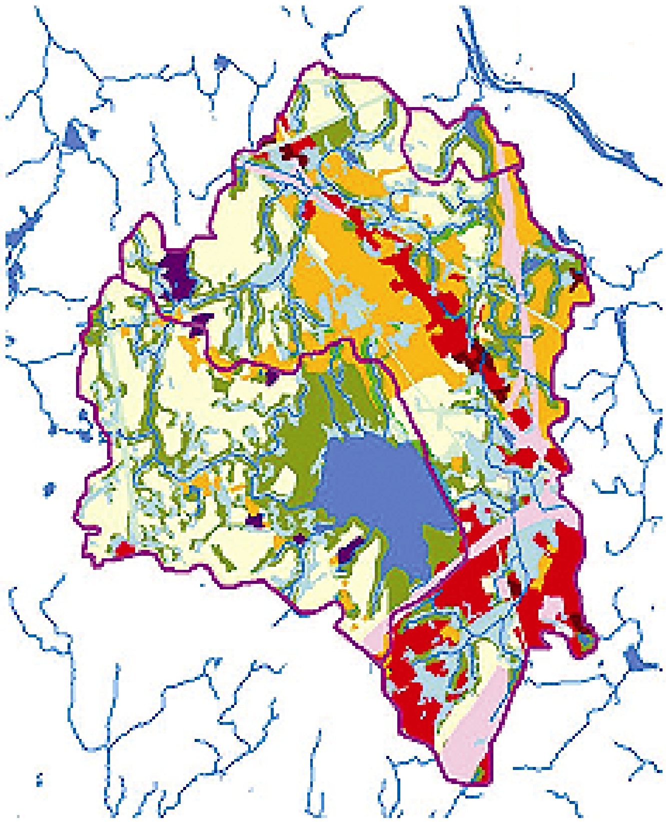
National Decentralized Water Resources
Capacity Development Project



Wastewater Planning Handbook

Mapping Onsite Treatment Needs, Pollution Risks, and Management Options Using GIS

University of Rhode Island Cooperative Extension
Kingston, Rhode Island

February 2004

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Mapping Onsite Treatment Needs, Pollution Risks, and Management Options Using GIS

Submitted by the
University of Rhode Island
Cooperative Extension
Kingston, RI

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ABSTRACT

This handbook is designed as a guide to wastewater management planning for small communities using geographic information systems (GIS). The intent of this handbook is to present methods that will provide the tools needed to foster tangible outcomes, which will enable communities to take action to meet wastewater treatment needs while protecting local water resources. The methods are designed as screening level approaches that use tools and techniques such as water quality risk indicators, hot spot mapping, and water resources vulnerability assessment. Local planning objectives, public participation, and available data on local resources provide the basis for conducting a wastewater needs assessment and successfully implementing a community wastewater management program. These methods are based on a decade of experience working with local communities through the University of Rhode Island Cooperative Extension Water Quality Program. Case studies of how communities in Rhode Island have used this needs assessment method to overcome onsite wastewater treatment problems are included.

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1 INTRODUCTION

This wastewater planning handbook describes methods for evaluating pollution risks within a watershed or aquifer recharge area in support of community decisions about land use and onsite wastewater management. It provides basic techniques for evaluating onsite wastewater treatment needs to ensure safe and sanitary treatment standards along with enhanced protection of surface waters, coastal embayments, and groundwater aquifers.

Geographic information systems (GIS) provide powerful tools for collecting, analyzing, and displaying information related to wastewater pollution. In the past decade, GIS software has become affordable and user-friendly. Basic skills are now attainable through short-courses, and many college graduates in planning and natural resources emerge with a working knowledge of GIS. Increasingly, local planners and land managers turn to GIS for routine tasks related to land management.

Aspects of this handbook emerged from a unique and comprehensive statewide GIS database available in Rhode Island. However, the lessons within this handbook are not restricted to Rhode Island. Digital databases and GIS are becoming more readily available to decision makers in counties and local municipalities throughout the nation. The Rhode Island situation is likely to represent the norm in the decade ahead, and this handbook seeks to help wastewater managers understand some of the power of GIS analyses.

Audience

This handbook is for planners, local officials, and resource managers who make land use and wastewater management decisions. Although the handbook illustrates GIS mapping applications, many examples are presented using a visual approach to provide insight for those with limited GIS skills. Using a visual approach, the handbook demonstrates the potential for using GIS not only for analysis, but also as an educational tool for describing pollution risks to public audiences. Table 1-1 shows specific applications for different groups.

Table 1-1
Potential Audiences and Applications for the Assessment Process

Audience	Example Applications
Community planners and local officials	Update town plans, develop wastewater management plans and ordinances, and develop resource protection overlay zoning
Wastewater management professionals, local Boards of Health, and Wastewater Management Commissions	Document onsite wastewater suitability and needs, forecast future needs, collect data for wastewater management plans, track inspections and permits, evaluate remediation alternatives
Environmental professionals, watershed managers, and regulators involved in evaluating watersheds for protection, management, or restoration	Conduct a screening assessment as the first step in a traditional wastewater management plan, or a Level 1 assessment under Total Maximum Daily Load (TMDL) study
Watershed groups, neighborhood associations, and other grass roots organizations	Provide guidance on how to promote and evaluate a simplified watershed assessment and /or recruit technical support from agencies, consulting professionals, or student interns
GIS professionals*	Technical support. Although the handbook assumes basic GIS software skills, some analysis steps are provided to guide new users and those who may be unfamiliar with specialized techniques

* Note: Engaging a computer specialist to assist in data analysis and mapping is essential. Since GIS analysis must be customized according to the unique characteristics of each state and local GIS database, detailed GIS instructions are generally not provided. However, most of the analyses require only a working knowledge of desktop GIS software.

Resource and Regional Focus

Although the risk assessment method presented in this handbook can be adapted to suit regional differences, it is best suited to rural and suburbanizing areas of the humid eastern region of the United States. Based on the type and extent of resources to be protected, individual study areas can be watersheds, groundwater recharge areas, neighborhoods, or whole towns.

Suburbanizing areas—Unsewered or partially sewered communities facing suburbanization of forests and farmlands are best suited for analysis. Communities facing the greatest growth pressures are most likely to see the need for conducting this type of analysis. Most analyses are not well suited to evaluating highly urban areas or predominantly agricultural landscapes where farm management practices could be the dominant influence on local water quality conditions.

Groundwater aquifers—Analyses can be conducted for both surface water and groundwater; however, the nutrient loading components of the assessment are best suited for analysis of pollutant inputs to groundwater recharge from different land uses.

Coastal embayments—Because nitrogen is a major constituent of wastewater effluent and coastal ecosystems are nitrogen-sensitive, the assessment approach is useful in identifying pollution risks. These risks apply specifically to shellfishing areas and seagrass habitat in coastal areas that experience a variety of stressors, including dense shoreline development and high seasonal use.

Eastern United States—Most of the assessment methods presented in this handbook have been developed and tested in the northeast and are based on typical glaciated and coastal landscape features, land use, and climate. Applications of this assessment approach in areas outside of the humid northeast should be carefully evaluated and adapted to local conditions. In this document, local refers to both municipal and county level resources and institutions.

Assessment Approach

This handbook was developed to provide a risk assessment and risk management framework for onsite wastewater (Jones et al., 2000). The methods outlined focus primarily on screening level analyses using available map databases and other information sources. In contrast to field monitoring or traditional water quality modeling, this approach is relatively rapid and requires limited resource investment.

This rapid assessment methodology is designed to guide and focus more in-depth analysis and monitoring. Because of the technical difficulty and expense in verifying pollution sources, results are presented as potential pollution risks to local surface water and groundwater resources. Assessment results can be used to

- Identify management priorities
- Identify data gaps
- Target locations for field investigations
- Support development of wastewater management programs

In situations with high accuracy and fine resolution data, the tools presented can lead all the way to implementation of management plans.

A summary of the basic elements of the assessment approach is as follows

- Builds upon existing GIS data and other readily available information sources
- Develops a cumulative assessment of pollution sources within local watersheds and aquifer recharge areas
- Focuses on small study areas (generally 300 to 3,000 acres) that reflect local resource protection priorities at human scales
- Links risk indicators of land management decisions to water quality
- Locates “hot spots” of high pollutant risk through map analysis of local hydrology and land use

- Envisions future impacts through “build-out” analysis and application of locally acceptable management practices
- Directs management practices using available technology
- Promotes active involvement of local officials and other community leaders in the assessment process from start to finish
- Encourages follow-up support to implement selected management practices

Typical Applications—Watershed and Wastewater Management

The techniques presented in this handbook focus on evaluating the environmental impacts of onsite wastewater treatment systems. The basic analysis begins with an inventory of existing conditions and pollution threats considering all types of land use activities and pollution sources. These are essential elements in all groundwater and watershed protection planning. Reasons for conducting an assessment might include any of the following:

- Pro-active water resource protection planning, often focusing on drinking water supplies or other critical resources, or one water body
  - Identify major sources of pollution and their relative importance
  - Evaluate effects of future growth
  - Weigh rezoning decisions in critical areas
  - Strengthen groundwater aquifer protection zoning
- Pollution remediation
  - Identify potential causes of water quality impairment
  - Screen management options
- Onsite wastewater management planning and analysis
  - Identify site suitability for onsite wastewater treatment
  - Document current needs for repair or pollution prevention
  - Identify potential future impacts
  - Investigate sewer avoidance strategies
  - Develop supporting documentation for wastewater management plans
  - Investigate need for advanced treatment in critical areas
- Public education
  - Use results to develop educational materials to raise public awareness of water resource issues and build support for adoption of wastewater management programs and other town actions

Table 1-2 lists examples of assessment applications.

