this nitrogen-rich rain falls on forested land, the organic matter in soil absorbs and stores the rainwater, and converts atmospheric nitrogen into nutrients for plants and microbes.

In areas rich in forests and meadows, about 95 percent of rainfall infiltrates the soil. It is estimated that of the eight pounds of nitrogen deposited from rain and snow, six pounds are naturally recycled back into soil as nutrients, and only about two pounds per acre are lost to runoff.

Source: Ollinger et.al. 1993 & Yang et.al. 1996.

Figure 3. Estimated Forest and Wetlands Cover



Results: Forest and Wetlands

- None of the assessment study areas contain optimal expanses of forest and wetlands for ensuring high water quality. All but one of the study areas is in the high-risk category for this indicator. For the Kickemuit Reservoir watershed as whole, remaining forested upland and wetland accounts for approximately 40 percent of the total watershed area, placing it in the high-risk category.
- Both of the Barrington groundwater recharge areas are highly urbanized. The Town of Barrington has taken steps to protect most of the remaining forested land in the area.
- In the Rhode Island portion of the Kickemuit Reservoir watershed, pollution risks associated with loss of forest land is somewhat off-set by the high percentage of pastureland (15%). Pastureland can provide pollutant attenuation functions similar to those of brushland and forest. The Town of Warren has taken significant steps to protect most of the remaining forest and farm land in the watershed.
- The Massachusetts portion of the Kickemuit Reservoir watershed is still roughly 40 percent forested and 11 percent wetland area, placing it in the medium-risk category for this indicator.
- The Shad Factory Reservoir and Anawan Reservoir watershed is in the medium-risk category for this indicator. The watershed is approximately 46 percent forested and 19 percent wetland area. Cropland and pasture account for an additional 13 percent of land use. Suburban development accounts for only 22 percent of the total area of the watershed.

SHORELINE LAND USE

High intensity, Impervious, and Forest and Wetland

Riparian simply refers to the shoreline zone, especially where surface and groundwater interact at the margin between land and water. To identify the most serious pollution threats to surface water, this assessment includes a separate analysis of land use and soils within 200 feet of surface waters. The shoreline area is calculated for all ponds, perennial streams, rivers and coastal waters that are large enough to be shown on a 1:24,000 scale USGS topographic map.

The riparian land use indicator actually incorporates a number of analyses, including the percent high intensity land use and percent impervious cover within the total shoreline zone of each study area. The proportion of undisturbed forest and wetland within the riparian area – and its inverse, disturbed forest and wetland – may also be used as a measure of watershed health in sensitive watersheds where any loss of protective buffers is a concern. Riparian characteristics are most useful in evaluating threats to surface waters, but may also indicate risks to wells hydrologically connected to nearby rivers and streams. Key findings are reported in this section with full results provided in the appendix.

Riparian functions

From a water quality perspective, riparian areas have the opportunity to function in two very different ways: 1) Vegetated shorelines can serve as water quality *treatment zones*, maintaining ecosystem health by filtering polluted runoff and removing groundwater nitrogen through biochemical processes; or 2) Disturbed buffers may become high risk *pollutant delivery zones*, especially when intensely developed. Consequently, developed shorelines have diminished capacity to filter pollutants, and may also contain impervious surfaces that can easily deliver pollutants directly to surface waters. Because of the potential for direct contamination of surface waters in the riparian zone, we assign a very low pollution tolerance to shoreline development. For analysis of drinking water supplies, the presence of any high intensity uses within the shoreline zone is considered a risk, with more than 15 percent is ranked as an extreme threat.

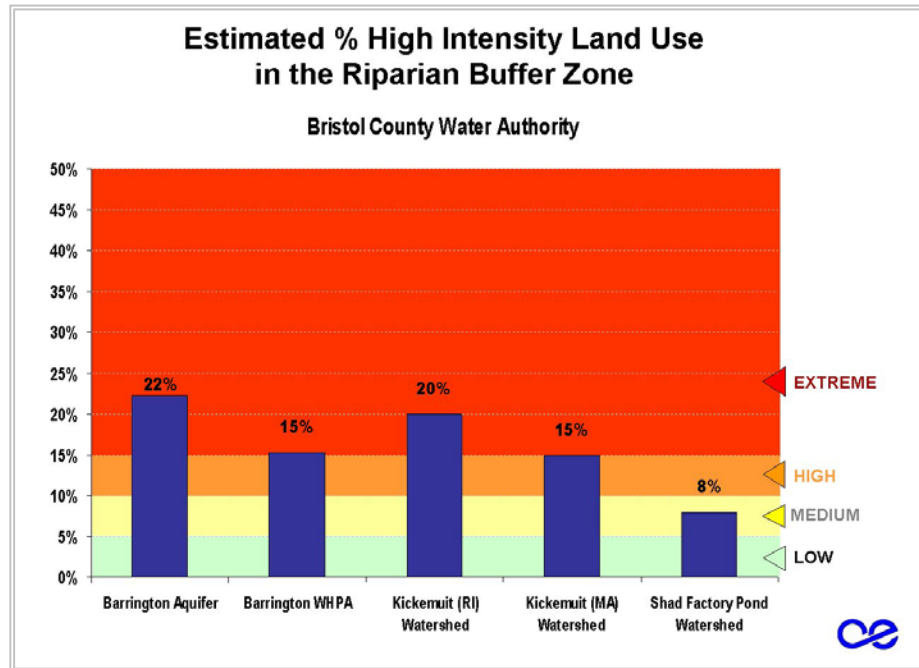
- It is important to note that in this assessment, the 200 ft. shoreline area is purely for analysis of immediate threats and not a recommended regulatory setback. State agencies or municipalities may require more or less than the 200 feet setback from surface waters. Because our goal is to identify the most direct threats to surface waters, our analysis does not include wetland buffers even though these are critical for wetland and water quality protection.

Water Quality Benefits of Shoreline Buffers

Vegetated buffers perform the following important functions

- *Filter sediment, phosphorus and other pollutants in runoff.*
- *Allow stormwater to infiltrate, promoting natural pollutant removal processes in the soil.*
- *Store floodwaters to reduce flooding and habitat scouring.*
- *Stabilize stream banks, especially with undisturbed forest soils and deep-rooted trees.*
- *Remove or recycle nutrients through plant uptake, especially with deep-rooted trees and shrubs.*
- *Maintain cooler temperatures and high dissolved oxygen levels for sensitive aquatic life such as native trout with tree canopy cover – especially important on smaller streams < 100' wide.*
- *Remove nitrogen, potentially transforming up to 80 percent of nitrogen into harmless nitrogen gas through microbial activity (Addy, K. et al. 1999).*
- *Other benefits include scenic views and open space, recreation, and wildlife habitat.*

Figure 4. Estimated High Intensity Land Use in Riparian Buffer



Results: Shoreline Land Use Features

- High intensity land use in riparian buffers (200 feet to a stream, pond, or reservoir) is a serious concern in all but one of the study areas. High intensity land use occurring in riparian zones creates an extreme risk of direct pollutant inputs to surface waters and limits the potential for buffers to function as treatment zones.
- Of the 173 acres of riparian land area in the Rhode Island portion of the Kickemuit Reservoir watershed, approximately 45 acres are being used for agricultural purposes and 23 acres for residential land use. On the Massachusetts side of the watershed, riparian buffer zones are being used for residential and commercial land use (65 acres) and agricultural operations (33 acres).
- Riparian buffer zones are urbanized in both of the Barrington groundwater protection areas. Higher density residential development accounts for the majority of development in these areas.
- The Shad Factory Reservoir and Anawan Reservoir watershed is in the medium-risk category for this indicator. There are, however, over 285 acres of agricultural land occurring within riparian buffer zones as well as close to 300 acres of suburban development (residential and commercial). It is important to bear in mind that the Palmer River, which flows into the Shad Factory Reservoir, is currently experiencing water quality impairments due to excess nutrients, flow alteration and pathogens (MA DEP, 2002). MA DEP has identified a number of agricultural operations occurring in riparian buffers as principal sources of pollution entering the Palmer River or one of its tributaries.

SOILS

The ability of pollutants to move through various soil types is a critical factor in determining the inherent vulnerability of a water supply. Highly permeable soils will allow water and soluble contaminants to move quickly toward a working well, while impermeable or shallow soils will promote runoff to nearby surface waters. Locating potential pollution sources that lie on highly permeable soils in groundwater re-charge areas, or on impermeable or shallow soils near surface water supplies is an important component of this source water assessment. The assessment uses RIGIS data from the Rhode Island Soil Survey to map soils by four standard categories known as hydrologic soil groups. These soil “hydrogroups” describe capability of soils to accept and infiltrate water. Other features evaluated include: seasonal high water table depth; presence of restrictive “hardpan” layers where downward infiltration is extremely slow; and erosion potential, based on slope and texture, where stabilizing construction sites and other land disturbance may be difficult.

When mapped together, hydrologic soil groups and water table depth reveal likely pathways for water flow and pollutant movement. For example, in areas with sandy soils and a deep water table, pollutants can easily infiltrate and percolate to underlying groundwater reservoirs. Alternatively, soils with slow permeability have lower infiltration rates and tend to have a higher water table. In New England wet soils are almost always connected to wetlands, intermittent drainage ways and small streams, forming an extended drainage network where pollutants can easily flow from wet soils to surface waters.

Limitations of soil types

Knowing the proportion and location of soil constraints is a critical variable in predicting pollution risks and in selecting pollution controls. However, soil types are less useful indicators of water flow and pollutant movement where artificial drainage systems are used. Urban storm drains, channelized streams, building sites with subsurface drains, and artificially drained fields all bypass natural rainfall storage and infiltration processes and quickly divert runoff to downstream discharge points. These artificial improvements are not identified and must be field-inventoried. Under the RIDEM Phase II stormwater regulations, municipalities with urban areas will be required to inventory these stormwater systems.

How accurate is that soil map?

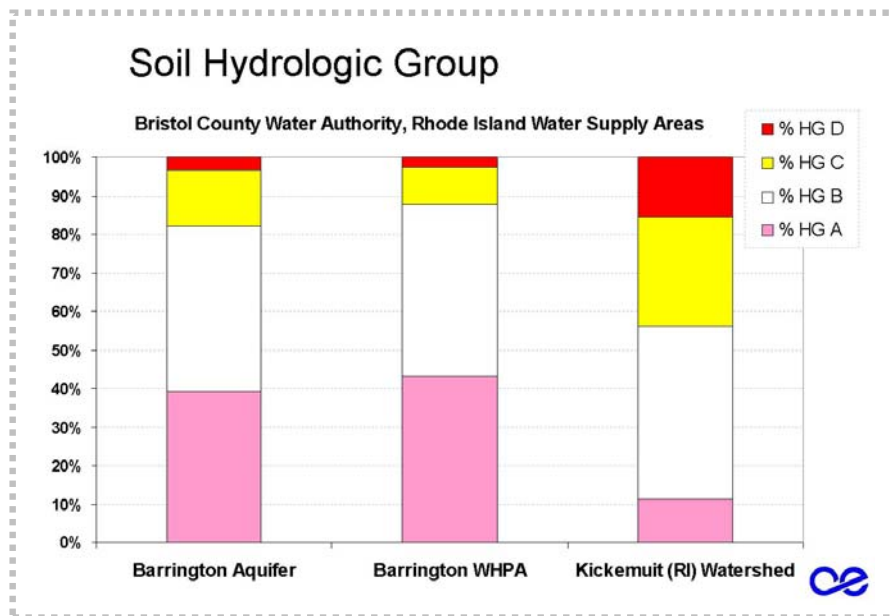
General

The soil boundaries delineated in the RI Soil Survey were field-mapped at a scale of 1" = 1,320 feet. At this scale the actual soil boundary on the ground may vary by up to 40 feet on either side of the line. The smallest mapped unit is 1/4 acre.

Soils in shoreline buffers

Using 100 randomly selected locations within a 100 foot stream shoreline zone, URI researchers recently compared field-verified soils with RI Soil Survey maps. These researchers found that soil maps were highly accurate, correctly identifying the presence or absence of wetland soils in 75 of 100 randomly selected locations within the shoreline zone. This study also found that map accuracy in narrow shoreline zones was also greater than would be expected, with the survey accurately identifying narrow bands of different soils types as small as 22 feet wide, even though national accuracy standards would allow up to 40 feet of deviation between the mapped and actual boundary. (Rosenblatt 1999).

Figure 5. Estimated Percent of Soil by Hydrologic



Results: Soils

Hydrologic Soil Groups

In this assessment soils are grouped by water table depth and hydrologic soil group, which indicates the potential for rainfall to either infiltrate or runoff the ground surface.

A – Excessively rapid drainage;
Water table > 6 ft.
High recharge, low runoff.

B – Moderate to rapid drainage;
Water table mostly > 6 ft.
High recharge, low-mod. runoff

C – Slow to restrictive drainage;
Water table mostly < 3.5 ft.
Low recharge, high runoff

D – Very slow drainage, mostly wetland, water table < 1.5 ft.
Low recharge, high runoff when wetland storage is full.

- Soils data for the Massachusetts study areas is currently unavailable.
- Figure 5 above represents the percentage breakdown of soils by hydrologic group in the Rhode Island study areas. In this assessment, we are most concerned with identifying the location of high runoff, hydrologic group “C” and “D” soils. These soils allow water to infiltrate slowly and commonly have seasonal high water tables. As a result, they tend to generate runoff. Managing stormwater runoff is difficult on these sites and they also pose a higher risk for septic system failure if developed.
- When evaluating risks to groundwater supplies, highly permeable hydrologic group “A” soils present the greatest concern due to rapid movement of water and pollutants to groundwater.
- In the Kickemuit Reservoir watershed, there are approximately 34 acres of agricultural land occurring on high runoff soils, close to half of which are located in riparian buffer zones. These areas are considered “hot spots”—high-risk areas for movement of pollutants to either groundwater or surface waters. Hotspots usually comprise a relatively small land area, but may contribute the largest percent of pollutants to the environment. Directing management actions to the most serious problem sites can be a cost-effective way to prevent or remediate pollution problems.

- In the Barrington groundwater protection areas, high intensity land use on highly permeable soils account for between 20 to 25 percent of the aquifer and wellhead protection area. Although both areas are almost entirely sewered, hence greatly reducing the risk of groundwater contamination from wastewater disposal, there is still the potential of groundwater contamination from hazardous waste spills and leaking underground storage tanks. Improperly treated and managed stormwater runoff also poses a risk to groundwater supplies in this urbanized area.

High Water Table Soils

Recent studies have found that in marginal soils with water tables less than 3.5 feet, groundwater is likely to rise higher than expected following rainstorms and stay elevated for long periods (Morgan and Stolt 2002). Development of these soils therefore requires careful planning to identify suitable areas for temporary storage and infiltration of stormwater, as well as septic system siting to avoid compromising wastewater treatment function.

3.3 Runoff and Nutrient Loading Estimates

The runoff and nutrient loading estimates presented in this section are predictions developed using a standard “mass balance” approach to generate a simple average annual water budget and estimated nutrient sources to runoff and groundwater. These provide additional information on pollution sources and relative contribution from various sources. Phosphorus is used as an indicator of sediment-bound pollutants in runoff. Nitrogen is used as an indicator of other dissolved pollutants in surface runoff and in recharge entering groundwater.

Methods

Calculations are made using an Excel spreadsheet, which also generates statistics on the other watershed indicators described in the previous section. The input data sources are extracted from the RIGIS map database to include site-specific soils, land use types updated by trained volunteers, population estimates, and the estimated number of septic systems in each area studied. The analysis is run first for existing conditions using current land use map data. To evaluate future impacts the analysis is repeated using town zoning maps as the future land use scenario. As noted in the land use summary, this “build out” scenario assumes full development of all unprotected land other than wetlands and surface water buffers (200’). No timetable is estimated for this development to occur.

The model used an average annual precipitation of 40 inches per year, with 18 inches per year lost to evaporation and plant use (U.S. Geological Survey, 1961). The proportion of remaining “available” precipitation (22 inches) that is converted to runoff is estimated using runoff coefficients based on the estimated impervious cover for each land use type and the underlying soil hydrologic group. This is adapted from standard methods (USDA NRCS, 1986). The remainder is assumed to seep into the ground to recharge either shallow or deep groundwater. Recharge to groundwater from septic systems is calculated separately based on average per capita water use and discharge to onsite systems of 50 gallons per person per year.

Nitrogen and phosphorus inputs to surface water from storm water runoff are estimated using generalized pollutant coefficients based on published literature values for 21 different land uses and direct atmospheric deposition on surface waters. Nitrate-nitrogen inputs to groundwater recharge are calculated separately, using results of URI field research on nitrogen losses to groundwater from specific sources, including septic systems, lawns, farmland and forest. Complete hydrologic and nutrient loading assumptions are provided in Appendix K, *Technical Documentation, MANAGE GIS-Based Pollution Risk Assessment Method, Database Development, Hydrologic Budget and Nutrient Loading*. Additional information about the MANAGE assessment method is available at <http://www.edc.uri.edu/cewq/manage.html>

Note on using models to evaluate land use impacts

Field monitoring and modeling are two basic approaches, often used hand-in-hand to evaluate effects of land use activities on water quality. In order to assemble a reasonable picture of watershed or aquifer conditions, water quality models use available information about pollutant interactions and apply it to a particular study area. Modeling is frequently used to estimate the source of pollutants to supplement water quality monitoring, especially when field data is sparse or inconclusive. As an alternative to project-by-project impact review, modeling offers a “big-picture” perspective that is needed to evaluate cumulative impacts. Modeling is a valuable tool in testing relative effects of different land use options or pollution management decisions because even simple models can be used to explore what might happen if land is developed in a different way.

Models can range from the simplest “back of the envelope” calculation, to complex methods that require extensive field data to simulate physical, chemical, and biological responses. In this assessment we use a simple “mass balance” method similar to those widely used in comparable applications elsewhere, including Cape Cod and the New Jersey Pine Barrens. These methods calculate an annual water budget based on water inputs (precipitation) and outputs (evaporation and plant use, runoff, and groundwater recharge). Research results of nutrient losses from different land uses are then used to predict nutrient loads from similar land uses mapped in the study area. This incorporates accepted input values from published literature. Our estimates of nitrogen leaching to groundwater are strengthened by use of carefully selected input values derived from local research.

Typically, results of most mass balance models are generated as average annual estimates of runoff, infiltration, and nutrient loading (loading, or total amount is expressed here as lbs/ acre/year) for each study area. These estimates are useful in comparing relative

differences in pollution risk among various land use scenarios or among sub-watersheds. The concentration of nitrogen (mg/l) entering groundwater can also be estimated based on dilution of inputs with infiltrating rainwater. However, concentration estimates may not necessarily represent the concentration at a well because it is difficult to account for nitrogen loss in wetlands or uneven mixing in deeper groundwater. There are times when a more sophisticated modeling approach is needed. Some examples include: situations when estimates must be compared with monitored water quality data; estimating pollutant loads in runoff or flowing waters on a storm event basis; or tracking movement of an effluent plume in groundwater. In order to generate reliable results however, complex models usually require extensive field monitoring information as necessary data inputs.

Selecting simple vs. sophisticated models

When choosing a model it is important to be aware of limitations of both simple and complex models. For example:

- All models generate results that are only as good as the input values; results of both simple and sophisticated methods are estimates.
- Because output data from sophisticated models can easily appear to be more solid than it actually is, users must be careful to avoid generating false confidence in uncertain results.
- Complex models may not generate more useful data for management, especially when comparing relative differences may be adequate for choosing pollution controls.
- The cost of complex modeling with field data collection is typically orders of magnitude greater than screening level modeling and assessment approaches.

The decision on whether to use a simple vs. complex model should consider the costs and benefits of additional study vs. implementing pollution controls. Management decisions need to be based on good science with sound findings of fact.

SURFACE RUNOFF

Runoff is not a common natural occurrence. In forested watersheds with sandy soils, up to 97 percent of precipitation can be expected to seep into the ground (Simmons, D. and R. Reynolds 1982). In well-drained upland areas, this infiltrating water recharges deeper groundwater supplies. In areas where the groundwater table is near the surface, water seeping into the soil enters shallow groundwater and flows to nearby wetlands and streams. In critical periods without rain, groundwater discharges to streams as “base flow” - the primary source of water in streams.

Runoff is associated with declining water quality because it disrupts the natural cycle of infiltration and gradual discharge to streams. Land development compacts the soil and adds acres of pavement, dramatically increasing the rate and total volume of storm water runoff. The result is increased flooding, stream scouring with loss of aquatic habitat, and reduced groundwater recharge. In addition to these hydrologic impacts, storm water runoff washes off and delivers pollutants directly to the nearest surface waters. Street runoff is contaminated with oil and grease, metals, sediment, nitrogen from atmospheric sources, and other pollutants. Runoff from residential areas carries pesticides, fertilizers, and animal waste. Runoff may also be contaminated with wastewater effluent from failing septic systems, improper connections of sanitary wastes to storm drains, or leaking sewers.

As a watershed health indicator, surface runoff levels signal potential pollution risks by identifying:

- High runoff zones where hydrologic impacts and runoff pollutants are likely to be greatest;
- Relative change in runoff between current and future conditions, and with use of storm water controls; and
- Water flow and pollutant movement pathways to support selection of management practices.

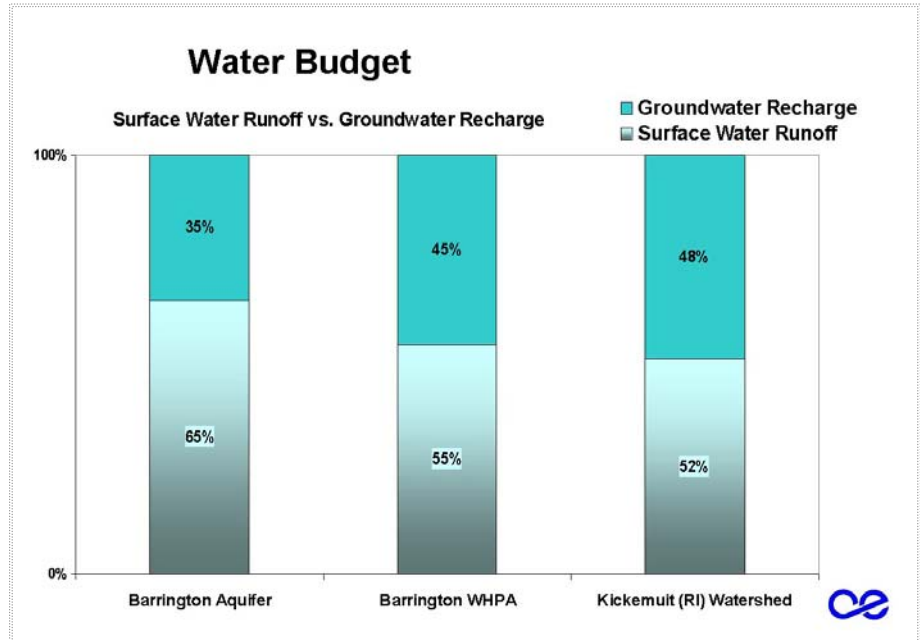
Interpreting runoff estimates

Runoff calculations estimate the proportion of rainfall that is likely to runoff rather than infiltrate the ground surface. This runoff estimate includes rainfall running directly off the surface and shallow subsurface flow that may reach surface waters during or shortly after rain events. However, runoff estimates do not take into account temporary storage and infiltration that will affect the amount of runoff actually reaching a surface water body. Moreover, the effect of closed drainage systems with the potential to rapidly convey runoff to a surface water discharge point is not considered separately from a higher runoff coefficient for more urban impervious land.

Results: Surface Runoff

- Data was not available for the Massachusetts study areas.
- Surface water runoff is the primary flow path for precipitation in the Rhode Island study areas. Assessment modeling results are based on the assumption that 40 inches of precipitation falls annually in Bristol County, 18 inches are lost to evapotranspiration, and 22 inches either recharge groundwater or enter surface waterbodies as runoff.
- In the Barrington groundwater protection areas, high levels of surface water runoff occur due to very high levels of impervious surface area. If these areas were undeveloped, groundwater infiltration would be the primary pathway for precipitation based on soil types in the area. Assessment-modeling results show that in the Barrington Aquifer recharge area, over 200 million gallons of recharge to groundwater is lost annually due to the large extent of impervious surface area.
- In the Kickemuit Reservoir watershed, the high level of surface water runoff (52%) is primarily due to the presence of high runoff soils and the reservoir itself, which accounts for roughly 20 percent of runoff in the watershed. Impervious surface area also contributes to high runoff in the watershed. For instance, medium-high density residential development accounts for 17 percent of the Rhode Island portion of the watershed, but contributes 30 percent of surface water runoff.

Figure 6. Estimates of Groundwater Recharge and Surface Water Runoff



NUTRIENT LOADING

Nitrogen Concentrations	
0.2 mg/l	Natural background level in Rhode Island groundwater
1 mg/l	A sign of human activities influencing groundwater.
5 mg/l	Planning action standard, indicator of degraded water quality
10 mg/l	Federal drinking water standard or Maximum Contaminant Level (MCL)
<i>Wastewater Effluent</i>	
40-60 mg/l	Effluent from standard septic system.
< 20 mg/l	Treated effluent from nitrogen-reducing septic system.
* In this report, monitored Nitrate-Nitrogen concentrations and estimated loading rates are referred to as nitrate concentrations.	

Note on Nutrient Loading Estimates:

The nutrient loading estimates used in this assessment assumes the use of reasonable management practices. However, inputs may be much higher where lawns are over fertilized and over watered or where fertilizers are spilled or otherwise wash into storm drains. In addition, nutrients and bacteria inputs are likely to be comparatively higher where pet waste on curbs and sidewalks wash directly into storm drains and where bird and wildlife waste flow directly from roads, storm drains, and under bridges into surface waters. Commercial and Industrial activities vary widely in both the amount of effluent generated and its strength. For a more accurate estimate, these should be calculated individually to determine average flows, flow variability, and concentration of wastewater inputs.

Nitrogen as a pollution indicator

The total amount, or “load,” of nutrients generated in the wellhead protection area or watershed is a widely used measure of pollution risk. Nitrogen loading estimates are most critical when assessing potential pollutant inputs to groundwater and coastal waters. Nitrogen is commonly used as an indicator of pollution from human activities for the following reasons:

- Nitrogen contaminates drinking water, interfering with oxygen absorption in infants and causing other health effects. The federal health standard for the nitrate form is 10 mg/l; the drinking water action level of 5 mg/l triggers increased monitoring. Some municipalities in Rhode Island are currently using 5 mg/l as regulatory limit.
- Nitrogen is associated with human inputs such as fertilizers and septic systems when groundwater nitrogen levels exceed 1 mg/l. The natural background level in Rhode Island groundwater is very low at 0.2 mg/l or less.
- Nitrogen moves easily in surface and groundwater, and can indicate the presence of other dissolved pollutants such as bacteria and viruses, road salt, and some toxic chemicals.
- Nitrogen over fertilizes coastal waters, leading to excessive growth of nuisance seaweed and algae, low dissolved oxygen events, loss of eelgrass, and declines of shellfish beds. Healthy coastal waters generally have extremely low nitrogen concentrations, so even relatively small inputs above naturally occurring background levels can cause a problem.

Input values designed to match the local study area

Nutrient loading predictions in this report are modeled estimates based on site-specific land use and soil conditions in each study. This uses accepted values for nutrient inputs from various land uses based on: 1) field research on nitrogen losses to groundwater from septic systems, lawns, turf and corn fields, and forests conducted in southern Rhode Island by URI scientists; and 2) current published literature values for surface runoff. Because groundwater inputs are based on extensive and reliable local data, nitrogen-leaching estimates to groundwater are more accurate than nitrogen inputs to surface runoff.

Nutrient source estimates are derived from the number of homes and businesses in the study area and the total acreage of different land use types. For example the number of septic systems, an important input variable for groundwater nitrogen loading, is estimated from the number of homes and businesses in unsewered portions of each study area based on five residential land use categories, four nonresidential

mapped land use types, and mapped sewer districts. To refine our estimate, we updated the RIGIS 1995 land use using corrections mapped by trained local volunteers and adjusted the residential units to reflect the town parcel database. U.S. Census data was used to estimate occupancy per dwelling unit. Nutrient loading assumptions were also reviewed by local assessment volunteers and revised as needed.

Types of Outputs

Nutrient inputs are estimated as the total average annual amount, or loading (pounds/acre/ year) of nitrogen and phosphorus entering surface water runoff, and the total amount of nitrate-nitrogen entering groundwater recharge annually. These estimates represent nutrient sources at the point of origin, not the amount that might ultimately reach a groundwater aquifer, pumping well, wetland, or other surface water body. The nitrogen inputs to surface water represent the amount entering surface runoff at the point where runoff is generated; nitrogen inputs to groundwater represent the amount of nitrogen percolating into the groundwater with precipitation and septic system effluent. Nitrate loading to groundwater recharge is also estimated as a concentration by diluting the total load with the volume of infiltrating rainwater and septic system effluent. Due to uneven mixing in groundwater we don't assume this concentration will be the same at a pumping well.

Uncertainties in Mass Balance Models

Since model estimates represent sources potentially generated, the actual amount that might ultimately reach a well or surface water body is likely to be less. The opportunity for nitrogen uptake is greater in large watersheds with abundant wetlands, where shoreline buffers have high nitrogen removal potential, and where pollution sources are further removed from sensitive receiving waters. The potential for nitrogen removal is lower in wellhead protection areas where nitrogen enters groundwater as recharge to a pumping well without treatment in wetlands. In these wellhead protection areas we assume that over time the quality of the underlying groundwater will begin to reflect the quality of recharge water entering the wellhead.

The estimates do not consider a number of factors such as: concentrated plumes of effluent where nitrogen levels may be much higher than average per acre loadings; the effect of storm events; other pollutants such as spills from underground storage tanks; and nitrogen uptake through natural processes. In addition, wastewater flow from nonresidential land uses are highly variable in both effluent strength and volume and should be calculated individually if a more accurate estimate is needed.

ASSUMPTIONS

Nitrogen loading to groundwater recharge

Septic systems

2.41 persons/dwelling unit
50 gal/person/day wastewater
2.3 lbs P/person/yr (15.1 mg/l)
7.0 lbs N/person/yr (46 mg/l)
90% leaching to groundwater

Commercial, Industrial and Institutional assumed equivalent to one dwelling unit /acre. Recreational land use assumed same but in use for 6 months annually.