Table 1-2
Assessment Applications—Examples from Rhode Island

Study Sponsors	Reasons for Conducting the Analysis	Actions Taken
Town Planning Board	Evaluate effects of future development on sole source aquifers.	Adopted wastewater management program with mandatory inspections and system upgrading. Performance standards for advanced wastewater treatment in selected areas adopted as groundwater protection overlay zone.
Nonprofit environmental organization and Town Planning Office	Identify sources of nitrogen contributing to decline of aquatic habitat; evaluate management options.	Developed public education materials to promote homeowner pollution prevention practices and support compliance with local inspection and maintenance requirements. Selected priority areas for funding system upgrades to advanced treatment.
Graduate student planning program and Cooperative Extension	Student project to evaluate sources of pollution to coastal pond.	Town used products to support development of town GIS system, public education materials; incorporated results into wastewater management plan.
Town Conservation Commission and Planning Office	Evaluate wastewater treatment options in known problem area.	Supported adoption of wastewater management ordinance; developed treatment standards for marginal soils.
State Department of Health	Prevent pollution in drinking water supply source water areas.	Developed recommendations for water supply protection; incorporated results into several local wastewater management plans and ordinances.

Using This Handbook

Because the assessment methods presented in this handbook are a collection of techniques applied within a risk assessment framework, users can create their own assessment from the “menu” of strategies presented. To guide assessment choices, the handbook identifies basic analyses that form the core of the assessment process. In this way, users can customize the assessment and take advantage of available GIS data, and focus on key resources and pollution threats unique to each study area. The whole suite of analyses can be applied for a comprehensive assessment or, by selecting from the menu of assessment options, individual assessment techniques can be used to conduct a simplified analysis or to supplement a larger watershed planning or assessment project.

Overcoming GIS Limitations

Many of the assessment techniques presented in this handbook assume that the user has access to digital map data at a scale appropriate for a planning-level analysis or can augment a GIS base map through "heads-up" digitizing (see Chapter 4, *Using USGS Digital Maps*). There are many ways to overcome GIS limitations using hard copy maps and best estimates, particularly when assessing smaller study areas. Much of the risk assessment can be performed using traditional planning approaches that combine sets of hard copy maps (such as soils, land use, geology, and topography maps) and overlays to decipher contribution areas, or techniques made popular by Ian McHarg in his seminal book *Design with Nature* (1969). For example, a hard copy parcel map is a valuable source of information for deriving current and future onsite wastewater system counts, housing densities, land use categories, and acreage. All of the important land use variables for the assessment can be derived from a hard copy parcel map and a tax assessor's database. Many parcel maps also have surface waterbodies drawn to scale, which is helpful for deriving riparian land use indicators.

For map data of landscape features such as soils and groundwater resources, it may be possible to overlay this information onto a parcel map using mylar, and manually code the information into a parcel database. For instance, a look at a hard copy county soil survey map may indicate that the majority of the study area falls into one or two soil hydrologic groups. By creating a new column in the tax assessor's database, parcels can be coded by predominant soil conditions. In combination with parcel data statistics such as land use and acreage, this information can be used to perform most of the modeling and indicator analyses presented in this document. If the assessment is to be conducted using the watershed approach, and the community does not have access to basic GIS data, a GIS technician will need to create watershed boundaries using a United States Geological Survey (USGS) topographical map and other nationally distributed GIS data (see Chapter 4, *Using USGS Digital Maps*).

How This Handbook Is Organized

Figure 1-1 provides an overview of the assessment approach presented in this handbook. The first three chapters of the handbook provide guidance on setting the scope of the needs assessment, incorporating public participation into the assessment process, and identifying key wastewater management issues and concerns.

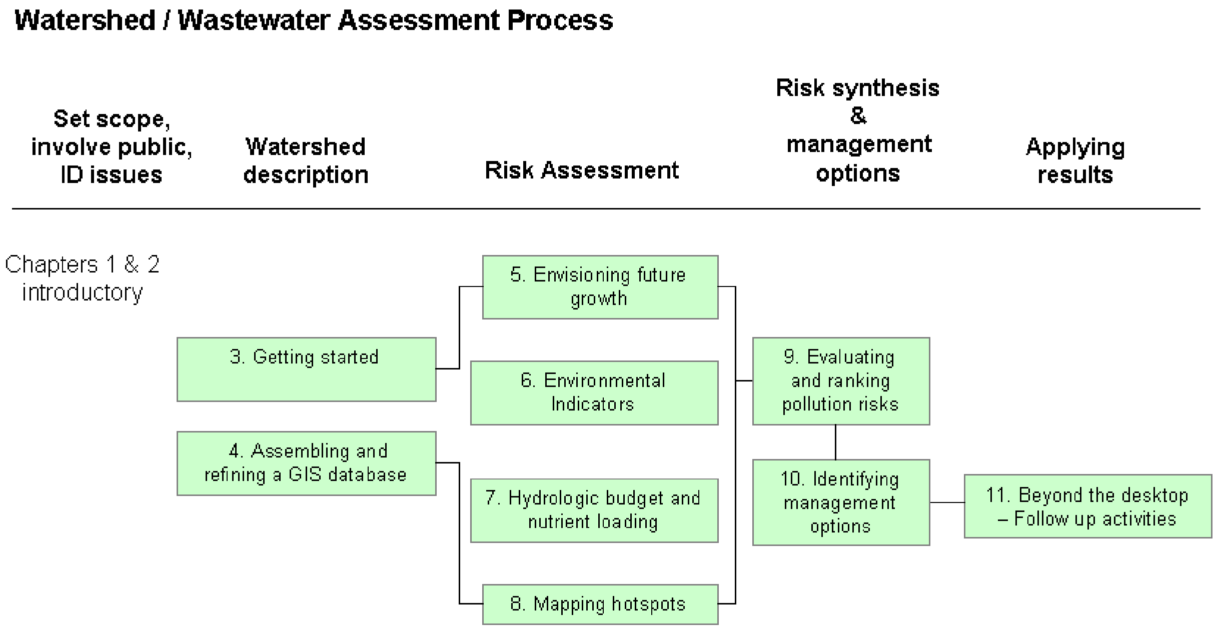


Figure 1-1
The Watershed/Wastewater Assessment Process: Steps of Assessment and Chapters of This Handbook

Chapter 2, *The Need for Comprehensive Wastewater Planning*, focuses on the need for a wastewater management program and the rationale for conducting a screening-level needs assessment.

Chapter 3, *An Overview of the Wastewater Needs Assessment Process*, provides guidance on initiating and conducting the assessment process, including how to form a wastewater committee, who should be involved, and how roles and responsibilities should be assigned. This chapter also provides direction on where to locate relevant information, such as government reports and regulations, local plans and ordinances, and university-based research.

Chapter 4, *Assembling and Refining a GIS Database*, provides detailed instructions on where to locate GIS data and how the data can be refined for assessment purposes. This chapter also provides instructions on how to overcome GIS limitations by using hard copy maps and USGS topographical map images to create base maps for the assessment.

Chapter 5, *Envisioning Future Growth*; Chapter 6, *Watershed Indicators: Linking Land Use to Water Quality*; Chapter 7, *Hydrologic Budget and Nutrient Loading*; and Chapter 8, *Mapping High-Risk Areas for Pollutant Movement*, comprise the more technical sections of the assessment process. These chapters provide step-by-step instruction on how to conduct a screening-level risk assessment. Users can consider applying one or all of the techniques outlined in the four chapters depending on available time, resources, and overall objectives for conducting the assessment.

Chapter 9, *Evaluating and Ranking Pollution Risks*, provides guidance on how to synthesize and display assessment results to guide management decisions.

Chapter 10, *Identifying Management Options*, provides guidance on how to use assessment results in the selection of management options and wastewater treatment levels to better protect public health and vulnerable water resources. This chapter introduces case studies of how communities in Rhode Island have used this needs assessment method to select sites for advanced treatment technologies, target and upgrade small lots with substandard systems, find shared solutions to failed systems, and to protect public drinking water supplies.

Chapter 11, *Beyond the Desktop*, provides advice on developing a public outreach strategy, incorporating assessment results into wastewater plans and ordinances, and designing an educational strategy to support development of a wastewater management program.

Case Studies—Practical Examples of Communities Using Screening Level Assessments to Support Wastewater Management Decisions

The following examples illustrate how one community utilized the pollution risk assessment methods presented in this handbook to direct and support management decisions. The applications ranged from a rapid, screening-level assessment to target town-wide wastewater needs to a more focused assessment of nonpoint source pollution entering an important coastal embayment. It is important to note that in each of the community examples described, the assessments were part of an ongoing land use planning process that includes regular updating of comprehensive community plans, zoning and subdivision ordinances, and groundwater protection planning. In this context, assessments can be viewed as useful tools for filling data gaps and for generating new information to adapt management actions to constantly changing community conditions and planning goals.

Case Study 1: Wastewater Management Planning to Protect Sole Source Aquifers, Avoid Sewering, and Restore Coastal Waters in North Kingstown, Rhode Island

Background

The town of North Kingstown, RI is a suburban community of approximately 26,000 residents situated along the western shore of Narragansett Bay. Located within commuting distance of Providence, the town is a mix of rural farmland, historic village centers, more contemporary strip commercial development, and low- to moderate-density suburban housing. A major state industrial technology center occupies the site of a former naval base. This state-owned industrial center maintains its own sewer system, which serves approximately 10 percent of the surrounding housing. Otherwise, the town is entirely unsewered and dependent on onsite wastewater treatment systems, including densely developed commercial districts, village centers, and waterfront seasonal dwellings now converted for year-round use.

Resource Issues

Groundwater aquifers underlying much of the town provide the sole source of drinking water for all residents and businesses (Figure 1-2); most rely on public water provided by municipal wells. The town's deep, unconfined sand and gravel aquifers provide a reliable but highly vulnerable source of supply. Protecting this supply is a top priority for the town.

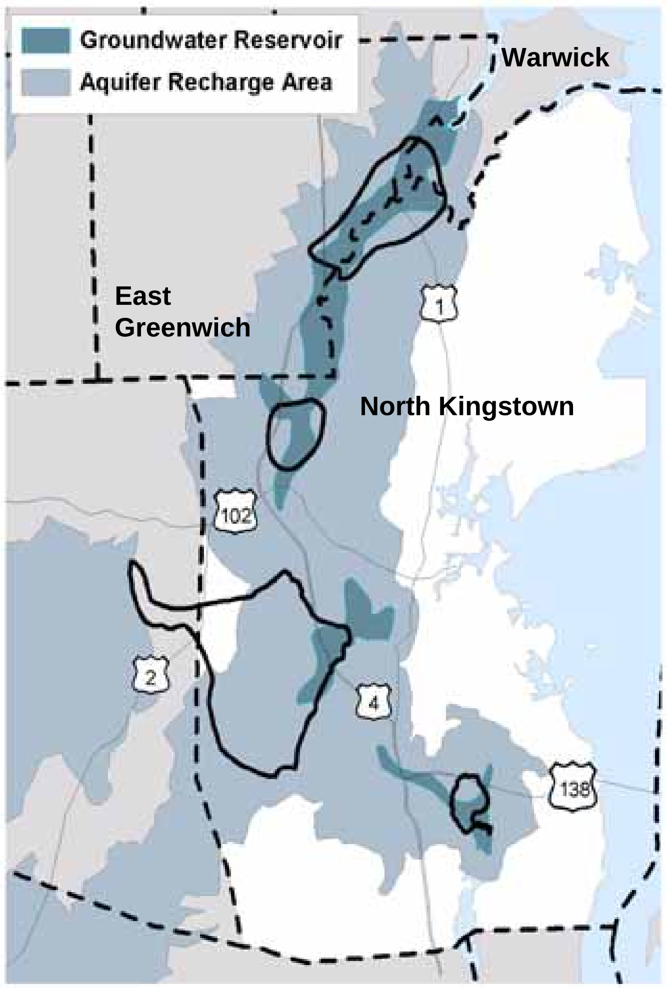


Figure 1-2
North Kingstown, RI Groundwater Resources Map

GIS-Based Wastewater Needs Assessment Using Plat Maps

Concerns over onsite wastewater treatment system failures and the ability of onsite systems to meet town needs led the town council to appoint a Sewer Study Committee to evaluate wastewater treatment needs and determine the need for sewers in all or portions of the town. A planning intern along with volunteer sewer committee members conducted much of the study.

Method

A simple GIS overlay analysis was used to evaluate the adequacy of existing wastewater treatment technologies to address current and future pollution problems in the town. An evaluation matrix was developed to include the following rated parameters, using town plat maps as the unit of analysis:

- Onsite wastewater system age
- Density of development
- Soil suitability
- Aquifer recharge areas
- Proximity to surface waters
- Water usage

Data for each parameter were organized by “plat” maps. A plat is a section of a town indicating the location and boundaries of individual properties (parcels). A rating was assigned to each factor and areas with multiple overlays were ranked by priority for remediation. Figures 1-3 and 1-4 show two of the parameters considered in this study: housing density and age of onsite system.

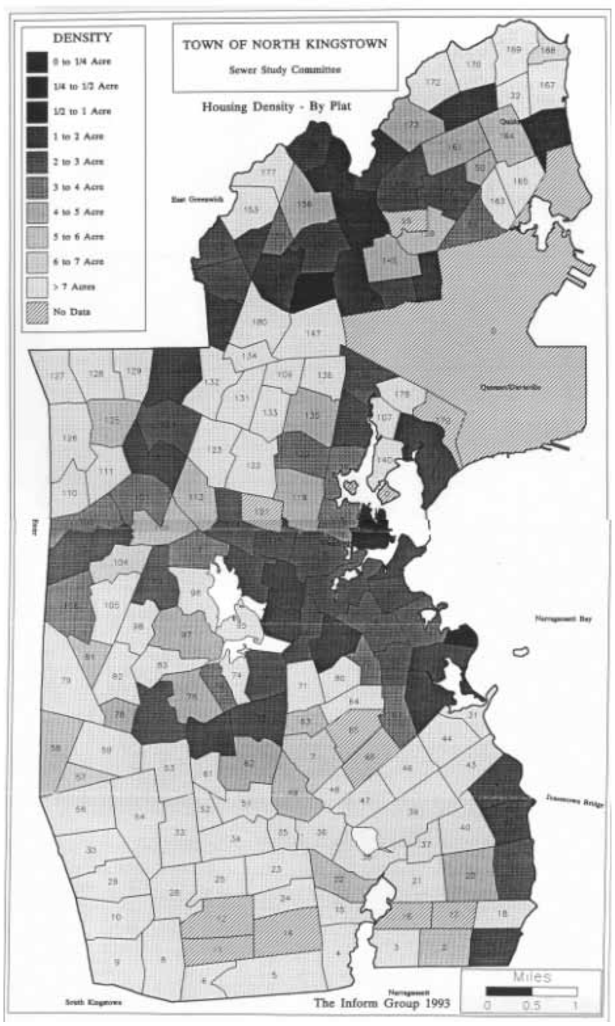


Figure 1-3
Housing Density by Plat Area

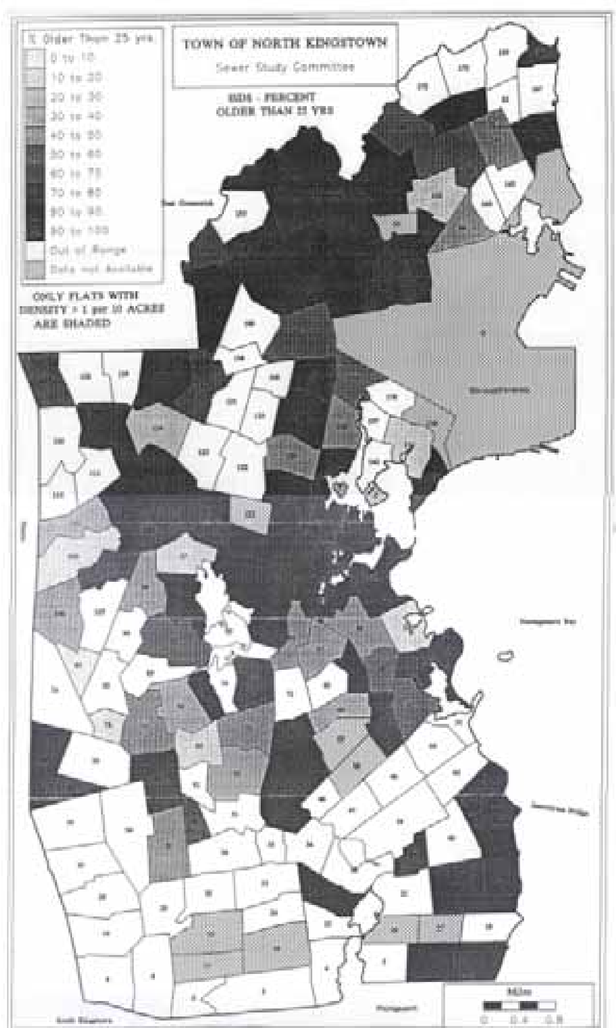


Figure 1-4
Age of Onsite Systems by Plat Area

Figure 1-5 shows the priority groundwater recharge protection areas, which also factored into the overlay.