Agricultural Fertilizers

*Active cropland and orchard
64.5 lbs N leached to groundwater based on 215 lbs N applied /acre/yr, 30% leaching.*

Lawn Fertilizers

*25 –50% residential area is lawn.
75% of landowners fertilize.
10.5 lbs N leached to groundwater based on 175 lbs (4 lbs N /1000 sq.ft.) N applied /acre/yr, 6% leaching.*

Pets

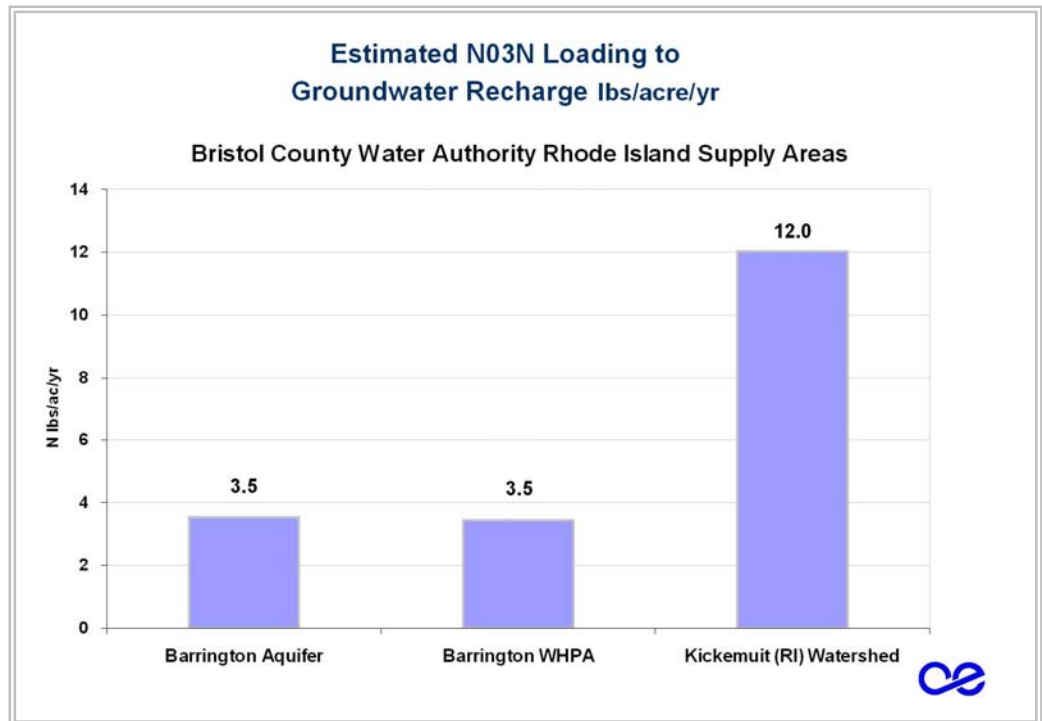
0.41 lb N/person/yr. Leaches to groundwater from pet waste.

Background

1.2 lbs/acre/yr leaches from unfertilized lawns, pastures, forests and brush areas.

As a result of uncertainties inherent in this mass balance approach, modeled nutrient estimates are most useful in comparing relative differences among land use types, among sub-watersheds, between current and future land use, and in comparing potential reductions nutrient inputs with use of management practice

Figure 7. Estimated Nitrogen Loading to Groundwater



Results: Nitrogen Loading

- Data is not available for the Massachusetts study areas.
- Nitrogen loading to groundwater is highest in the Kickemuit Reservoir watershed. At 12 lbs/acre/yr the estimated loading to groundwater is considered a high risk to downstream water quality. This represents a concern for groundwater resources in the area as well as downstream coastal waters which may be nitrogen-sensitive. Agricultural fertilizers account for close to 70 percent of loading. Although most of the dense suburban development in the watershed is sewered, septic systems still account for an estimated 13 percent of total nitrogen loading to groundwater recharge.
- Nitrogen loading in the Barrington groundwater protection areas, at less than 5 lbs./acre/year, is considered a low risk. Lawn fertilizers and pet waste are the primary sources of nitrogen entering groundwater recharge (3.5 lbs/acre/yr). Estimates of nitrogen loading from lawn fertilizer are based on modeling assumptions that 75 percent of residents and businesses apply fertilizers at a rate of 175 lbs/acre/yr or 4.0 lbs/1000 sq.ft./yr, with 6 percent leaching to groundwater recharge. Leaching rates to groundwater can rise appreciably if lawns are over-watered or fertilized prior to a storm event.

Phosphorus as a pollution indicator

Phosphorus is the key nutrient responsible for over fertilizing freshwater lakes, ponds, and streams. Although phosphorus is essential for algal and aquatic plant productivity, even minute increases in the amount of phosphorus can trigger tremendous increases in growth. For example, the natural background concentration of phosphorus in Rhode Island waters is only 5 to 10 *parts per billion*, which is equivalent to .005 to .010 parts per million or mg/l. The RIDEM maximum average total phosphorus standard for freshwater lakes and reservoirs is 25 parts per billion.

The degree of nutrient enrichment or “eutrophication” in a lake or pond is measured by the abundance of aquatic plants and algae, and phosphorus. Although eutrophication is a natural process whereby nutrients, sedimentation, and aquatic plant productivity increase as a lake or pond ages, phosphorus inputs from human activities can greatly accelerate this process. Managing phosphorus inputs to surface drinking water supplies is particularly important for man-made reservoirs as they tend to become eutrophic more rapidly than naturally formed lakes. There is a tendency for these reservoirs to revert back to their original state, usually a stream system or marsh (Addy and Green, 1996).

In drinking water reservoirs, nutrient enrichment is a problem because algae and accumulating sediment from runoff and decaying aquatic plants increases organic matter and suspended solids. These affect the taste and odor of drinking water. And while organic matter is not necessarily a health hazard, it reacts with chlorine in the disinfection process to create trihalomethanes. These byproducts are considered a health hazard and EPA has recently reduced that maximum allowable level from 100 to 80 ppb. One way to reduce disinfection byproducts is to reduce excessive organic matter in drinking water supplies by controlling nutrient inputs. Phosphorus’s tendency to attach to sediment makes controlling erosion and sedimentation from farming and construction sites, controlling runoff from highways and other sources, and protecting shoreline buffers effective control measures.

We use phosphorus loading estimates as a pollution indicator for the following reasons:

- Land use activities have significant, measurable impacts on phosphorus levels in surface water bodies.
- High phosphorus levels in freshwater bodies are often associated with the use of phosphate-based detergents, lawn and garden fertilizers, improperly sited and maintained septic systems, leaking sewers, agricultural drainage, pet waste, and urban storm water runoff.
- Phosphorus tends to be associated with sediment and is a good indicator of other runoff-borne pollutants such as metals and bacteria.

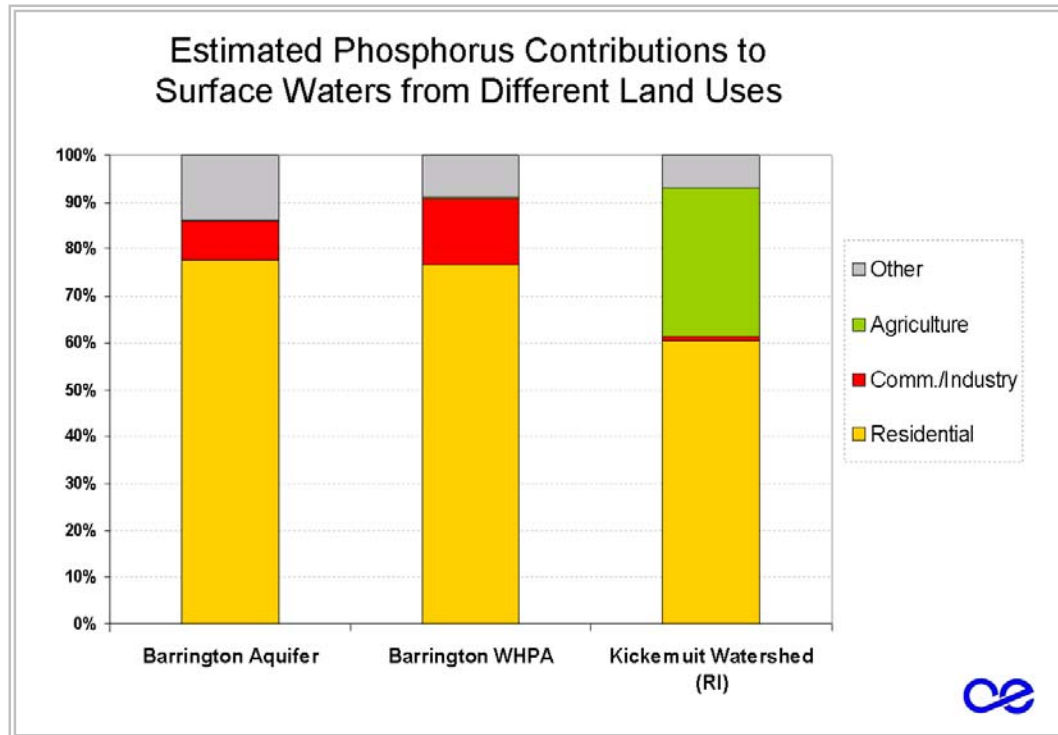
Trihalomethanes (THM) are a group of four chemicals — chloroform, bromodichloromethane, dibromochloromethane, and bromoform — that are formed when chlorine or other disinfectants used to control microbial contaminants in drinking water react with naturally occurring organic and inorganic matter in water.

Individual TTHMs have been classified as being potentially hazardous to human health. To reduce this health risk, EPA published the Stage 1 Disinfectants/Disinfection Byproducts Rule in December 1998. This requires water systems to use treatment methods to reduce the formation of disinfection byproducts and meet stricter regulatory standards.

This rule reduced the federal standard for Total Trihalomethanes (TTHM) from the 100 parts per billion maximum allowable annual average level to 80 parts per billion for all public supply systems beginning in December 2003.

*For more information go to EPA's website:
www.epa.gov/enviro/html/icr/dbp.html#regulatory*

Figure 8. Phosphorus Contributions from Different Land Uses



Results: Phosphorus Loading

- Data is not available for the Massachusetts study areas.
- Residential development is the primary source of phosphorus entering surface waterbodies in each of the three Rhode Island protection areas. Sources of phosphorus from residential development include stormwater runoff containing sediment, lawn fertilizers, pet wastes, and in unsewered areas, failing septic systems.
- The amount of phosphorus entering surface waterbodies is closely associated with levels of impervious surface area and compacted or high runoff soils. Proper erosion control, management of stormwater runoff, reductions in impervious surface area, and proper fertilizer management practices can all significantly reduce levels of nutrients entering surface waterbodies.
- In the Kickemuit Reservoir watershed, pasture and cropland contributes 30 percent of the estimated 771 pounds of phosphorus entering surface water annually.

3.4 Mapping Pollution Risks

Map analysis of land use activities and landscape features helps target the site-specific location of pollution sources and other features that can increase or minimize pollution risk, such as the presence of vegetated shorelines. Mapping supplements the information on pollution risk indicators summarized above, which are calculated as averages for different land use types, or for the study area as whole, not by geographic location. In this section we briefly summarize the two types of map analyses conducted: pollution source “hot spot mapping” and an inventory of potential sources of contamination. Results are incorporated into the basic source water assessment ranking and provided to the town as large-format maps that are not easily reproduced here. A full list of the natural features inventory maps, pollution “hotspot” maps, and other map analyses are provided in the appendix to this report.

POLLUTION SOURCE HOTSPOTS

Contrary to popular belief, pollutants from land use activities – referred to as non-point pollution sources – are not diffusely spread throughout the landscape in random or unpredictable patterns. In fact, much of this “non-point” source pollution can be traced to: 1) high intensity land use activities that generate known pollutants; and 2) specific landscape characteristics such as soil types and shoreline buffers that promote pollutant movement, either to surface waters via stormwater runoff or to groundwater with infiltration. Fortunately, most municipalities in Rhode Island have easy access to mapped data of both land use activities and important landscape features.

When this data is in electronic form, it is relatively easy to overlay known high intensity land uses with problem soils to rapidly pinpoint pollution “hot-spots” – high-risk areas for movement of pollutants to either groundwater or surface waters. These hotspots generally comprise a relatively small land area, but may contribute the largest percent of pollutants to the environment. Directing management actions to the most serious problem sites can be a cost-effective way to prevent or remediate local pollution problems.

Results: Pollution Source Hotspots

The pollution source “hotspot analysis” completed for the Bristol County Source Water Assessment focused on identifying high risk areas for pollutant movement to both surface water and groundwater. This map analysis used updated RIGIS land use data and soils data to locate high intensity land use overlying rapidly permeable soils in groundwater protection areas, and high intensity land use overlying high water table soils (> 1.5 ft) in surface water reservoir watersheds (results are only available for Rhode Island areas). Hard copy maps of these maps will be made available to town planning departments. Both the Kickemuit watershed and the Barrington wellhead protection

Limitations of “Hotspot” Mapping

It is important to emphasize that this assessment and “hotspot” mapping is a rapid, screening level analysis. The soils and land use information are planning level and less accurate for small areas and at boundaries of mapped data layers created at different scales, such as the overlay of soil types, wetlands included under the land use coverage, and stream boundaries. Also, estimates of high runoff areas are overshadowed by man-made drainage alterations. Follow-up field investigations are necessary to verify land use, soil conditions, and presence of potential pollution sources.

NOTE: *It is important to emphasize this is a rapid, screening-level analysis. The soils and land use information used are planning level and less accurate for small areas and at boundaries of mapped data layers created at different scales, such as the overlay of soil types, wetlands included under the land use coverage, and stream boundaries. Also, estimates of high runoff areas are overshadowed by man-made drainage alterations. Follow-up field investigations are necessary to verify land use, soil conditions, and presence of potential pollution sources.*

area ranked in the high risk category for this indicator. See Appendix B for more detailed information.

All high intensity land use activities located in source water areas should be considered potential sources of contamination. It is also important to identify the specific type, location and extent of high risk land uses in relationship to each reservoir or tributary. These mapped locations should be investigated to determine the actual land use at the site and potential for pollutant movement.

Because RIGIS coverages are generally most suitable for planning-level analysis, it is important to understand limitations of the database. In particular, mapping potential “hotspots” based on water flow pathways is less useful where extensive drainage alterations have been made. In this analysis we did not specifically identify and map stormwater discharge locations. A comprehensive source water protection strategy should include field inspections and mapping of these potential problem areas, in coordination with storm drainage system mapping required under EPA Phase II stormwater management planning. Areas of concern include the following:

- Urban stormwater drainage systems short circuit natural water flow and pollutant removal processes. Direct tie-in of sanitary wastes to storm drains, known as illicit discharges, can be an associated contamination source, especially in older settlements.
- Subsurface drains installed in farmland and building lots to lower water tables can serve as a conduit for untreated runoff, carrying fertilizers and untreated effluent to downstream discharge points, especially in high water table areas where the practice may be widespread. These areas should be identified and impacts evaluated at least through observation.
- Water withdrawal resulting in low stream flow during summer periods is a growing concern in areas where various uses compete for limited water supplies or where direct runoff to streams results in loss of groundwater recharge. Similarly, loss of recharge through out-of-basin water supply lines or sewer service can be an additional source of stress.

MAPPED POTENTIAL SOURCES OF CONTAMINATION

The primary goal of the Source Water Assessment is to encourage more comprehensive protection of drinking water sources by providing a consistent framework for identifying and evaluating potential contamination risks. For this purpose, a susceptibility ranking system was developed by RI HEALTH and URI Cooperative Extension that incorporates information on both the vulnerability and sensitivity of each water source. Mapping the location and number of potential sources of contamination is a key component of this ranking system.