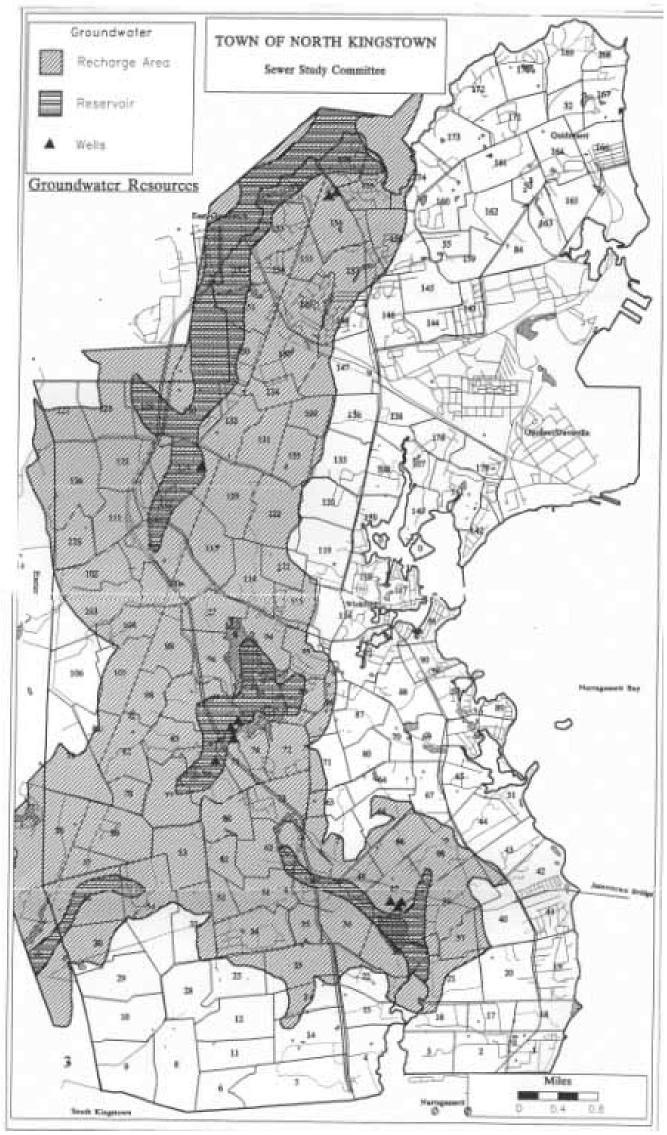


Figure 1-5
Groundwater Protection Areas by Plat Area

One of the strengths of this study is the illustration of the range of options available to the town in addressing pollution prevention. However, averaging results by plat area can mask data, resulting in moderate values overall. In reality, small pockets of densely developed lots and businesses with high strength wastewater, especially when located in poor soils or in shoreline areas, might actually contribute a disproportionately higher risk. Chapter 8, *Mapping High Risk Areas for Pollutant Movement*, demonstrates the value of “hot spot” mapping techniques that can target locations at higher risk and facilitate more focused solutions.

Assessment Results

Assessment results consist of treatment options and general findings.

Treatment Options

The assessment identified potential areas for use of alternative onsite wastewater technologies for individual or cluster systems in areas of high density, poor soil, past failure, and high water use. Plats with these limitations, but in close proximity to sewer lines, were identified as priorities for central collection to gravity sewers. Wastewater management with town oversight of onsite system maintenance was recommended in groundwater recharge areas, with education efforts town-wide.

General Findings

Overall, the study showed that:

- The density and age of onsite systems in the town warranted the adoption of a management program, particularly in the town's groundwater protection areas and along the coast.
- Sewers are appropriate in certain areas of the town, but traditional sewers are only one of the recommended treatment options.
- There is potential for improved wastewater treatment capacity to promote more intensive land use activities, but there is a need for better land use controls. These controls, which preserve and enhance the quality of life, are necessary prior to the adoption of wastewater management solutions.
- The development of a formal facilities plan to evaluate technical, environmental, and economic feasibility of sewer extensions is recommended.

Case Study 2: Wickford Harbor Watershed Assessment

Background

Wickford Harbor is a 400-acre sheltered cove of Narragansett Bay in North Kingstown, RI (see Figure 1-6). A working port since the 1600s, the harbor area is a thriving waterfront village of historic homes, gardens, and shops. Recreational paddling, boating, and shellfishing are popular in Wickford Harbor's many coves. The harbor provides a valuable nursery for fish, wading birds, and shellfish. It also supports one of the few remaining eelgrass beds in Narragansett Bay. This important underwater grass filters pollutants and provides essential habitat for shellfish. Because it is sensitive to pollution from runoff and septic effluent, especially nitrogen, it also serves as a vital indicator of coastal water quality.

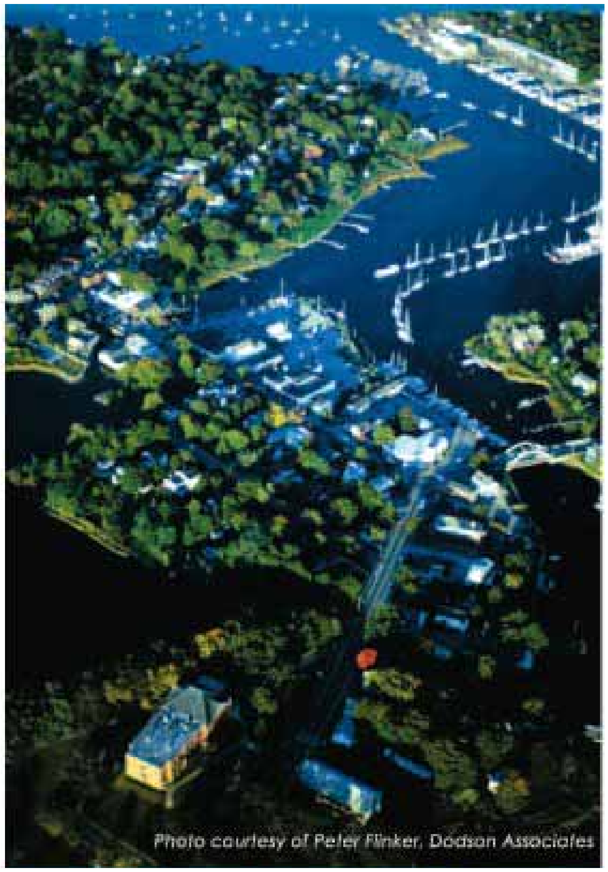


Figure 1-6
Wickford Harbor and Village

Resource Issues

Previously, the town's resource protection efforts had focused on groundwater. In particular, the town's wastewater management efforts were largely motivated by the need to protect drinking water supplies. In 1999, with growing interest in restoring coastal eelgrass habitat, Save the Bay, a nonprofit environmental group, joined with the Town of North Kingstown and the University of Rhode Island, Cooperative Extension to evaluate sources of pollution entering Wickford Harbor.

GIS-Based Subwatershed Analysis

The study goals were to

- Assess sources of nitrogen in the Wickford Harbor watershed
- Identify management options
- Locate sites for stormwater retrofits

To do so, the 4,500-acre watershed was divided into six subwatersheds (see Figure 1-7). The undeveloped Cocumcussoc subwatershed served as a reference watershed that indicated natural background conditions. Each study area was then assessed using a variety of land use and landscape factors.

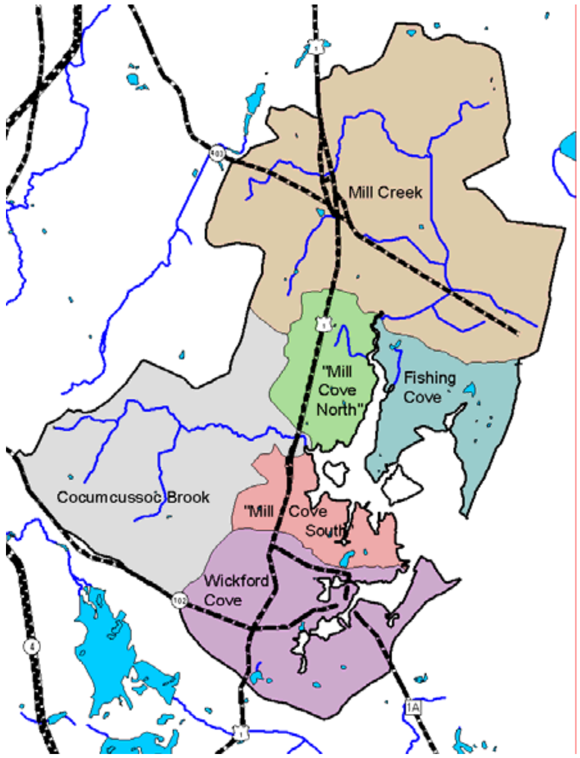


Figure 1-7
Wickford Harbor Subwatersheds

Method

GIS overlay analysis was used to develop a variety of water quality risk indicators related to development in each subwatershed. These risk indicators included:

- Percent impervious cover (Figure 1-8)
- Percent high-intensity land use in shoreline areas (Figure 1-9)
- Percent nitrogen loading in Wickford Harbor watershed
- Estimated proportion of nitrogen loading from onsite wastewater systems (Figure 1-10)

In addition, GIS-based "hot spot mapping" was performed using detailed parcel data containing information on onsite system age and repair status (

Figure 1-11).

Assessment Results

Figure 1-8 shows that the amount of pavement and other impervious cover was high in all areas, especially in the Mill Creek subwatershed where a large state industrial park and port are located. The town used these findings to discuss the need for reducing impervious cover with proposed roadway extensions through the industrial park. Figure 1-9 shows that the amount of shoreline area compromised by intense development is high, especially in the Wickford Cove subwatershed. Restoring these shoreline areas is a priority.

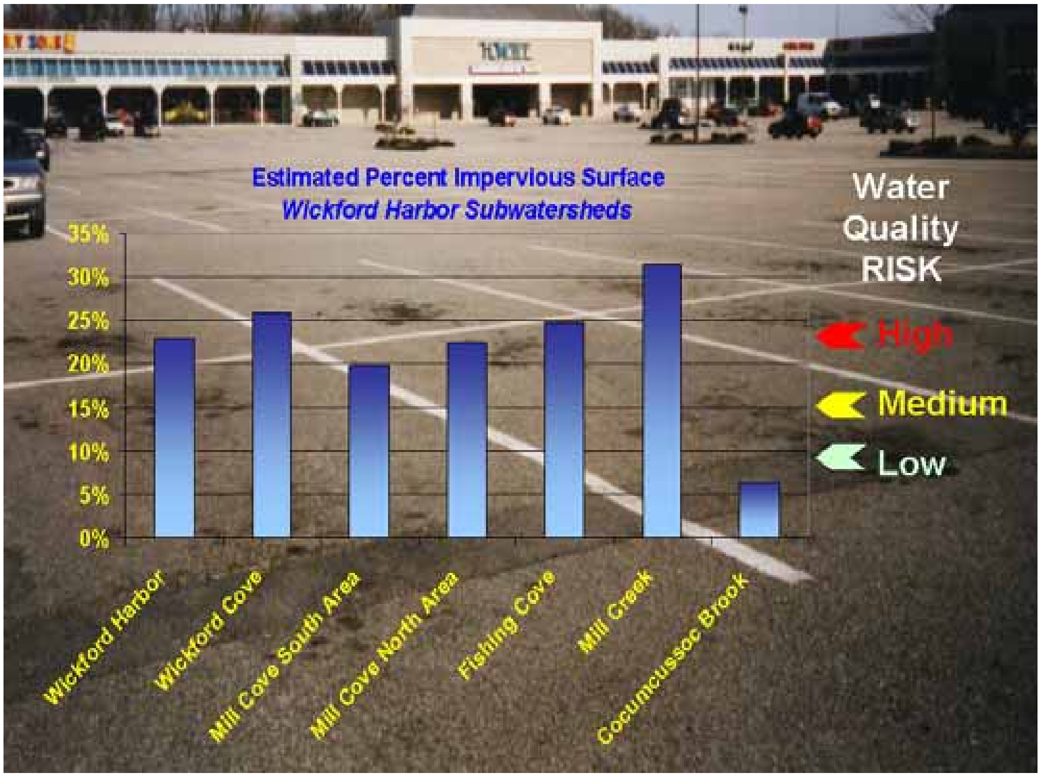


Figure 1-8
Estimated Percent Impervious Surface Cover

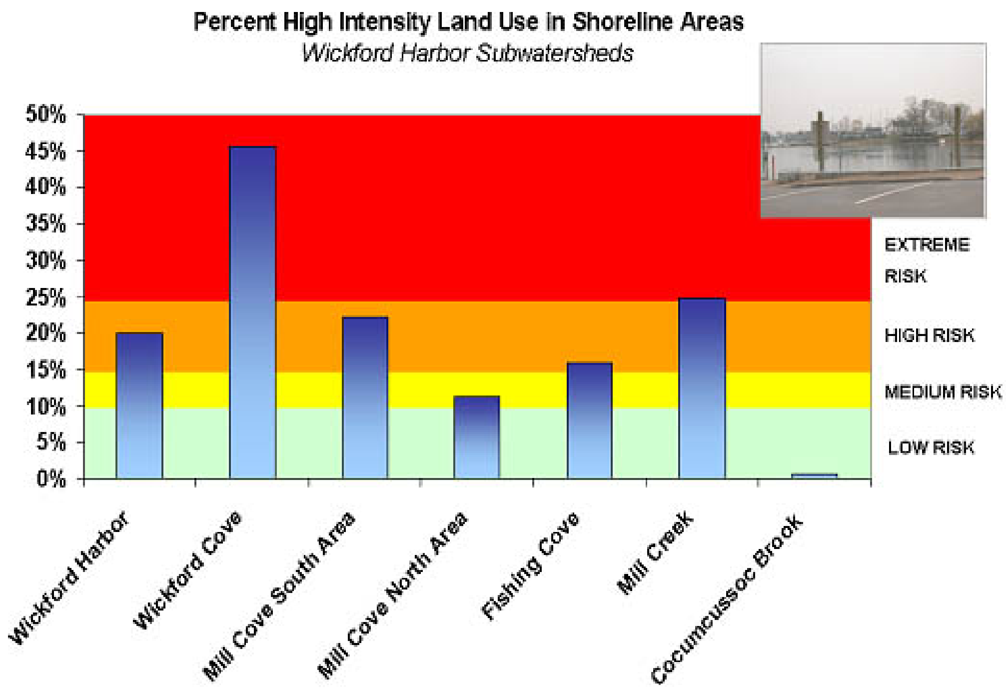


Figure 1-9
Estimated Percent High Intensity Land Use in Shoreline Areas

The results of the GIS-based analysis showed high nitrogen loading to the harbor from watershed land use activities, with onsite wastewater systems estimated to account for more than 80 percent of the sources (Figure 1-10). In addition, GIS parcel mapping, and review of building records and onsite system permits concluded that at least 70 percent of village onsite systems were likely to be cesspools or substandard (Figure 1-11).