Volunteer-identified potential sources of contamination

Mapping volunteers involved in the source water assessment were asked to identify specific high-risk land uses within the individual wellhead protection areas. A master list of these land uses was developed by Rhode Island Department of Health based on the contaminants normally associated with each type of land use, to include:

- **Agricultural** operations were identified based on the likely presence of pesticides, organic compounds, bacteria from animal waste, and nutrients.
- **Automotive** businesses were identified based on the likely presence of solvents and other organic compounds and underground storage tanks.
- **Medical Facilities** were identified based on the likely presence of organic compounds, microbes and nutrients.
- **Other Commercial** including beauty salons, dry cleaners, paint shops, printing or photographic processing and golf courses were identified based on the likely presence of solvents and other organic compounds.
- **Industrial/Manufacturing** businesses were identified based on the likely presence of solvents and other organic compounds.

RIGIS-mapped sources of contamination

Known point sources of pollution included under the RIGIS database were also mapped. These were identified using three RIGIS hazardous material coverages:

- **CERCLA** (Superfund) sites—point locations of hazardous material sites designated by the U.S. EPA and RIDEM.
- **Rhode Island Point Discharge Elimination System** (RIPDES)—point locations for all sanitary waste sites where permits have been issued by RIDEM.
- **Leaking Underground Storage Tank** sites (LUSTS)—point locations for storage tanks and associated piping used in petroleum and certain hazardous substances that have experienced leaks as determined by RIDEM.

Incorporating mapped data into the basic SWAP ranking

The basic Source Water Assessment Program ranking incorporates the results of the hot spot mapping analysis and the number of identified potential sources of contamination as key elements of the ranking. A numeric rating was given to each study area based on the number of mapped pollution sites located in the study area and also the number of sites within the 400-foot inner protective radius of each wellhead or within the shoreline area of a surface reservoir.

The ranking method considers four types of pollution risks, three of which are obtained by RIGIS map analysis:

- The extent and location of high intensity land use in the source area – including mapped “hot spots” such as high intensity land use within a shoreline area or overlying slowly permeable soil;
- Number of potential sources of contamination such as underground storage tanks and dry cleaners;
- Aquifer type, with stratified drift aquifers considered more vulnerable than bedrock aquifers.
- Monitoring record, including history of contaminant detects and nitrate levels in groundwater. This is based on a review of RIHEALTH sampling data for a five-year period and is the only ranking value not obtained by RIGIS.

The SWAP ranking methodology and results for the study area(s) are included in the appendix to this report.

3.5 Summary Results

Fact Sheet

Results of the Source Water Assessment are summarized in a number of ways. To make results easily accessible to local officials and the general public, key findings were summarized in fact sheet format. This color, 4-page summary is available to view or download from the University of Rhode Island website at www.uri.edu/ce/wq and at www.HEALTH.ri.gov/environment/dwg/Home.htm, the RI HEALTH website. Paper copies are also available from RI HEALTH and the water supplier.

Basic Source Water Assessment Ranking

The basic assessment and ranking used for all public water supplies in Rhode Island synthesizes a range of risk factors potentially affecting drinking water quality. These factors include: the intensity of development, number of sites where hazardous materials are used, and location of development in soils where contaminants may move easily to surface waters, and existing water quality based on RIDEM records and the sampling history of the water supply. The SWAP ranking results are included in Appendix B of this report.

The results of this ranking show that the Bristol County water supply has a **MODERATE** susceptibility to contamination. According to RI HEALTH a moderate rating means that the water could become contaminated one day. Protection efforts are important to assure continued water quality.

It is important to note this is an average ranking for the supply as a whole. Individual areas may be more susceptible to contamination due to site-specific conditions and land use activities. When study areas are ranked individually, the Barrington wellhead protection area

and the Shad Factory Pond watershed are ranked as moderately susceptible to contamination, with the Barrington area approaching the high risk level. The Kickemuit watershed is ranked at high risk of contamination due to the number of potential sources of pollution within the shoreline area and nutrient-enriched status. The number of identified facilities using or storing hazardous materials is also high enough to be a concern in the Shad Factory and Barrington wellhead study areas. In the small, 480-acre Barrington wellhead, 21 potential sources of pollution were identified. It is important to note this ranking is based on current land use only, without considering future threats with continued development.

Summary of Land Use Risks

The risk factors described in this chapter, such as percent impervious cover and estimated nutrient inputs, provide additional information on potential threats from land use features beyond the basic Source Water Assessment ranking. Table 1 summarizes results of several key indicators collectively to highlight areas that may be at risk from multiple factors. This “at a glance” overview highlights relative differences in potential pollution risks among study areas.

The first part of Table 1 shows results obtained directly from map analysis or modeled estimates. The cell for each input value is color coded to show the pollution risk rank for current and future values. The second half of the table further synthesizes results by “adding” together results of difference indicators. This is accomplished by converting low to extreme ratings to a simple numerical ranking from 0 to 3. These values are then added up for each study area to create an average value for the study area. Final values are then grouped into categories from low to extreme risk, and a final rating assigned based on total scores from less than 1 to 3, as shown below.

This summary of land use characteristics shows that key risks in the Kickemuit area are high intensity land uses, developed shoreline areas and number of septic systems per acre. In the Barrington area, high intensity land uses and impervious cover are the greatest threats to groundwater, however, runoff and phosphorus inputs are serious risk factors for surface waters such as Brickyard Pond. The Shad Factory area is considered to be at low risk overall but loss of forested buffers is a concern here. It is important to note these estimates are based on existing land use only. Future growth in developing areas is likely to increase future risks beyond current estimates.

This overview is intended to help summarize assessment results and support selection of pollution controls. Since any method used to summarize and rank results can easily mask important data, even “low risk” areas may be subject to contamination. Site-specific mapping and field data should be used to identify pollution sources and guide selection of management practices.

Table 1

Summary of Current Land Use Risks - Bristol County Water Supply

	Kickemuit	Shad Factory	Barrington WHPA
Septics /acre	0.26	0.07	0.00
%Intensive Land Use	20%	11%	43%
% Impervious	7%	4%	29%
Riparian forest & wetland	65%	76%	75%
Riparian Impervious	6%	2%	10%
Nitrate to recharge lbs/ac/yr	4.9	Not Available	3.5
Phosphorus to runoff lbs/ac/yr	0.68	0.39	1.1

	Kickemuit	Shad Factory	Barrington WHPA
Septics /acre	2	0	0
% Intensive Land Use	2	1	3
% Impervious	0	0	3
% Riparian forest & wetland	2	2	2
Riparian Impervious	1	0	2
Nitrate to recharge lbs/ac/yr	0	Not Available	0
Phosphorus to runoff lbs/ac/yr	1	0	3
Final Summary	1.1	0.5	1.9

Pollution Risk Rating

Low	Moderate	High	Extreme
<1	1 -1.9	2 - 2.9	> 3

4. Source Water Protection Tools

The long-term quality of drinking water depends on the combined actions of state and local government officials, water suppliers, and all others who live or work in source water areas. This chapter offers recommendations on some of the most important steps each group can take to protect valuable drinking water resources. Because municipal decision makers have primary authority over land use, and the responsibility to control associated impacts, recommendations focus on protection measures that can be implemented through local plans, ordinances and development standards. These measures consist of current, standard best management practices for managing land use impacts that are generally applicable to all source water areas. Water system security, distribution, or treatment issues that may affect drinking water quality are not part of the source water assessment but would be included in water supply management plans.

Because the focus of the Source Water Assessment Program is on identifying and ranking pollution risks, it was beyond the scope of this assessment to develop a detailed action plan for each study area. Major community water suppliers in Rhode Island are required to prepare a Water Supply System Management Plan that must describe specific measures needed to protect each reservoir or well field from sources of contamination. In addition, town comprehensive plans must include a water supply management component with a detailed implementation plan for drinking water protection.

Given this planning framework, the recommendations in this chapter are designed to complement existing efforts by providing a checklist of protection tools against which town officials can compare current practices, identify successful programs to be maintained and gaps to be filled. Because the effectiveness of any protection measure lies in the details, an audit of current plans, land use ordinances, and actions already taken to prevent pollution is need to determine their actual effectiveness. For example, the value of a groundwater zoning overlay district would depend on the area covered, the permitted uses and performance standards, the standards for review and approval of variances and special exceptions, and enforcement procedures. Municipal staff and boards who work with these programs on a regular basis are best qualified to conduct this review and make practical recommendations. Priority actions can then be incorporated into municipal plans, capitol improvement budgets, and ordinances to strengthen protection of valuable groundwater resources.

Water Supply System Management Plans

All large community water suppliers in the State are required by Rhode Island law to submit a water supply system management plan to the RI Water Resources Board.

The “water quality protection” component of the plan specifically requires large suppliers to identify “measures needed to protect each reservoir or well field from sources of contamination, including acquisition of buffer zones, diversion of storm water or spills, and desirable land use control regulations,” and to prepare “a priority list of actions for implementing these protection measures.”

www.wrb.state.ri.us/index.html

Unique Features of Source Water Assessments

SWAP assessments provide a screening level analysis and are not a substitute for a thorough Watershed Management or Groundwater Protection Plan. Yet assessments do have unique and useful features:

- Applied to all RI supplies, large and small,
- Consistent methods used for all supplies,
- All supplies rated for susceptibility to contamination.
- Future impacts evaluated through “build-out” analysis site specific to each wellhead and subwatershed of each major supplies.
- Cumulative effects of land evaluated using nutrient loading, percent impervious cover, other “indicators” and map analysis.
- Geographic information systems used for mapping and analysis provides basis for future planning.
- Results are made available to suppliers, local officials and others for use in developing priority protection actions.

4.1 Factors to Consider in Selecting Management Practices

The risk ratings used in this assessment are intended to help guide selection of management practices and direct efforts to the most serious threats. Given that all public water suppliers already have safeguards in place, it can be difficult to assess when existing efforts are sufficient and when more stringent controls are needed. RI HEALTH makes it clear that no source is free of contamination risk, and that without sufficient protection, any water supply can become contaminated. Even where there is general agreement on the need for stronger drinking water protection, there are no simple formulas for selecting the best mix of controls to achieve the desired degree of protection. This section outlines some of the factors to consider in making management decisions. However, making decisions about drinking water protection depends on town goals and policies that go beyond technical assessment results, as described below.

Municipal support for protecting drinking water and degree of protection desired

Comprehensive community plans establish goals for drinking water protection that identify critical resource areas and the degree of protection desired. These goals are implemented through zoning, land development regulations and budgeting for capital projects. The actual priority given to maintaining water quality is relative to competing goals such as minimizing local land use restrictions and promoting economic development. Some of the factors that influence the degree of protection needed and community willingness to adopt additional protection measures include, for example, the following:

- Co-occurrence of other sensitive resources within or downstream of the source water area. Sensitive aquatic habitat may actually require more pristine water quality than drinking water supplies. Two examples are cold-water trout streams, which are highly sensitive to sediment and increased temperature; and poorly flushed coastal waters, which are sensitive to nitrogen at levels far below 1 mg/l while the drinking water action level is 5 mg/l.
- Availability of multiple supplies, auxiliary supplies or alternative water sources within a system to provide emergency backup or replacement if one source is contaminated. Situations where no options are available call for a greater degree of protection. On the other hand where drinking water taste and odor is already impaired, local officials may feel that restoration is not cost effective and that funds are better spend seeking new sources.
- Willingness to rely on remediation and additional treatment in the case of contamination. Chlorination of groundwater supplies or use of more advanced treatment technologies may be viewed as a viable option to a high level of protection. However, the cost of treatment and changes in taste and odor should be evaluated. Formation of chlorination by-products known as total trihalomethanes may be

difficult to control with nutrient-enriched surface waters even with a high level of water treatment. Contamination by MTBE, fuel or solvents is much more costly and difficult to treat.

- Public perception of the potential for the supply to be compromised and willingness to accept this risk. For example, in developed watersheds where high-risk land uses have co-existed in within a watershed or wellhead without serious impact to water quality, local officials may reason that contamination is unlikely and that current protection practices are adequate.
- Confidence in existing protection measures. The municipality may already have adopted protection measures that may be viewed as sufficient for the time being, especially if additional protection measures are costly or unpopular.

Need for local action: State vs. municipal roles

A common misconception is that state agencies such as the RI Department of Environmental Management are responsible for protecting environmental quality and local controls are unwarranted or even beyond local authority. In reality, state agencies establish statewide, minimum standards for resource protection. Even where more stringent water quality criteria or development standards exist for drinking water supplies, these may not be sufficient to protect sensitive resources or to control cumulative impacts for the following reasons:

- State regulations are directed to avoiding impacts from individual projects on a case-by-case basis and do not specifically address the combined effects of multiple projects. As a result, state regulations may not be sufficient to protect sensitive water resources depending on the intensity of development and it's location in sensitive areas.
- At the State level, permit review is often compartmentalized based on resource type or pollution source. For example, applications for design of septic systems are reviewed based on the potential for a system to function properly on a particular site. Other impacts to wetlands or stormwater runoff must be evaluated separately.
- State agencies may grant variances from minimum standards on a case-by-case basis through established permit review procedures. For example, land that may have been considered unbuildable or uses considered too intense for a site may be approved by variance from individual sewage disposal system regulations or freshwater wetlands alteration permit.
- State agencies may lack site-specific data to identify sensitive resources requiring more stringent control to either prevent degradation of high quality waters or reduce impacts to water bodies showing signs of stress.
- State agencies have limited staff and are under pressure to review and approve permits in a timely fashion. Staff resources for follow-up field inspections and enforcement is often inadequate.

Given the need for resource protection at both the state and local level, the RI Zoning Enabling Legislation specifically authorizes RI cities and towns to designate critical resources and establish more stringent standards that take into account the sensitivity and vulnerability of local resources.

Selection of management practices based on sound planning

Although this chapter takes of broad view of “best management practices” to include planning and zoning strategies, discussion of pollution controls frequently centers on pollution control technologies, such as the type of stormwater treatment system used. Selecting performance standards and accompanying treatment systems is actually the last step in protecting water resources and not a substitute for sound planning and careful site design. Standard resource-based planning practice is based on a hierarchy of these three basic principles.

1) Wise land use planning and zoning. The type and intensity of land use should be appropriate for the resource. Low density, low impact uses, in combination with purchase of land or development rights for the most critical areas and unique resources, offers the surest protection for drinking water supply watersheds and recharge areas. These low-risk uses correspond to source areas with an average of less than 10 percent impervious, well-forested source areas, and undisturbed, forested shoreline zones.

2) Good site design. Careful site analysis based on natural resource mapping and field investigations, use of creative design to preserve the most sensitive and valuable site features, and use of building envelopes to limit clearing and grading within suitable areas are all low-cost, low-maintenance methods for minimizing project impacts.

3) Appropriate “best management practices” are used where impacts can’t be avoided or minimized through planning or site design alone. These include, for example, techniques for hazardous materials storage, stormwater treatment systems and wastewater treatment technologies. To provide flexibility to address site-specific constraints performance standards can be set specifying the level of treatment to be provided by stormwater and wastewater systems, with the selection of the actual methods and technologies left to the designer.

When properly designed, operated and maintained, engineered management practices can effectively offset impacts of more intense development, but usually with much higher maintenance demands. High-maintenance technologies also require greater local oversight to ensure maintenance is carried out properly and that safety precautions are used over the long term. As a result, more complex pollution control systems require the greatest local investment of resources over the long run. In undeveloped areas where options are still available, relying on low density land uses is generally the least costly since

simple, nonstructural controls such as grassed swales, protected wetland buffers and conventional septic systems are the least costly to maintain over the long run. In communities with limited staff to oversee or assume responsibility for maintenance, prohibiting high risk uses and relying on simple, nonstructural controls may be more practical over the long run. As one town highway supervisor put it when referring to the type of stormwater controls allowed in his rural community – “if it can’t be maintained with a backhoe, it doesn’t get built”.

Use of current management practices

Ongoing research on pollutant movement and effectiveness of various control strategies means that methods for controlling water quality impacts are constantly evolving. What may have been state-of-the-art even a few years ago may now be recognized as inadequate, especially for more sensitive resources. New, updated pollution control methods may also be simpler, with lower maintenance needs, as in the case of “low impact” stormwater controls. The current 5-year review cycle for updating municipal plans and supporting zoning ordinances and land development standards provides a good opportunity to bring performance standards for drinking water supply areas in line with current practices. Because the wheels of state government often move slowly, updating municipal land development standards may require use of new approaches that go beyond State minimum standards.

Level of management appropriate for the type of resource

In general, the more stringent practices are appropriate for more sensitive, high value, or high-risk areas where the goal is to protect very high water quality or restore impaired waters. In these situations, state minimum standards may not be adequate to address cumulative effects of land use activities within a watershed or recharge area using minimum standards. On the other hand, adoption of more stringent performance standards must be grounded in sound science, with required controls based on the pollutants of concern in a particular source area, existing water quality conditions and reasonable expectations for maintaining or restoring water quality.

Focus on pollution prevention

The management practices in this chapter emphasize pollution prevention techniques as the simplest and most cost effective approach to protecting water supplies, as opposed to pollution remediation or additional water treatment. A compelling justification for pollution prevention is that even low-level contaminants can affect taste and odor of drinking water standards at concentrations far below maximum health standards.

Threats to Coastal Waters

30% of RI coastal waters are closed to swimming, shell fishing or unsafe for aquatic life due to bacteria, nutrients or low oxygen.

The major sources are:

- *Runoff*
- *Septic systems*
- *Natural sources*
- *Combined sewers in urban areas.*

RIDEM 2002

Cost effectiveness and multiple benefits

Water quality benefits of pollution controls may be difficult to measure. For the most part we recommend management practices with documented pollution removal efficiency. Practices with uncertain water quality benefit may also be included where implementation costs are low and where multiple benefits can be achieved. For example, use of conservation development designs are recommended as a useful technique for reducing site disturbance and preserving undisturbed forest and wetland buffers. Water quality benefits are difficult to measure and may vary project by project. However, because cost is the same or lower than with standard development and we designed projects usually offer multiple aesthetic and open space benefits, conservation development design is included as a primary protection strategy for developing watersheds.

4.2 Management Actions for Municipal Government

The following management practices are loosely organized according to the eight watershed protection tools outlined by the Center for Watershed Protection in the Rapid Watershed Planning Handbook and other publications (Center for Watershed Protection, 1998; 2000; and http://www.cwp.org/tools_protection.htm). These tools correspond to the stages of the development cycle, from initial land use planning, site design, construction, and land ownership. This is a logical progression and integrates a range of pollution controls. Additional information about these practices and guidance on selecting the appropriate level of control based on watershed vulnerability is also available through the Center for Watershed Protection and other sources.

1. Planning and zoning

Review assessment results and incorporate recommendations into town plans

Designate a committee to review assessment results with the following responsibilities: compare general assessment findings with watershed features and actual water quality conditions to validate results with review of technical assumptions as needed; evaluate effectiveness of current water supply protection measures to address identified risks, select priority actions, and report back to council with recommendations.

- Work with neighboring communities sharing water supply sources or service areas.
- Coordinate drinking water protection with stormwater planning under the RIDEM Phase II stormwater program.
- Provide continued support and resources to implement key recommendations, including updating town plans and ordinances.

Update water resource protection goals in comprehensive community plans

Are groundwater recharge areas and watersheds of drinking water supplies and other sensitive water resources clearly identified in town plans as protection priorities? Source water areas and other sensitive water resources should be clearly set apart as resources requiring the highest level of protection.

Establish specific water quality goals for critical areas, specifying the level of water quality and associated sensitive uses to be met. Typical goals include for example: maintaining existing high level of water quality to avoid the need for additional treatment, protection of co-occurring sensitive resources such as cold water fisheries or unique aquatic habitat, and ensuring maximum quantity of groundwater supply by maintaining pre-development infiltration rates.

Update town plans to incorporate source water protection goals and recommended actions at the 5-year Comprehensive Plan revision and associated visioning sessions.

Set aside an annual council work session with staff to review progress on meeting plan goals. Invite representatives of Planning and Zoning Boards, Conservation Commission, water suppliers, groundwater committee and others. Set annual action items.

Evaluate current and potential future impacts of zoning

In areas where current land use activities already present a high risk, are zoning standards and land development regulations adequate to minimize existing threats? A detailed review of current practices in comparison to recommendations of this assessment, water supply management plans, and other existing plans is needed to

Compare the change in risk from current to future land use for the study areas using bar charts for individual indicators in the “pollution risk results” chapter of this report. In a few cases where a build out analysis was not conducted, town future land use or zoning maps should be consulted to identify areas where commercial, industrial or high intensity development are planned.

Where future risks are noticeably higher than current conditions, are permitted uses consistent with town goals for the area? If not, is it possible to revise permitted uses in keeping with water quality goals?

Is there an opportunity to re-zone to lower intensity activities? If not, have standards for site design and best management practices been established to minimize risks?

Threats to rivers and streams

35% of RI rivers and streams do not meet fishable or swim quality due to bacteria, nutrients or metals. Major sources are:

- Runoff
- Septic systems
- Waterfowl and wildlife
- Direct discharges in urban areas

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Set goals for average watershed impervious cover

Use estimated impervious levels to set maximum levels based on current and future estimates. Wherever possible set average impervious goals below 10 percent for undeveloped watersheds (or less than eight percent in watersheds with sensitive aquatic habitat). Where watershed restoration is a priority, set average impervious goal at less than 25 percent. These are average levels for the watershed or recharge area as a whole; low-density residential areas may be 8-10 percent, while commercial areas may be set at 25 percent. In all cases target levels should be realistic based on estimated current levels and build out projections.

Incorporate impervious cover limits into zoning ordinances and land development regulations. Define maximum lot coverage to include all improvements such as buildings, driveways and parking areas, accessory structures with a foundation, impermeable patios, pools and similar surfaces.

Specialized plans

Groundwater / watershed protection plan. Has a municipal groundwater protection plan or watershed protection plan been adopted? If so, compare current practices with plan recommendations. Evaluate need to update plan or accelerate progress in implementing recommendations.

Water Supply Management Plan. Have town boards and commissions been involved in development of water supply management plans? Development and implementation of these plans should be closely coordinated with municipal planning and zoning activities.

Wastewater Management Plan. Municipalities are responsible for ensuring onsite wastewater treatment systems are properly maintained. Adopting a wastewater management plan is the first step in this process. This plan describes the existing status of onsite systems, including areas in need of remediation. It identifies future treatment needs and potential problem areas, evaluates septage handling capacity, sets town policies for promoting proper system maintenance, repair and upgrading, and describes proposed actions such as proposed inspection ordinances and educational strategies. An approved plan qualifies town residents to access low interest loans for septic system repair using the state revolving loan fund.

Update Water and Sewer facility plans with service boundaries

Have water and sewer utility districts been established, setting limits for future sewer and water extension into source water areas? How are applications handled for changes to established utility districts? Major changes to sewer districts require revision of sewer facility

plans, which must be approved by RIDEM. However, small changes that may be inconsistent with town plans and utility plans may be approved more easily. Urban growth boundaries may also be set, consistent with utility service districts, to clearly demarcate village and urban areas where infill is encouraged, sensitive source water areas where sewered development is contained, and outlying areas where low density is maintained without utilities.

Consistency with State Plans

Town plans must be reviewed by the Rhode Island Statewide Planning Program and other state agencies and approved for consistency with the State Guide Plan and programs administered by various state agencies. Situations remain, however, where drinking water source areas are zoned for high-risk activities such as industrial, commercial or high density uses after town plans are approved. State planners should consider establishing standards for review of town plans and ordinances to ensure that minimum protection measures are in place. Where more intensive land use is allowed through zoning, land development standards should be strengthened accordingly to minimize impact of high-risk activities.

Update zoning ordinances and land development standards consistent with adopted plans

Zoning standards and land development regulations are the mechanism used to implement land use goals. As noted above, the actual effectiveness of land use standards lies in the detailed provisions and their implementation. Specific strategies for controlling land development impacts are described in other section of this chapter.

Groundwater / watershed overlay zoning

Special protection measures are often adopted as part of an overlay zone where more stringent provisions apply to the source water area in general or to particularly sensitive areas such as shoreline zones and areas with high water table or other siting limitations. Factors to consider in evaluating effectiveness of the overlay zone include the following:

- Does the district cover all important recharge areas such as the aquifer recharge area, not only deeper reservoirs or wellhead protection areas?
- Are general protection measures in place for areas served by private wells outside of the key recharge areas?
- Are high-risk activities that use, generate or store hazardous materials prohibited? (Note: RIDEM regulates hazardous waste, not storage of hazardous products before waste is generated.)
- If commercial or industrial zones exist within the protection area are these activities consistent with town plans? If not, is a zoning change possible? If so, are site design, performance standards and

RIDEM's Wellhead Protection Program and Requirements

Since 1997, RIDEM has required under its "Rules and Regulations for Groundwater Quality," that municipal governments and all large water suppliers submit detailed wellhead protection plans.

The Wellhead Protection Program applies to all 671 public wells in the State.

Required plan elements include:

- 1) An evaluation of the groundwater quality within the wellhead protection area
- 2) A description of past and present efforts to protect groundwater quality
- 3) Identification of the protection strategies determined to be most appropriate for protecting groundwater quality
- 4) Recommend or draft a five-year implementation plan.

RIDEM. Wellhead Protection Plan Guidance, September 1996

town oversight and enforcement procedures strict enough to minimize impact?

- In areas that are already intensively developed, do land development standards include provisions to minimize impact with infill and redevelopment? For example, redevelopment of urbanized areas often provide an opportunity to retrofit drainage system for improved stormwater treatment, reduced impervious area through good design or use of permeable materials, restoration of wetland buffers, and improved wastewater treatment.
- Are new underground fuel storage tanks prohibited? Does this apply to all tanks, including new home heating fuel tanks? Are owners of existing home heating tanks required to remove tanks at the time of house sale or are incentives offered to encourage tank removal? For example, the town of New Shoreham offers a \$300 rebate for each tank removed.

Other provisions for control of stormwater and wastewater discharges that may be included in overlay zoning are described in other parts of this chapter.

2. Land Conservation

Open Space Planning

Most water supply lands are designated for protection of the water supply and are not open for public recreation for security reasons. Municipalities should consider working with water suppliers and nonprofit organizations and neighboring communities to develop a regional open space plan for recreation and conservation, with linkages to existing open space. Low intensity recreation, preservation of unique habitat, and protection of unfragmented forest for habitat or woodland management, are all uses that are compatible with watershed and recharge area protection.

Use new subdivisions as opportunities to implement open space plans

Land protection priorities set out in town or regional open space plans can then be used to guide selection of common open space in new subdivisions. With each subdivision, protected open space can be pieced together into greenways, habitat corridors, expanded wetland buffers and protected unfragmented forest. The same might be accomplished with traditional cluster subdivisions but often inflexible design standards, with rigid lot frontage widths and building setbacks limit the designer's ability to adjust placement of roads and buildings to achieve the same level of protection. Conservation development design technique are effective in any area but large-lot residential zoning offer the greatest opportunity to preserve the largest acreages, especially if 50 percent or more of each parcel is preserved.

Continue to acquire land or development rights for water supply protection.

Priorities areas for water quality protection include:

- Reservoir intake and shoreline areas, stream shoreline areas throughout the watershed, and marginal lands that if development, present a higher risk of impact.
- Inner well protection areas and areas of deep, well-drained soil serving as deep groundwater recharge areas.
- Open space protection priorities identified through open space planning.

3. Shoreline buffers to Wetlands and Surface Waters

Maintain forested buffers to wetlands and surface waters.

Protecting or restoring forested shoreline buffers to wetlands, streams and other surface waters is one of the most effective methods for protecting surface drinking water supplies. In groundwater recharge areas, shoreline buffers have less direct benefit but help to maintain the overall health of water resources.

Establish or update setbacks from surface waters and wetlands in drinking water supply areas. Within the buffer zone, prohibit or regulate high-impact activities such as onsite wastewater treatment systems, new building construction, and land alterations such as clearing, filling and grading.

Where activities in buffers are allowed by special use permit or variance, evaluate whether standards for permit approval provide specific guidelines to minimize disturbance and reduce potential impacts to the maximum extent possible.

Include identification and protection of vernal pools in wetland protection provisions, to include a buffer surrounding the pool and travel corridors to surrounding upland or wetland habitat.

Consider establishing standards for wetland and surface water buffers to include:

- Maximum protection of forest and other natural vegetation with the shoreline zone, with the goal of maintaining or restoring a contiguous forested buffer.
- Revegetation of disturbed buffers following construction using native trees and shrubs.
- Restoration of developed buffers as existing uses in shoreline area are re-developed or expanded.
- Maximum protection of wetland buffers having high potential for nitrogen removal where source waters are located in coastal watersheds.

Small streams, big benefits

Small headwater streams (first and second order) are the workhorses in protecting good water quality despite their small size. These small tributaries, which typically comprise 60-80% of stream miles in less developed watersheds, are considered to have much greater ability to remove pollutants because of their extensive shoreline contact. (Alexander et al. 2000). In larger streams, the proportion of stream flow interacting with bottom sediments is considered too small to have notable effects on nitrogen dynamics.

Small streams are however, more susceptible to disturbance because they are abundant in the landscape and may be perceived to be less important. Because of their small size they are more likely to be impaired through direct disturbance during subdivision construction, secondary backyard "improvements", and by related changes in flow and sedimentation. To protect these valuable small streams, maximum buffer distances are often recommended for third order streams and smaller. (Center for Watershed Protection, 2000b; Alexander et.al. 2000)

- Avoid shoreline alterations such as bulk heading that circumvent nitrogen removal in riparian areas.

Consider implementing a shoreline buffer mitigation program where all onsite protection standards can't be met and after all possible efforts have been made to minimize onsite impacts to the extent possible. Applicants unable to meet all buffer requirements due to lot size, other site features or intense use for the parcel, would be required to provide compensation toward restoration of disturbed shorelines or permanent protection of shoreline areas on other properties.

In surface water supply watersheds, identify and prioritize shoreline areas in need of restoration. Target these for restoration with applications for redevelopment or expansion. Seek funding for restoration through RIDEM and the Natural Resources Conservation Service.

Educating residents about maintenance or restoration of shoreline zones is most critical in neighborhoods where wetlands and streams flow through backyards, and in waterfront developments. Topics include avoiding dumping yard wastes shoreline zones, maintaining or restoring naturally vegetated shorelines, discouraging waterfowl, avoiding shoreline alterations and bulkheads, and limiting disturbance for shoreline access.

Shoreline buffer widths

The optimum width for an effective buffer varies depending on the type of pollutant to be removed, the percent removal needed to protect sensitive waters, and site conditions. In their widely accepted buffer guidance document, the USDA Forest Service (Welsh 1991) recommends a minimum shoreline buffer distance of 95 feet, and up to 185 feet in areas of high water tables and steep slopes. These guidelines are specifically designed to maintain pollutant removal effectiveness of shoreline buffers in forested, farmland, and suburban /rural areas.