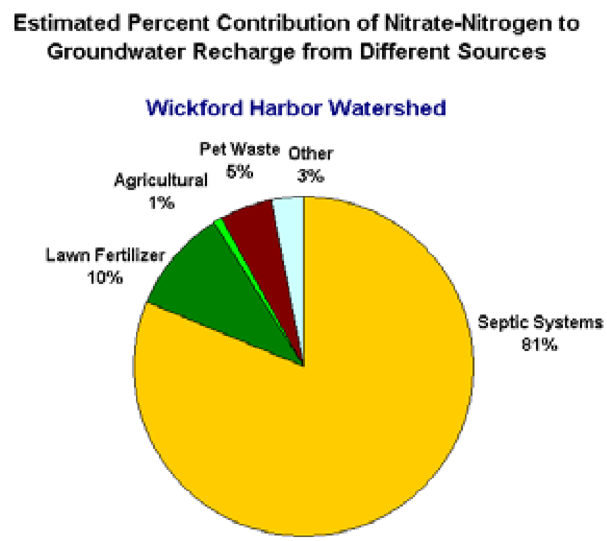


Figure 1-10
Nitrogen Sources in Wickford Harbor Watershed

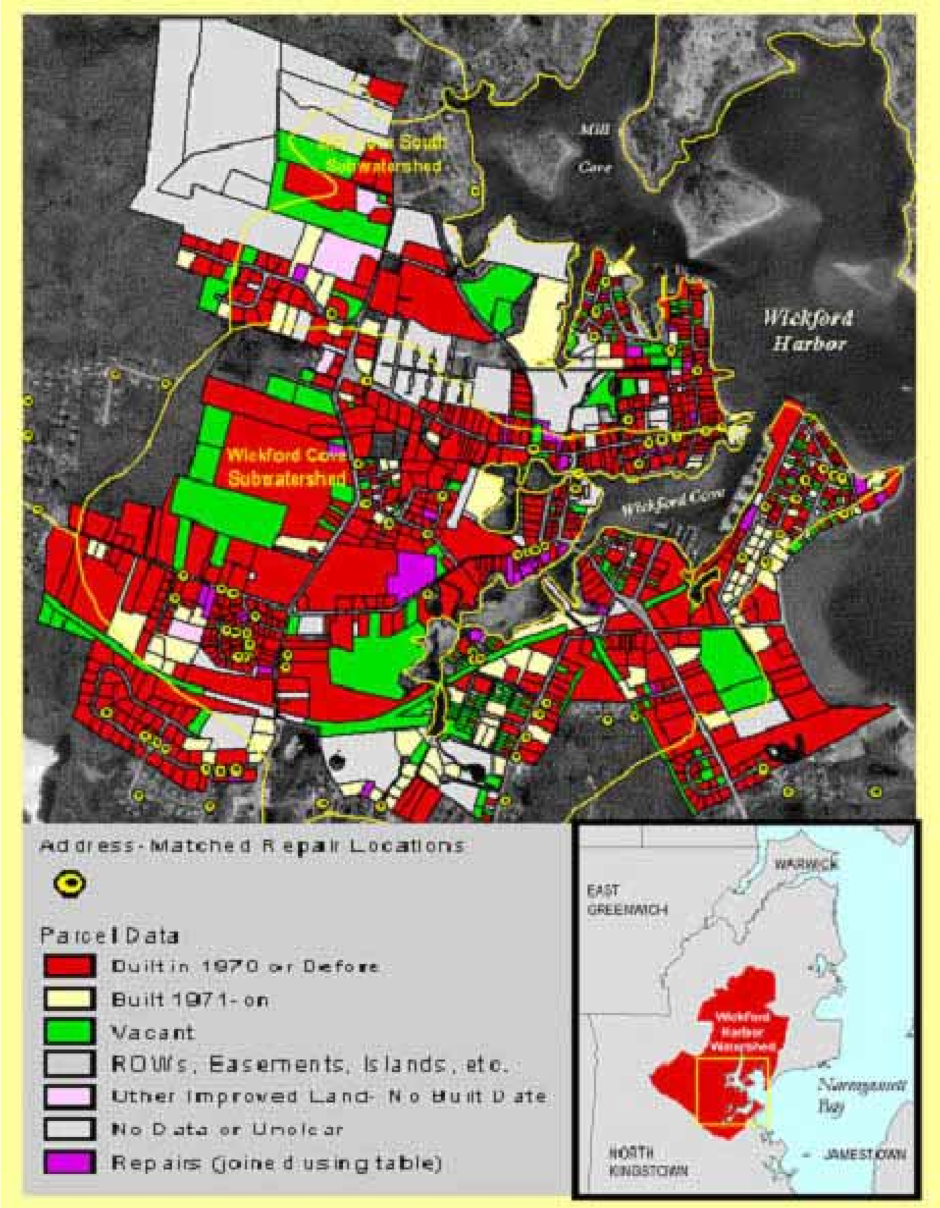


Figure 1-11
Hot Spot Mapping of Wickford Harbor Watershed Parcels Coded by Age and Onsite System Repair Status

GIS analyses were useful in evaluating the extent of nitrogen abatement that could be derived from retrofitting different portions of the watershed with alternative onsite wastewater technologies specifically design for nitrogen removal. Figure 1-12 shows that retrofitting all the onsite wastewater systems with nitrogen removal technology would lower nitrogen loading by more than one-third. This decrease is comparable to the results obtained by extending centralized sewers to the developed areas of the watershed.

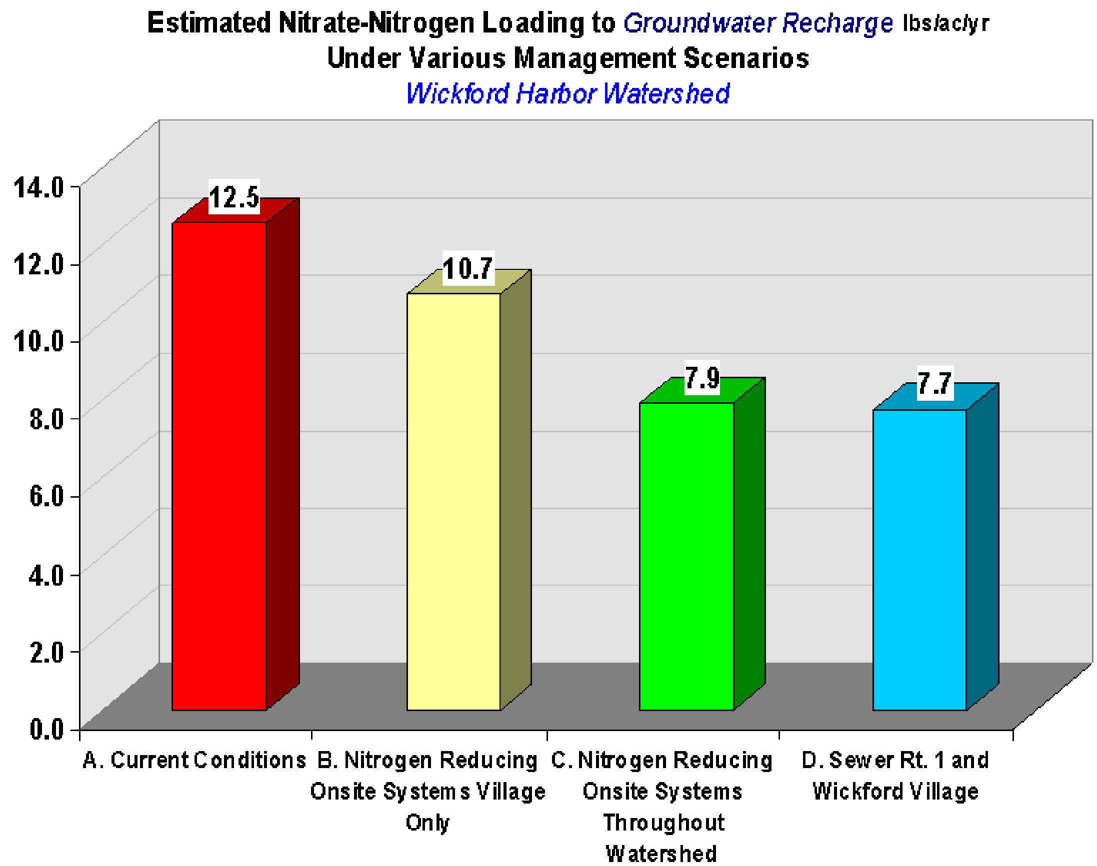


Figure 1-12
Alternative Wastewater Treatment Options

The town advisory group had determined that a sewer extension was not a realistic or feasible option, so the comparative analyses between options was of critical concern to the town decision-makers. As a result of the assessment:

- The town and Save the Bay identified additional areas for bacteria monitoring.
- The Rhode Island Department of Environmental Management used evidence collected to place the Harbor on the State's List of Impaired Waters. The agency will conduct a field investigation of potential pollution sources.
- Save the Bay and the University of Rhode Island (URI) developed a summary fact sheet, which the town mailed to watershed residents to support compliance with the wastewater management program.
- A grant program for treatment system upgrades was developed.

Grants for Onsite Wastewater Treatment System Upgrading

To help promote onsite system repair and replacement using advanced treatment systems in the Wickford Harbor watershed, the University of Rhode Island, Cooperative Extension and the town, with United States Environmental Protection Agency (EPA) support, developed a grant program. The program provided partial grants for repairs that used advanced treatment systems. Applicants in critical harbor areas, along shoreline tributaries, and in locations with problem soils were given priority (Figure 1-13).