In their review of effectiveness of riparian buffers, Desbonnet and others (1994) concluded that a buffer between 200 and 250 feet wide is needed to reduce phosphorus and other pollutants by 80 percent. However, effectiveness of buffers for removal of nitrogen is less dependent on buffer width alone. Instead nitrogen removal by microbial denitrification requires shallow groundwater flow through wetland sediments, which varies, based on site conditions (Addy et.al.1999). Rosenblatt (REF) found that wetlands and associated buffers located on gently sloping outwash soils were more likely to provide proper conditions for denitrification.

The preceding recommendations focus on buffers in rural and agricultural area where, according to analysis by the Center for Watershed Protection, pollutant removal “appears to be due to relatively slow transport of pollutants across the buffer in sheet flow or under it in shallow groundwater. In both cases, this relatively slow movement promotes greater removal by soils, roots, and microbes.” These findings stress the importance of infiltrating runoff for maximum water quality benefit. However, the Center for Watershed Protection qualifies this by noting, “Ideal buffer conditions are rarely encountered in urban watersheds. In urban watersheds, rainfall is rapidly converted into concentrated flow. Once flow concentrates, it forms a channel that effectively short-circuits a buffer” (Center for Watershed Protection 2000b). The management implications are that buffers need to be carefully designed to promote infiltration, avoid channelized flow, and in high-use areas, provide additional stormwater treatment and avoid over-reliance on natural buffer functions.

Summary guidelines for multiple use vegetated buffers

The approaches to establishing a buffer distance vary from standard, one-size fits all approach to more complex formulas based on site-specific conditions. For the sake of simplicity most RI municipalities adopt a standard buffer setback, then review and approve special use permits or variances on a case-by-case basis. Where buffer standards have been established, standards for approval of special use permits and variances should be evaluated to determine their adequacy in avoiding and mitigating impacts, while maintaining the water quality function of the buffer. Factors to consider include:

- Sensitivity of the nearby resource.
- Characteristics of the buffer itself, such as erodible soil types, steep slopes, high water table or floodplain, and poor vegetation. Many rating systems recommend greater buffer distances to compensate when any of these conditions are present within the buffer.
- Use of the parcel and potential for the buffer to be disturbance, with high-intensity activities requiring greater buffer distances.
- Management practices to maintain buffer function over the long term and prevent encroachment.

Table 2
Summary of standard buffer widths for water quality protection*

Buffer distance (ft)	Type of buffer	Pollutant removal / special conditions
150	Multiple use standard buffer	75% removal of sediment and nutrients
250	Protection of sensitive areas	80% removal of sediment and nutrients
100	Minimum buffer for water quality protection for low-intensity uses.	60- 70% removal for phosphorus, nitrogen and total suspended solids or less. Assumes good site conditions and runoff managed through sheet flow or infiltration through buffer.
360	Viral inactivation	Based on rapid ground-water flow rate of three feet/day; also temperature dependant.
35 – 50	Restoration of urban buffers	50 – 60% removal of sediment and nutrients possible; poor wildlife habitat.

Increased buffer distance is generally recommended where buffers include steep slopes, high water tables and sensitive habitat. Wildlife habitat values not included above.

Sources: Addy et.al. 1999; CWP 2000b; Desbonnet et.al.1994; Herson-Jones et.al. 1995; Horsely & Witten, Inc. 1997; Welsh 1991.

Buffers for new land development projects

Shoreline buffers located on private property are most susceptible to gradual alteration by landowners – activities that are very difficult to monitor and enforce. Reduce potential for gradual wetland loss by delineating parcel boundaries within suitable building areas and including wetlands and associated buffers within designating open space

Review of variances or special exceptions from buffer standards on existing lots of record

- Consider buffer characteristics in establishing buffer widths and uses – are there limiting conditions such as high water table or erodible soils that would reduce effectiveness of the buffer?

- Minimize extent of disturbance to the maximum degree possible, moving construction and clearing out of the buffer wherever possible.
- Require the applicant to seek variances from side, front, and other setbacks before seeking reduction in buffer distance.
- Reduce size of project to minimize impact, with smaller building footprint and reduced wastewater flow from septic systems.
- Establish performance standards for control of stormwater and wastewater discharges. Limit impervious cover and require use of low impact stormwater controls to maintain pre-development runoff volume. Require advanced wastewater treatment systems in sensitive areas and problem soils.
- Establish limits of disturbance on plans and fence off in field to avoid unnecessary construction damage.

Protect the buffer from alteration after construction

- Mark the upland boundaries with permanent fencing and signs that describe allowable uses.
- Require revegetation after construction using native shrubs and trees.
- Educate buffer owners about the purpose, limits, benefits and allowable uses of the buffer. Also educate residents about the operation and maintenance of stormwater drainage systems located on individual lots, such as drainage swales and rain gardens that homeowners may need to maintain or avoid altering.
- Use pamphlets, neighborhood association meetings, demonstration sites and stream walks to educate homeowners.

4. Land Development standards: Site Design, Erosion and Sediment Control, and Stormwater Management

At the project level, managing development impacts begins with careful site design to direct development to suitable areas, limit site disturbance and impervious area, and incorporate nonstructural stormwater controls into project design from the earliest stages. Good land development practices are needed even where pollution risks are estimated to be low because this rating is an estimate for the study area as a whole. In practice, impacts are likely to occur in site-specific locations, affecting water quality of stream segments and surface waters locally. In addition, our estimates assume use of good management practices to avoid steep slopes and high water table, keep wetland buffers intact, implement effective erosion controls, and keep septic systems functioning properly with good maintenance. Actual impacts may be much greater depending on the site conditions, the location of development and intensity of use. Establishment of mini farms with horses or other animals would also result in much higher pollutant inputs than predicted, especially if animal wastes are not properly managed. Because of the potential for site-specific

Changes in hydrology = water quality impacts

Urban runoff alters basic water flow and pollutant pathways in a way that robs watershed ecosystems of natural pollutant removal functions.

- *Water running off, rather than infiltrating the ground bypasses natural pollutant removal pathways in soil.*
- *Stormwater flowing to wetlands and surface waters is often channelized in pipes, swales, or other drainage ways, bypassing most of the riparian buffer area and escaping treatment in shoreline buffers.*
- *Reduced recharge as a result of high runoff is known to lower water tables. As a result, groundwater discharging to streams may flow below, rather than through shallow wetland sediments, bypassing potential groundwater nitrogen treatment zones of high microbial activity.*

impacts, use of good land development practices remains important when watershed risks are low, and becomes critical where marginal sites are subject to development.

Guidelines for land development

The following practices represent current management practices for new land development as well as re-development and expansion of existing uses. These are not intended to be comprehensive. Implementing these may require amendment to zoning ordinances and land development regulations. In each case, education, field inspection and enforcement would also be needed.

Project planning and review

Soil mapping provides critical information such as soil permeability and water table depths needed to locate sites for buildings, onsite wastewater treatment systems, and both structural and non-structural stormwater facilities. RI Soil Survey maps are useful for general planning purposes but are not accurate at the parcel level. Site-specific soils mapping by a professional soil scientist should be required for all land development projects to accurately identify soil conditions as early as possible in the site planning process, ideally, when wetland boundaries are first delineated. Accurate soil mapping results can then be used to identify sites for more costly site investigations such as installation of water table monitoring wells and soil evaluation pits excavated using heavy equipment.

Use conservation design principles to preserve forest cover and protect wetland buffers from backyard encroachment. Relatively undeveloped areas with large lot zoning stand to gain the greatest acreage of open space with this technique, especially if at least 50 percent of the parcel is reserved as open space. The principles are equally appropriate for more dense development, including commercial and village areas where effective use of even small open space areas can have substantial benefits.

Use site analysis to identify permeable soils suitable for stormwater infiltration. Integrate planning for nonstructural stormwater drainage systems with site layout, to include rooftop runoff diverted to vegetated areas, use of small landscaped stormwater storage and infiltration areas known as “rain gardens” and use of roadside swales rather than traditional curb and catch basin.

Limit impervious cover with narrower roads and modified cul-de-sacs. Consider use of permeable pavements in sensitive areas and where necessary to achieve impervious target levels.

Review parking requirements and set maximum parking requirements for commercial and industrial developments. Use permeable materials for overflow parking.

Establish limits of disturbance for new road construction, with individual building envelopes for buildings and driveways. Mark disturbance limits on plans and fence off in the field. Where septic systems are used, fence off the proposed leach field to protect against compaction by heavy equipment during construction. Earmark individual trees or groups of trees to be protected and fence off at the dripline or other root protection zones identified by qualified arborists. With new septic system construction, fence off the leach field during construction to protect against compaction by heavy equipment. This is essential to ensure long-term function of the leach field.

Clearly identify all material storage areas, stockpiles and stump dumps (if on-site disposal is allowed) on plans. Keep within specified limits of disturbance or store at another location.

Prohibit disposal of “clean fill” in source water areas, which, by definition, may contain construction debris such as asphalt.

Prohibit use of subdrains to lower high water tables for development sites. Prohibit use of subdrains to intercept high water table for individual building sites and septic systems unless the discharge can be accommodated on site without contributing to offsite runoff. In environmentally sensitive areas, or where lot sizes are small, prohibit construction of basements in high water tables, which require either extensive filling or use of subdrains.

Establish standards for control of runoff volume, keeping the amount of runoff at pre-development levels in sensitive areas.

Identify highly erodible areas during project review and take additional erosion and sediment control precautions in these areas. Where town staff is limited, establish permit review fees to cover cost of hiring outside consultant to review erosion control and stormwater management plans, and most importantly, conduct field inspections during construction.

Require plans for erosion and sediment control and for stormwater management for all land development projects, including minor subdivisions. Require approval of maintenance plans for stormwater systems, with responsible parties identified and enforceable provisions for ensuring routine maintenance.

Develop and distribute educational materials to homeowners on importance of nonstructural stormwater controls, maintenance requirements for facilities located on private lots, and penalties for altering drainage systems. Follow up with field inspections and enforcement.

Resources for site design and low impact development

Excellent resources for controlling environmental impacts through site design and innovative stormwater control are available for in-depth guidance. The following are particularly useful and all but one are designed for Rhode Island communities.

- The *Conservation Design Manual* describes the step-by-step process for evaluating a site, identifying open space for preservation, and selecting suitable areas for development. Produced by Dodson Associates for RIDEM. Available to view or download at the www.state.ri.us/dem/programs/bpoladm/suswshed/ConDev.htm , the RIDEM website.
- The two-volume set: *Low –Impact Development Design Strategies: An Integrated Design Approach*, and *Low-Impact Hydrologic Analysis*, describes the current approach to stormwater management emphasizing control of runoff volume using nonstructural controls. The manual stresses site design and micro-management of runoff to keep stormwater on site and mimic pre-development hydrology. Produced by Prince George’s County with EPA support and available to view or download at <http://www.epa.gov/nps/lid/> . Hard copies may be ordered through the EPA National Service Center for Environmental Publications on line at www.epa.gov/ncepihom/ordering.htm , or by phone at 1-800-490-9198.

South County Technical Planning Assistance Project. Prepared by Dodson Associates for RIDEM. Includes several resources for land use planning and design to protect open space, all available to at www.state.ri.us/dem/programs/bpoladm/suswshed/sctpap.htm, including:

- Model ordinances for conservation development and other land use strategies;
- South County Design Manual, which uses actual sites in southern Rhode Island to illustrate future development scenarios using conventional development vs. more compact designs with conservation development techniques.
- Rapid Site Assessment Guide – Produced by URI Cooperative Extension for RIDEM. Offers guidance on use of Geographic Information Systems to conduct a planning level site analysis using simple static maps available on the web and RIGIS coverages for those with access to ArcView GIS software.

Scituate Reservoir Watershed Zoning Project – Parts 1 and 2. 1998. Two-volume set prepared by Newport Collaborative Architects for RIDEM. Describes design strategies to preserve rural character while protecting local water quality. Includes model development standards. Additional information at the RIDEM website at www.state.ri.us/dem/programs/bpoladm/suswshed/Scituate.htm. Available only in paper copies through RIDEM. Contact Scott Millar at 401-222-3434.

5. Wastewater Management

When properly sited, operated and maintained, onsite systems provide a safe, cost-effective and environmental sound treatment option for low-density areas. The RIDEM Individual Sewage Disposal System (ISDS) program establishes minimum standards for siting, design and installation of onsite wastewater treatment systems. Once installed, however, Rhode Island municipalities are responsible for making sure septic systems are properly maintained. To keep these systems functioning over the long term, and to protect public health and local water quality, many Rhode Island communities are establishing onsite wastewater management programs with support and funding by the RIDEM. Use of advanced onsite wastewater treatment systems is becoming commonplace, however, these systems are bound to fail unless properly maintained. Town oversight is needed to ensure all advanced wastewater treatment systems, including existing systems, have maintenance contracts in place that are renewed annually.

Management of centralized wastewater systems - Sewers

Make sewer leak detection and repair a priority in source water areas. Watertight lines and pump stations prevent wastewater leakage, loss of groundwater recharge, and overloading of wastewater treatment facilities with infiltrating groundwater.

Establish sewer and water district boundaries to avoid sewer expansion into source water areas unless necessary to accommodate existing high density and high risk land uses, and where all other onsite options have been evaluated, such as improved wastewater management and use of advanced onsite wastewater treatment systems. Where sewers already exist or are planned for source water areas, existing zoning and land development standards should be carefully evaluated to determine if current standards are adequate to control high risk land uses, limit development of marginal sites, and mitigate potential impacts of more intense development supported by sewers. Control of hazardous materials, stormwater treatment and recharge, and protection or restoration of wetland buffers are particularly critical in more intense development is permitted.

Local management of septic systems - decentralized onsite wastewater treatment systems

Develop a local wastewater management program. Most communities begin with development of a wastewater management plan. A RIDEM-approved plan qualifies town residents for low-interest loans for septic system repair under the RI State Revolving Loan Fund. Implementation of the plan includes public education and in many cases, development of a wastewater management ordinance that requires regular system inspection with pumping as needed, repair or replacement of failing systems. Some communities require gradual phase-out of cesspools over time. When hiring staff to manage the program, consider joining with neighboring communities to share personnel and equipment.

Consider establishing treatment standards specifying use of advanced treatment systems in critical areas. Examples of existing programs: Block Island has set treatment standards townwide, with advanced treatment required in the town's primary drinking water supply wellhead, and based on soil type in other wellhead protection areas. Little Compton requires alternative systems as a condition of approval for construction in wetland buffers. Jamestown requires advanced treatment in densely developed areas served by private wells with high water table.

Prohibit use of deep leaching chambers (4'x4' galleys) due to lack of treatment potential with deep discharge.

Require alternative treatment systems for large flow and high strength systems within source water areas; and also for smaller systems located in critical areas, including shoreline buffers and inner protected well radius, and in areas with poor soils where horizontal and vertical setbacks can't be met.

Where development is clustered on small lots and high water table, require use of advanced treatment systems rather than raised fill systems to avoid increased runoff and nuisance flooding to neighboring properties.

Where monitored nitrate levels are elevated (>2 mg/l) and where septic systems are estimated to be the dominant source and where projections show nitrogen sources from onsite systems increasing with future development, require use of advanced treatment systems for new or replacement systems for high intensity development. The need for advanced treatment is especially critical where monitored nitrate concentrations are near the 5 mg/l level, especially where projections indicate increased future inputs.