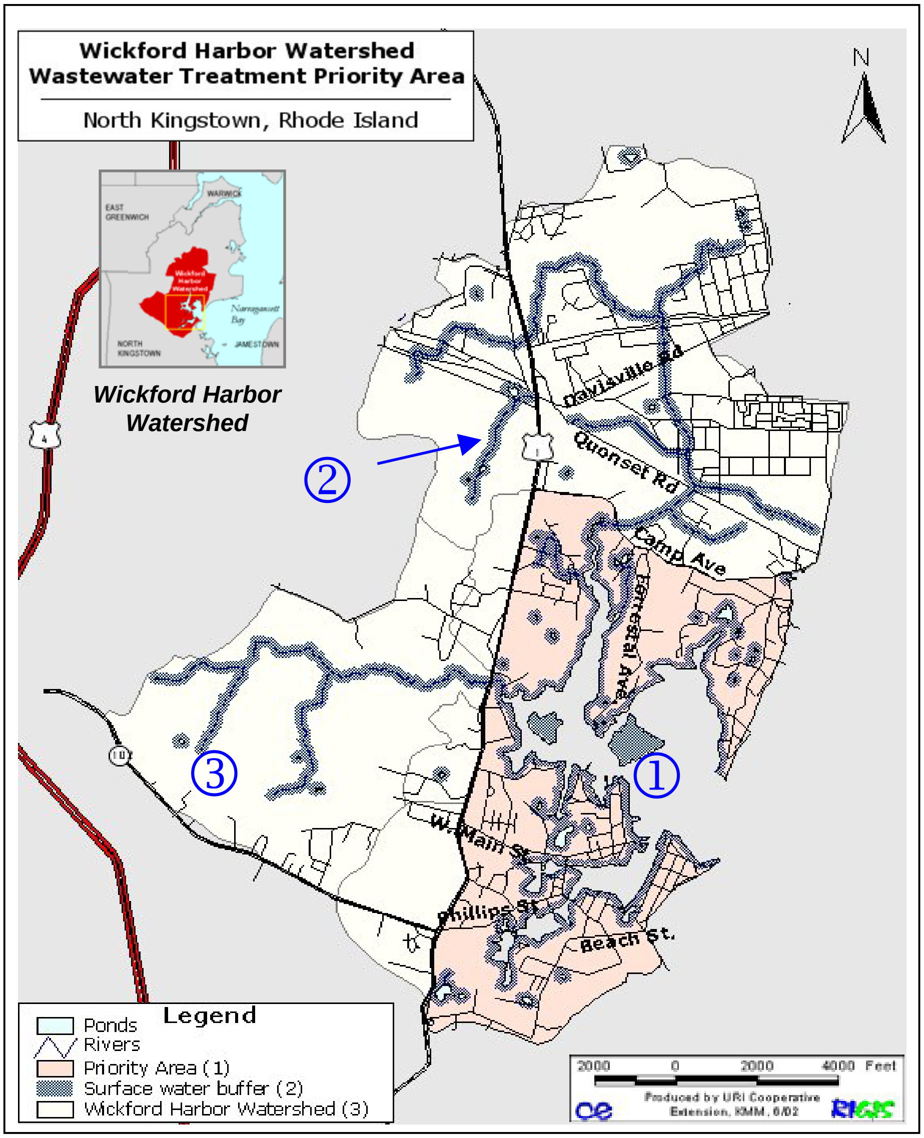


Figure 1-13
Priority Areas for Onsite Wastewater Treatment System Grants

Developing Treatment Standards

The treatment priorities for grant funding can easily be developed into treatment standards for new systems and repairs in the Wickford Harbor watershed. Specifying the areas where nitrogen and/or pathogen treatment is needed to protect water resources and overcome site constraints such as a high water table provides guidance to designers and homeowners on the type of technology that is most appropriate for a site. Often the most appropriate systems are also the most cost effective, because systems designed for difficult sites can be expected to have a longer useful life.

Treatment performance standards are typically adopted through zoning overlay districts. Because technologies are constantly evolving, a list of technologies capable of achieving a standard—such as 50 percent nitrogen removal—can be maintained in a separate list at the town hall (see Chapter 10, *Identifying Management Options*).

Implementing Comprehensive Wastewater Management

The town is completing the first three years of the mandatory inspection program and will be evaluating its effectiveness. Based on inspection results, the need for program modifications, such as more thorough reporting, replacement of cesspools, and need for treatment standards, will be evaluated. Meanwhile, advanced treatment systems are routinely being used for new systems and repairs, particularly in environmentally sensitive areas, on small lots, and for businesses. The senior high school treatment system—a subject of concern in the 1993 sewer study—was replaced using a re-circulating sand filter. In densely developed areas of the town, such as Wickford Harbor, systems are being replaced as needed.

2 THE NEED FOR COMPREHENSIVE WASTEWATER PLANNING

Wastewater is a leading cause of water quality impairment. According to EPA studies, malfunctioning onsite systems are a significant source of groundwater contamination, beach closures, shellfish advisories, and eutrophication of ponds, lakes, and coastal estuaries nationwide. Currently, one-fourth of the population of the United States (approximately 60 million) utilizes onsite systems and one-third of all new developments will have onsite systems (Census Bureau, 1999). Of the systems now in the ground, more than half are estimated to be over 30 years old and at least 10 to 20 percent of these are believed to have stopped working all together (USEPA, 2002b, USEPA 2003).

In many older communities structural failure and substandard design promote direct leakage of septic effluent into storm drains. Over the last decade, EPA has adopted a Total Maximum Daily Load (TMDL) approach to assist communities in the assessment and restoration of impaired waterbodies (USEPA, 1999a; NRC, 2001). A TMDL approach seeks to identify contaminant sources to set total daily load limits for contaminants of concern and to guide abatement efforts.

A properly sited, designed, installed, and maintained conventional system is considered the system of choice for a straightforward lot with few site problems. It is important to note, however, that conventional onsite systems do not treat nitrogen in wastewater; dilution in groundwater is the primary treatment path for nitrogen. Regardless of how well systems are functioning, high densities of onsite systems in coastal watersheds generate nitrogen pollution in groundwater and coastal embayments (Gold and Sims, 2001).

A conventional onsite system (Figure 2-1) consists of a septic tank, D-box, and drainfield (leachfield). The septic tank is a watertight vessel designed to help settle out solids in the wastewater and to provide a zone for decomposition of those solids. Septic tanks can be single or multiple compartments, made of concrete (most common), fiberglass, or polyethylene. Septic tanks should be inspected periodically and pumped on an as-needed basis. The typical septic tank pump out frequency is every three to five years.

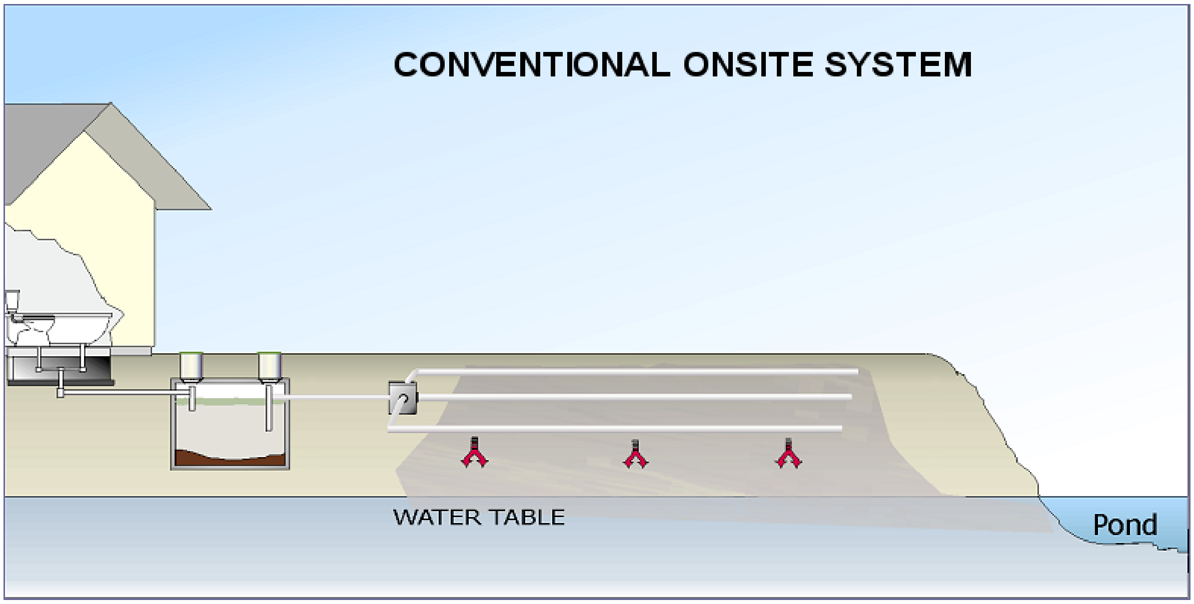


Figure 2-1
Conventional Onsite System

The past decade has seen profound advances in the reliability and effectiveness of alternative and innovative technologies for onsite wastewater treatment. These new systems can be used to retrofit older systems that have structural defects or are located on sites that are unable to support conventional technologies (Loomis et al., 2001a). In addition, alternative systems can provide added safeguards for new development that is planned near valuable water resources. Chapter 10 provides examples of how these systems can be incorporated into the potential action strategies that might result from the wastewater management planning process outlined in this handbook.

Types of Contaminants in Septic Effluent

Wastewater from improperly sited or malfunctioning onsite systems contains unacceptable levels of

- Pathogens
- Nutrients (nitrogen and phosphorus)
- Endocrine disrupters
- Heavy metals
- Suspended solids

(Crites and Tchobanoglous, 1998)

Pathogens

Pathogens are disease-causing agents such as viruses and bacteria. Pathogenic microorganisms in polluted water are difficult to identify, isolate, and enumerate, and are highly varied in characteristics and type (USEPA, 2001b). Due to the difficulty in monitoring harmful pathogens in water and wastewater, bacteria such as *E. coli* may serve as general indicators of fecal contamination (Cliver, 2001). Because of their small size, pathogens are easily carried by surface water runoff and other discharges into surface waterbodies. Pathogen removal within functioning onsite wastewater systems is generally related to the texture and depth of the unsaturated zone. Gross pathogen contamination from onsite wastewater systems is most often associated with failing systems and systems with structural defects or improper construction.