Prohibit new development on marginal sites (less than 2 ft. water table depth) in source water areas due to risk of treatment failure where water tables are likely to rise to the surface during wet periods.

Where advanced treatment systems are already being used, establish maintenance fees to cover cost of town oversight in tracking annual renewal of maintenance contracts and ensuring that maintenance is properly conducted.

Establishment of a mandatory inspection program will identify failing systems and illicit discharges, as required under the RIDEM Phase 2 stormwater program. Wastewater and stormwater management planning should be closely coordinated.

Establish a computerized database for tracking septic system inspection results and maintenance schedules. Several programs are available, including low-cost, web-based reporting systems with minimal staff requirements. Begin by putting town-owned onsite wastewater treatment systems on inspection and maintenance schedules. Budget for upgrading of large institutional systems to advanced treatment in critical areas. Technical assistance in selecting appropriate technologies is available through the URI Onsite Wastewater Training Center. For more information about conventional and alternative systems, go to the URI Cooperative Extension site: www.uri.edu/ce/wq/owtc/html/owtc.html.

6. Use and Storage of Hazardous Materials

Background

Underground fuel storage tanks are the major source of new groundwater contamination incidents in Rhode Island (RIDEM 2002).

Prohibiting siting of new underground storage tanks in source water areas is the most effective way to prevent increased risk of contamination.

The technology does not exist to ensure underground storage tanks and components will be 100% leak proof and only small quantities can contaminate water supplies.

Even with a major overhaul of state regulations for UST in the last few decades, with new standards for tanks, a DEM review of its waste management program has found that leaks and spills from underground storage tanks are almost impossible to prevent entirely (RIDEM 2001). Improved double wall and fiberglass tanks are now much less prone to leaks but leaks from fuel lines and pumps are common and unpredictable, and no method exists to test. Leak detection methods are imprecise. Leaks may go unnoticed for a long

period and even relatively small quantities can have disastrous effects. Tank pressure testing is not 100 percent accurate, and even small leaks can be a major source of contamination. There is no convenient way to test pumps and lines for leaks.

Not all underground tanks are regulated.

RIDEM regulates all commercial tanks but does not regulate underground tanks storing heating fuel consumed on-site at homes or businesses. RIDEM underground storage tank (UST) regulations prohibits new underground storage tanks in community wellhead protection areas only; new tanks are allowed in all other areas, including, non-community wellhead protection areas, aquifer recharge areas, and surface water supply watersheds.

RIDEM has limited staff to inspect these facilities and even more limited resources to effectively enforce violations.

In 2001, the RIDEM Office of Waste Management carried out 47 compliance monitoring inspections of UST facility operations. The purpose was to determine compliance with continuous monitoring systems or corrosion protection systems to ensure that tanks are not leaking and releasing gasoline or other hazardous materials such as MBTE into the environment. Results: DEM inspections found noncompliance at just about every facility inspected (RIDEM 2001)

Enforcement is difficult and time consuming. In 2001 RIDEM notified 59 UST facilities of non-compliance, but only 27 were brought into compliance. Municipal staff lack the training, time or jurisdiction to inspect these facilities on their own (RIDEM 2001).

Recommended local actions

New underground storage tanks

Prohibit installation of new underground storage tanks, in town-identified critical areas through groundwater protection overlay zone or site review standards. Include both commercial tanks and heating oil tanks for onsite use.

Existing underground storage tanks

Make formal inquiry to DEM to identify existing state-regulated underground storage tanks and other facilities generating or storing hazardous waste within town critical areas. Determine type of facility and compliance record. Identify additional improvements that can be made beyond minimum standards. Invite representatives of Planning Board, Conservation Commission, water suppliers, groundwater committee to participate in review. Set annual action items.

Establish standards for existing facilities triggered by renovation, expansion, or sale of existing uses. Required improvements should be based on RIDEM recommendations to include for example: replacement of underground storage tank with above ground unit; improved monitoring and reporting requirements, including use of downgradient wells and sampling; and employee training.

Require removal of existing heating fuel tanks for homes and businesses at the time of property sale, building improvement or expansion. Establish sunset clause for removal of tanks in high risk areas; offer rebates for voluntary removal in less critical areas. For example, the New Shoreham offers a \$300 rebate for each underground tank removed.

Promote private well water testing of all wells located within 1000 feet (or greater for larger wells) of underground storage tanks for fuel components and MTBA

Commercial and industrial facilities using or storing hazardous materials

RIDEM regulates storage and transport of hazardous waste but does not have jurisdiction over facilities that use hazardous materials, even though the hazardous product and the waste may be the same material.

Review and update groundwater /watershed zoning to prohibit siting of new facilities that use, store, or generate hazardous materials and wastes. Regulate storage of hazardous materials in the same way that hazardous waste is regulated. A useful guide to best management practices is the RIDEM Hazardous Waste Compliance Workbook for RI Generators, available through the Office of Waste Management at www.state.ri.us/dem/programs/benviron/waste/index.htm .

Identify areas where new lower-risk commercial /industrial facilities may be permitted by right or by special exception in less critical portions of the groundwater recharge area. Establish local performance standards for design, siting and monitoring.

Update standards for stormwater management, wastewater treatment and wetland buffer protection for businesses in aquifer recharge areas. For example, gas stations and convenience stores are known to generate more heavily contaminated runoff and require special stormwater runoff controls. Oil and water separators typically used may not be appropriate; other treatment units are now available that may have better pollutant treatment performance. All such units require routine care and maintenance contracts should be in place.

Update standards for review and approval of special use permits or variances to bring businesses in closer conformance with current performance standards. These requirements may include for example, shoreline buffer restoration, stormwater system retrofitting, or site design and landscaping improvements.

Town owned facilities

Identify town-owned facilities using or storing hazardous materials. Evaluate management practices at these locations and in routine operations such as road maintenance and landscape care in town parks. Install model practices at town facilities. Coordinate these activities with required improvements under RIDEM Phase 2 stormwater planning.

7. Monitoring, Education and Stewardship

Investigate results of hotspot mapping

Identify appropriate methods to investigate sites to determine if mapped site is actually a potential source of pollution, determine if action is necessary. Consider different strategies for residential, business and agricultural properties. For example, to investigate potential hotspots in agricultural areas: work with local farmers, the Natural Resource Conservation Service, and the RIDEM Division of Agriculture to determine if mapping represents actual field conditions, current conservation practices, and need for additional management to minimize impacts. Use RIDEM Division of Agriculture mapping to review current type of crop, location and number of large animals, and animal waste storage sites. Cooperate with these groups to conduct field investigations and contact landowners to discuss assessment results and management options.

Municipal Lawn and landscape Care

Provide training for municipal staff in lawn and landscape care. Low-impact landscape care, using current fertilizer and irrigation practices, and use of low-maintenance sustainable plants, can improve local parks and lawns while reducing landscaping costs over the long run. Contact the URI GreenShare program at www.healthylandscapes.org/

Hydrologic modifications

The RI Water Resources Board is currently working with governmental officials and water suppliers to identify water use needs and establish policies for allocating water among different users, including protection of downstream water flow for habitat. All interested parties are welcome to participate in this process. For more information go to www.wrb.state.ri.us/ .

Compliance and enforcement

In many cases plans and regulations are comprehensive but staff is lacking to monitor and enforce current activities. Municipalities and water suppliers should discuss opportunities to coordinate in improving enforcement of local regulations, including hiring an environmental enforcement officer to work with town staff such as the building inspector, wastewater management coordinator and others conduct field inspections, educate landowners and developers, and pursue enforcement actions where needed.

Community pollution prevention education

As a joint effort between water suppliers and local officials, expand public education to promote awareness of local water resources and the need for protection. Use educational campaigns to encourage individual adoption of good management practices and also to build public support for local source water protection ordinances.

- Start by mailing the assessment summary fact sheet to watershed residents and water users.
- Join forces with existing organizations promoting conservation and education. Work with nonprofit organizations to implement watershed education programs in schools.
- Support private well water protection education and facilitate private well water sampling; actions taken to protect private wells will also protect public supplies.
- Aim to establish a continuous educational program targeting different audiences through a variety of methods. Occasional educational efforts are less effective. The most successful communities have appointed a committee with citizen volunteers to spearhead efforts, such as the North Kingstown Groundwater Committee, which works closely with the town water supply department, the planning department, and other town officials.
- Target residents and businesses in critical areas for education on issues of concern in their neighborhood such as shoreline development in waterfront areas, lawn care in areas with large lots and high-maintenance lawns, and areas in need of septic system repair and upgrading.
- Work with business groups to promote good “housekeeping” practices among commercial and industrial property owners.

4.3 Management Actions for Water Suppliers

Implementing municipal management actions listed above would require coordination with water suppliers and their active support. In many cases water suppliers already are leading non-regulatory efforts, such as educational outreach and monitoring. Additional actions water suppliers can take to protect drinking water supplies follow. In

Consumer Confidence Reports

The 1996 Amendments to the Safe Drinking Water Act (SDWA) require public water supply systems that serve residential customers to prepare and distribute annual consumer confidence reports. These reports are intended to help educate public water supply consumers and to promote a dialogue between water suppliers and their customers on the importance of source water protection.

many cases, water suppliers already have active watershed management programs that incorporate many of these elements.

- Implement all recommendations of the latest water supply systems management plan.
- Continue to prioritize and acquire land for protection.
- Identify priorities for restoration, including potential sites for stormwater drainage system improvements and shoreline revegetation. In cooperation with government agencies and nonprofit organizations pursue funding to implement projects through capital budgets and competitive grants.
- Post signs alerting the public to location of Wellhead or Watershed Protection Area.
- Cooperate with local officials to update local plans and ordinances to implement land use protection measures.
- Inspect water supply and protection area regularly for potential pollution sources.
- Provide assistance to communities in review of development proposals to evaluate potential impacts and identify alternative designs and management practices to minimize impact.
- Expand monitoring where needed to evaluate stream water quality through simultaneous monitoring of stream quality and flow. In surface reservoirs track nutrient enrichment status through standard benchmarks such as Carlson's Trophic State Index.
- In groundwater aquifers promote private well water protection education and encourage private well water sampling. Actions taken to protect private wells will also protect public supplies.
- Cooperate with local officials and nonprofit organizations to develop and carry out watershed/groundwater education programs for those who live and work in source water areas.

4.4 What Residents, Landowners and Businesses Can Do

Drinking water protection eventually comes down to the individual actions of those who live and work in water supply areas. The following are basic actions each person can take to protect public supplies and the health of their own home and yard.

Residents

Vehicle and Engine Maintenance

- Recycle used motor oil. Never pour waste oil on the ground or down storm drains.
- Local sanitation departments or service stations can often accept used motor oil.
- Keep up with car maintenance and the maintenance of other motorized equipment such as lawn mowers and snowmobiles, to reduce leaking of oil, antifreeze, and other hazardous fluids.

Heating fuel

Replace underground home heating fuel tanks with properly-contained above ground tanks.

Household Hazardous Products

- Follow the product label directions for use and storage very carefully.
- Keep products in their original, labeled containers and out of the reach of children.
- Buy only as much as you will need. Give surplus products to friends, neighbors and groups who can use them.
- Consider using nontoxic, nonhazardous alternative products.
- Do not pour paints, used oil, cleaning solvents, polishes, pool chemicals, insecticides, and other hazardous household chemicals down the drain, in the yard, or on the street.
- Dispose of household hazardous waste properly and recycle wastes where possible.

Septic system care

- All septic systems need regular care to function properly and avoid costly repairs. Inspect septic systems annually and pump when needed, usually every 3 – 7 years.
- Comply with local wastewater management requirements.
- Repair or replace failing septic systems. If you have a cesspool plan to replace it.
- Avoid using septic system additives.
- Place only toilet paper in the toilet.
- Don't pour grease or hazardous household products down the drain.
- Compost kitchen wastes rather than using a garbage disposal.
- Conserve household water to reduce the amount of wastewater generated.

Yard and garden care

- Maintain wooded buffers or restore natural vegetation along wetlands or watercourses that run through your property.
- Avoid dumping leaves and brush in shoreline areas.
- Use native, low-maintenance plants that require less fertilizer and water.
- Reduce fertilizer and pesticide use. When using these, follow product labels carefully.
- Use organic fertilizers or compost instead of chemical fertilizers.
- Limit outdoor water use. Summer water demand typically doubles or triples due to outdoor watering.
- Reduce stormwater runoff by limiting paved surfaces. Direct runoff to well-vegetated areas or gravel rather than pavement leading to storm drains.
- If you have a private well have it tested annually.

Pets and livestock

- If you have horses or other livestock, provide proper animal waste collection and storage. Keep animals out of streams and waterways.
- Pick up after your pets.

Contacts:

Healthy yard and garden care:

URI Cooperative Extension Master Gardener Hotline

URI GreenShare Program <http://www.healthylandscapes.org/>

Septic systems

URI Onsite Wastewater Training Center www.uri.edu/ce/wq and

Master Gardener Hotline 1-800-448-1011, M-Th. 9am –2pm.

Private well protection:

URI Home*A*Syst, 401-874-5398,

Animal waste management:

USDA Natural Resources Conservation Service 401-828-1300,

www.ri.nrcs.usda.gov .

Hazardous waste recycling and disposal:

RI Resource Recovery Corporation, Eco-Depot 401-942-1430.

Farmers and Landowners

Work with the USDA Natural Resource Conservation Service to develop a conservation plan that addresses proper nutrient, manure, pest, and irrigation water management.

Consider use of conservation tillage to minimize erosion.

Maintain and restore naturally vegetated buffers to surface waters. This is especially critical in watersheds of drinking water supply reservoirs.

Contact them at (401) 828-1300, www.ri.nrcs.usda.gov

Businesses

- Adhere to all laws, regulations, and recommended practices for hazardous waste management, above and underground storage tanks, floor drains and wastewater discharges.
- Clearly post signs to show proper hazardous material handling and storage practices
- Provide regular training for employees in management of fuel tanks, monitoring equipment, and safety practices.
- Contact RIDEM Pollution Prevention Program for assistance in reducing use of hazardous materials and in voluntary good “housekeeping” inspections.

Check local regulations with city/town hall and state regulations with the RI DEM Office of Water Resources (401) 222-4700, www.state.ri.us/DEM/program/benviron/water/index.htm .

REFERENCES

- Adamus, C. and M. Bergman. 1993. "Development of a nonpoint source pollution load screening model." Technical Memorandum No. 1. Department of Surface Water Programs, St. Johns River Water Management District, Palatka, FL.
- Addy, K.L., Gold, A.J., Groffman, P.M., and Jacinthe, P.A. 1999. "Ground Water Nitrate Removal in Subsoil of Forested and Mowed Riparian Buffer Zones." *Journal of Environmental Quality* 28: 962-970.
- Alexander, R.B., R.A. Smith and G.E. Schwarz. 2000. "Effect of stream channel size on the delivery of N to the Gulf of Mexico." *Nature*. 403: 758-761.
- Ammann, A.P. and A.L. Stone. 1991. "Method for the comparative evaluation of nontidal wetlands in New Hampshire." New Hampshire Dept. of Environmental Services. NHDES-WRD-1991-3.
- Arnold, C. L. and C. J. Gibbons. 1996. "Impervious surface coverage, the emergence of a key environmental indicator." *Journal of American Planning Association* 62: 243-258.
- Azous, A. and R. Horner. 1997. "Wetlands and urbanization: implications for the future." Final report of the Puget Sound wetlands and stormwater management research program. Washington State Department of Ecology, Olympia, WA. King County Water and Land Resources Division and the University of Washington, Seattle, WA.
- Brown, K. W. and Associates. March 1998. "An Assessment of the Impact of Septic Leach Fields, Home Lawn Fertilization and Agricultural Activities on Groundwater Quality." Report to the New Jersey Pinelands Commission.
- Budd, L.F. and D.W. Meals. 1994. "Lake Champlain Nonpoint Source Pollution Assessment." Lake Champlain Basin Program Technical Report No. 6A.
- Center for Watershed Protection. 1998. *Better Site Design: A Handbook for Changing Development Rules in Your Community*. Ellicott City, MD: Center for Watershed Protection, 1998a.
- Center for Watershed Protection. 1998. *Rapid Watershed Planning Handbook. A Resource Guide for Urban Subwatershed Management*. Ellicott City, MD: Center for Watershed Protection, 1998b.
- Center for Watershed Protection. 2000. "The architecture of urban stream buffers." Article 39 In: *The Practice of Watershed Protection*. Center for Watershed Protection, 2000a.
- Center for Watershed Protection. 2000. "The impact of stormwater on Puget Sound wetlands." *Watershed Protection Techniques* 3(2): 670-675: Center for Watershed Protection, 2000b.
- Center for Watershed Protection. March 2001. *The Watershed Treatment Model*. EVS Holding Company, LLC. Ellicott City MD
- Center for Watershed Protection (CWP). 2002a. Is Impervious Cover Still Important? A review of recent urban stream research. www.cwp.org/Impacts_Part1.PDF. Ellicott City, MD. 15pp. 2002a.

- Center for Watershed Protection (CWP). 2002b. Watershed Vulnerability Analysis. www.scw.org/tools_assessment.htm. Ellicott City, MD 22pp. 2002b
- Connecticut River Joint Commissions. 1998. Introduction to Riparian Buffers. <<http://www.crjc.org/buffers/Introduction.pdf>>
- Delaware Department of Natural Resources and Environmental Control. 1997. *Conservation Design for Stormwater Management*. Delaware, MD.: Delaware NREC and the Environmental Management Center of the Brandywine Conservancy.
- Desbonnet, A., et al. 1994. "Vegetated buffers: A summary review and bibliography for their use in the coastal zone." Coastal Resources Center Technical Report No. 2064. University of Rhode Island Graduate School of Oceanography. Narragansett, RI.
- DeSimone, L. and L. Ostiguy. 1999. "A vulnerability assessment of public supply wells in Rhode Island." Water Resources Investigations Report 99-4160. U.S. Geological Survey and R.I. Department of Health. Denver, CO.
- Dunne, T. and L. Leopold. 1978. *Water in Environmental Planning*. W.H. Freeman and Co. New York.
- Frimpter, M.H., J.J. Donohue IV, and H.V. Rapacz. 1990. "A Mass-Balance Model for Predicting Nitrate in Ground Water." *J. of New England Water Works Association* 104: 214-231.
- Fulton III, R. S. 1994. *Phase I External Nutrient Budget and Trophic State Modeling for Lakes in the Upper Ochlawaha River Basin*. Division of Environmental Sciences, Department of Water Resources. St. Johns River Water Management District, FL (DRAFT).
- Gibbons, Jim. n. d. "Addressing Imperviousness in Plans, Site Design and Land Use Regulations." Technical Paper No. 1. University of Connecticut NEMO. Haddam, CT.
- Gold, A. J., W. R. DeRagon, W. M. Sullivan, and J. L. Lemunyon. 1990. *Nitrate-nitrogen losses to groundwater from rural and suburban land uses*. *J. of Soil and Water Conservation* 45: 305-310.
- Gold, A.J. and J.T. Sims. 2000. "Research Needs in Decentralized Wastewater Treatment and Management: Fate and Transport of Nutrients." *National Research Needs Conference Draft Proceedings: Risk-Based Decision Making for Onsite Wastewater Treatment*. EPA and EPRI National Decentralized Water Resources Capacity Development Project. EPRI Community Environmental Center. St. Louis MO.
- Herson-Jones, L., M. Heraty, and B. Jordan. 1995. *Riparian buffer strategies for urban watersheds. Prepared for US EPA Office of Wetlands, Oceans, and Watersheds*. Urban Watershed Planning Section. Metropolitan Washington Council of Governments. Washington, DC.
- Hicks, A. 1997. *Freshwater wetlands Invertebrate Biomonitoring Protocol*. The Environmental Institute, University of Massachusetts. Amherst, MA.
- Higgins, J. & T. Groves. 1999. "Nitrogen loading from non-residential facilities." *Proceedings, Eighth Annual Conference and Exhibit*. National Onsite Wastewater Recycling Association. Northbrook, IL. 137-141.
- Holden, S. and M.H. Stolt. 2003. "Effectiveness of Shallow-Narrow Drainfields to Treat Domestic Wastewater" Research project in support of a Master of Science degree in Soil Science (draft) unpublished data, University of Rhode Island, Natural Resources Science Dept. Kingston, RI.

- Horsely & Witten, Inc. 1997. Nonpoint source pollution control workbook for Rhode Island cities and towns. Prepared for Rhode Island Chapter of the American Planning Association. American Planning Association, Research Department. Chicago. Illinois.
- Kellogg, D.Q., L. Joubert, and A.J. Gold. 1997. *MANAGE: A method for assessment, nutrient loading, and geographic evaluation of nonpoint pollution*. University of Rhode Island Cooperative Extension, Department of Natural Resources Science. Kingston, R.I.
- Kopp, B.S., A.M. Doherty, and S.W. Nixon. 1995. *A guide to site-selection for eelgrass restoration projects in Narragansett Bay, Rhode Island*. Report: Rhode Island Aqua Fund Program.
- Maine Department of Environmental Protection. 1996. *A citizen's guide to coastal watershed surveys*. Maine State Planning Office. Augusta, ME.
- Maryland Department of Natural Resources and Department of the Environment. 2003. Surf Your Watershed www.dnr.state.md.us/watersheds/surf/index.html.
- Massachusetts Department of Environmental Protection. 1999. *DEP Nitrogen loading computer model guidance*. Boston, MA: Massachusetts Department of Environmental Protection.
- . 1999. "Nutrient loading approach to wastewater permitting and disposal." Bureau of Resource Protection Interim Policy for Groundwater Discharge Regulations 314 CMR 5.00 and Groundwater Quality Standards. 314 CMR 6.00. Boston, MA: Massachusetts Department of Environmental Protection.
- Morgan, C. and M.H. Stolt. 2002. Unpublished research project "Investigating the Relationships Between Soil Features and Water Table Depth on Block Island" in support of Master of Science in Soil Science, URI Natural Resources Science Dept. Funded by the Block Island and Green Hill Pond Watershed Wastewater Demonstration Project. Kingston, RI.
- Morris, Jackie. 1996. *Source Protection: A guidance manual for small surface water supplies in New England*. New England Interstate Water Pollution Control Commission. Wilmington MA.
- National Research Council. 1993. *Ground Water Vulnerability Assessment, Predicting relative contamination potential under conditions of uncertainty*. Committee on Techniques for Assessing Ground Water Vulnerability, Armando Carbonell, Chair. National Academy of Sciences. National Academy Press, Washington, DC.
- Nelson, K.L., et al. 1988. *Predicting nitrogen concentrations in ground water - an analytical model*. In Proc. National Water Well Assoc. Conference.
- New England Interstate Water Pollution Control Commission. 1999. "Facts Focus." *Interstate News*. Issue 23. NEIWPC. Lowell, MA: New England Interstate Water Pollution Control Commission.
- Nolan, B.T., et al. 1997. "Risk of nitrate in groundwaters of the United States – a national perspective" *Environmental Science and Technology*, 31:8, 2229-2236.
- Ollinger, S.V., J. Aber, G. Lovett, S. Millham, R. Lathrop and J. Ellis. 1993. *A Spatial Model of Atmospheric Deposition for the Northeastern U.S.* *Ecological Applications* 3:3 (1993): 459-472.
- Olsen, S., D Robadue and V. Lee. 1980. "An Interpretive Atlas of Narragansett Bay." Bulletin 40. University of Rhode Island, Marine Advisory Service. Narragansett, RI.

- Olympia, City of. 1994. "Impervious Surface Reduction Study." Technical and Policy Analysis Report. Public Works Department Water Resources Program. Olympia, WA.
- Pitt, R., S. Clark, and K. Parmer. 1994. "Potential Groundwater Contamination from Intentional and Nonintentional Stormwater Infiltration." EPA/600/SR-94/051. U.S. Environmental Protection Agency, Risk Reduction Engineering Laboratory. Cincinnati, OH.
- Poiani, K.A., B.L. Bedford, and M.D. Merrill. 1996. A GIS-based index for relating landscape characteristics to potential nitrogen leaching to wetlands. *Landscape Ecology* 11:237-255.
- Postma, F. B., Gold, A. J., and Loomis, G. W. 1992. Nutrient and Microbial Movement from Seasonally-Used Septic Systems. *Journal of Environmental Health* 55(2): 5-10.
- Prince George's County, MD. 2000. *Low-Impact Development: An Integrated Design Approach*. Department of Environmental Resources, Programs and Planning Division, Largo, MD and US EPA National Service Center for Environmental Publications, Cincinnati, OH.
- . 2000. *Low-Impact Development Hydrologic Analysis*. Department of Environmental Resources, Programs and Planning Division, Largo, MD and US EPA National Service Center for Environmental Publications, Cincinnati, OH.
- Prisloe, S., L. Giannotti, and W. Sleavin. 2000. "Determining Impervious Surfaces for Watershed Modeling Applications." *Proceedings, National Nonpoint Source Monitoring and Modeling Workshop*. Harford CT.
- Reckhow, Kenneth H., and Steven C. Chapra. 1983. *Data Analysis and Empirical Modeling*. Butterworth Publishers, Boston, MA. Vol. 1 of Engineering Approaches for Lake Mgt.
- Richardson, Mac. Personal interview. n.d.
- RI Coastal Resources Management Council. 1998. "Council Adopts New Policies for the Protection of Submerged Aquatic Vegetation." *Coastal Features*. 7.3 (Fall, 1998).
- . 1999. "A Watershed-Based Management Strategy." *Coastal Features*. Special Edition. 7.4(1999)
- . 1999. *Rules and Regulations Governing the Protection and Management of Freshwater Wetlands in the Vicinity of the Coast*. Providence, RI: RI Coastal Resources Management Council.
- RI Department of Environmental Management. 1997. *Water quality regulations*. RI DEM Division of Water Resources. Providence, RI.
- . 1998. *Rules and regulations governing the administration and enforcement of the Freshwater Wetlands Act*. Providence, RI: RI Department of Environmental Management.
- .1998. *State of the State's Waters Rhode Island, A Report to Congress (PL 94-500, Section 305(b) Report)*. Supporting assessment data, per conversation Constance Carey. Division of Water Resources. Providence, RI.
- .1999. *Status and trends of freshwater wetland protection and management in Rhode Island*. Office of Water Resources. Providence, RI.
- . 2002. State of Rhode Island 2002 Section 305(b) State of the State's Waters Report. RIDEM Office of Water Resources. Providence, RI.

- . 2002. *State of Rhode Island 303(d) List of Impaired Waters*. Providence, RI.
- RI Department of Health. 1999. *RI Source Water Assessment Plan*. Providence, RI.
- RI Geographic Information System. 1995. *Land Use Coverage*. Department of Administration. Providence, RI.
- Robertson, W.D., J.A. Cherry, and E.A. Sudicky. 1991. "Ground-water contamination from two small septic systems on sand aquifers." *Ground Water* 29(1991):82-92.
- Rosenblatt, A.E., et al. 1999. "Groundtruthing hydric status of riparian soil map units in the glaciated Northeast." Annual Meetings. SSSA Agronomy Abstracts. In press.
- Rosenblatt, A. 2000. *Hydric soil patterns in riparian corridors of the glaciated northeast: Groundtruthing the soil survey geographic data base (SSURGO)*. Master's thesis. University of Rhode Island Department of Natural Resources Science. Kingston, RI.
- Schueler, T.R. 1987. *The Simple Method in controlling urban runoff: a practical manual for planning and designing urban BMP's*. Metropolitan Washington Council of Governments, Water Resources Planning Board. Washington D.C.
- Schueler. 1995. *Site Planning for Urban Stream Protection*. Center for Watershed Protection, Ellicott City, MD.
- Simmons, Dale and R. Reynolds. 1982. "Effects of Urbanization on Base Flow of Selected South-shore streams, Long Island, New York." *U.S. Geological Survey. AWRA Water Resources Bulletin*. 1982.
- Stolt, M.H., B.C. Lesinski, and W. Wright. 2001. "Micromorphology of Seasonally Saturated Soils in Carboniferous Glacial Till." *Soil Sci.* 166(2001):6 406-414.
- U.S. Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS). 1986. "Urban hydrology for small watersheds." Technical Release 55. Washington, DC. U.S. Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS).
- . 1999. *A Procedure to estimate the response of aquatic systems to changes in phosphorus and nitrogen inputs*. National Water and Climate Center. Portland, OR.
- U.S. Environmental Protection Agency. 1990. *Buzzards Bay Comprehensive Conservation and Management Plan*. Boston, MA: U.S. Environmental Protection Agency.
- . 1993. *Guidance Specifying Management Measures for Sources of Nonpoint Pollution In Coastal Waters*. (Issued under Section 6217(g) of the Coastal Zone Act). EPA Office of Water, Washington DC.
- . 1996. "Environmental Indicators of Water Quality in the United States." Office of Water and Wetlands Page. <<http://www.epa.gov/OWOW/indic.tblcont.html>>
- . 1997. *State Source Water Assessment and Protection Programs Guidance*. EPA 816-R-97-009. Office of Water. Washington, DC.
- . 1997. *The Rhode Island Resources Protection Project Report*. EPA Region 1. Boston, MA.
- . 1999. *Protocol for Developing Nutrient TMDLs*. EPA 841-B-99-007. Office of Water. Washington, DC.

- .1999. "Total Maximum Daily Load (TMDL) Program." *Identification of Water Quality Indicators and Target Values*. Office of Water. Washington, DC.
- U.S. Geological Survey. 1999. "The Quality of Our Nations Waters – Nutrients and Pesticides." *USGS Circular 1225*. NAWQA Program. Reston, VA.
- U.S. National Oceanographic and Atmospheric Administration. 1999. *Cooperative Station Normal 1961-1990 Climatic Observations*. USDA Natural Resources Conservation Service National Cartographic and Geospatial Center. Fort Worth, TX.
- Valiela, I. et al. 1992. "Couplings of watersheds and coastal waters – Sources and consequences of nutrient enrichment in Waquoit Bay, Massachusetts." *Estuaries*, 15 (Winter 1992): 433-457.
- Veeger, A.I., et al. 1997. *Water Quality and Hydrogeology of Northern Conanicut Island, Rhode Island*. University of Rhode Island Department of Geology. Kingston, RI.
- Weiskel, P.K. and B. L. Howes. 1991. *The Use of Loading Models to Predict Nitrogen Inputs to Coastal Waters*. NWWA Eastern Focus Conference, Oct 29-31.
- Welsh, David J. 1991. *Riparian Forest Buffers*. NA-PR-07-91. US Department of Agriculture (USDA), Forest Service. Radnore, PN.
- Yang, X., D.R. Miller, S. X. Xu, L.H. Yang, H. Chen, and H. Nikolaidis. 1996. *Spatial and Temporal Variations of Atmospheric Deposition in Interior and Coastal Connecticut*. *Atmospheric Environment* 30:22 (1996): 3801-3810.