The presence of any fecal indicators in a waterbody is a sign that the water is potentially unsafe for consumption, and standards exist that set safe limits for shellfishing and recreational use. Often associated with human activity, pathogens arise from sewage outfalls, failing onsite systems, pet waste, and agricultural activities. Wildlife is also a source of pathogen contamination in surface water. Contact with pathogens can occur during recreational use of contaminated waterbodies, when these waterbodies are used for drinking water, or through consumption of contaminated shellfish.

Nutrients

Nutrients, primarily nitrogen (N) and phosphorus (P), can be introduced into subsurface flows and groundwater through onsite wastewater discharges. Nutrients, particularly mobile forms of nitrogen, may then be carried towards surface waterbodies. Failing onsite systems can also promote rapid nutrient movement to surface waterbodies during storm events through storm drains or in overland flow. Other sources of nutrient enrichment include atmospheric deposition, agriculture, lawn fertilization, pet waste, and wildlife. Properly sited and functioning onsite systems can remove substantial amounts of phosphorus, but nitrate-nitrogen can be released from well-maintained conventional systems (Gold and Sims, 2001).

Nutrient enrichment leads to the excessive growth of algae in waterbodies. Excessive amounts of algae can cloud surface water and reduce light levels for vital plant species. Algal decomposition also consumes available dissolved oxygen, which stresses fish and shellfish populations. A low level of dissolved oxygen, a condition known as hypoxia, is one of the most serious water quality impairments to coastal waters (NRC, 2000).

Endocrine Disrupters

Endocrine disrupters are chemicals that adversely affect human health through disruption of glandular function. A growing body of research is now examining the potential risks from pesticides, ingredients in household chemicals, detergents, pharmaceuticals, and heavy metals such as cadmium, lead, and mercury that may act as endocrine disrupters (USEPA, 1997b; Kavlock et al., 1996)

Heavy Metals

Elevated levels of heavy metals including lead, mercury, cadmium, chromium, and copper have occasionally been detected in household wastewater leakage flows (USEPA, 2002b). These heavy metals are derived from household cleaners and from aging plumbing structures. Heavy metals in drinking water can lead to delays in physical and mental development, kidney disease, gastroenteritis illnesses, and neurological problems (USEPA, 2002b). These heavy metals are typically removed by the soil in properly functioning onsite wastewater treatment systems.

Suspended Solids

Most wastewater-related solids consist of sediment, grease, or fats that, in a normally functioning system, would sink or be trapped by a filter (USEPA, 2002b). Suspended solids are generally removed by the septic tank and passage through unsaturated soils. When septic tanks are not maintained, these solids can clog a soils absorption field and create hydraulic failure (Siegrist et al., 2001). Hydraulically failing onsite systems create surface ponding and allow suspended solids to be carried to surface waters during storm events. In streams and coastal waters, suspended solids pose a threat to aquatic life by blocking out sunlight that is required for photosynthesis, and decomposition of organic solids can reduce the levels of dissolved oxygen in surface waterbodies.

The Importance of Wastewater Needs Assessments

A wastewater needs assessment enables a community to proactively protect water quality before contamination occurs. Wastewater management planning entails coordination of a variety of administrative, regulatory, financial, environmental, and educational entities. Integrating wastewater planning with other community planning efforts is one way to significantly reduce the costs of a new program. Wastewater planning objectives can also be tailored to support existing town goals and programs such as the protection of potable drinking water supplies or a local fishery.

The Need for Watershed and Aquifer Scale Approaches

Due to the significant risks that failing or improperly sited onsite systems pose to both surface water and groundwater resources, coupled with past difficulties in making regulatory decisions based on their cumulative impacts to water resources, wastewater management professionals across the country have begun adopting watershed and aquifer scale approaches to assessing, planning, and managing decentralized wastewater systems (USEPA, 2003). A watershed (Figure 2-2) consists of all the lands contributing water and waterborne substances (such as nutrients, pathogens, sediment) to a given waterbody. Every waterbody has a watershed and large waterbodies often receive inputs from many subwatersheds.

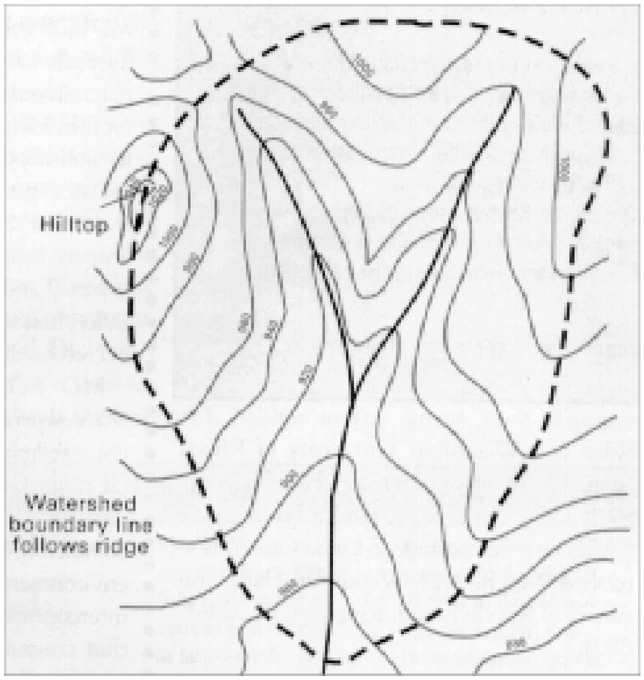


Figure 2-2
Top View of a Watershed Boundary Drawn from a Topographical Map

Similarly, the water that recharges groundwater aquifers comes from a geologically defined area of land (Figure 2-3). The risk of groundwater contamination from land use activities is highest in sandy soils within these recharge areas, particularly when contaminants are discharged directly into the ground, such as septic effluent from onsite systems.

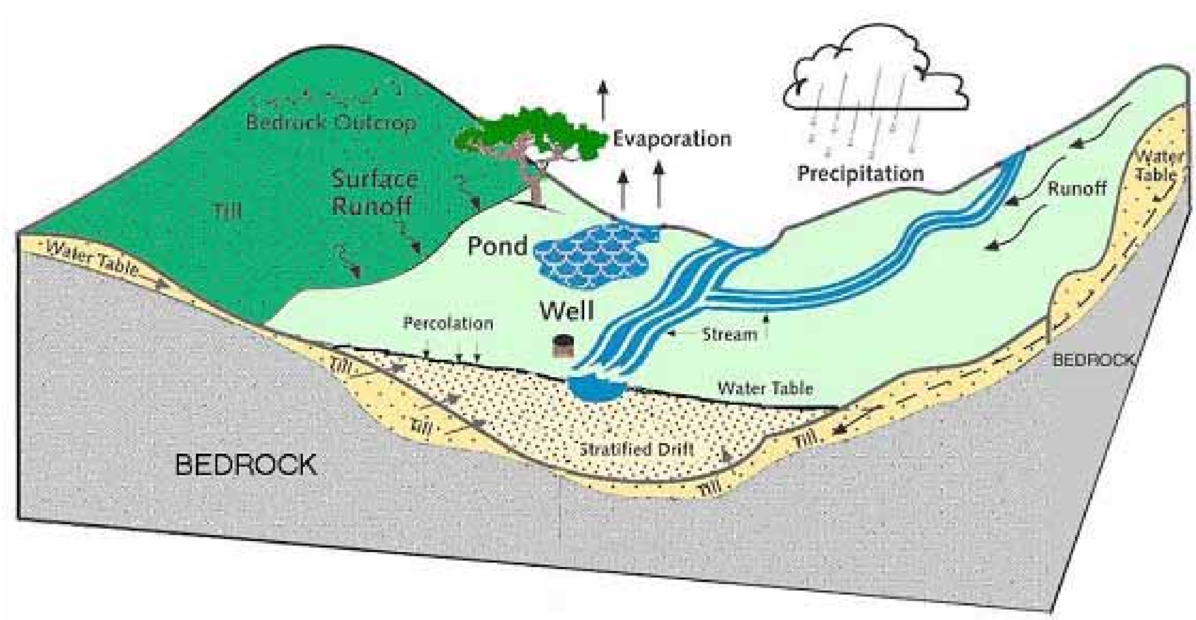


Figure 2-3
Aquifer Recharge Area

Traditionally, onsite system siting and permitting decisions have been based solely on individual site constraints and the pollution risks of individual systems to groundwater or surface water. Watershed or aquifer scale approaches focus planning and management efforts on the cumulative impacts of all current and future onsite systems on local surface water and groundwater resources. Using these approaches, wastewater managers and environmental protection officials can better identify and focus management efforts on problematic areas and at risk waterbodies (USEPA, 1995; USEPA, 2003). Watershed or aquifer scale approaches to wastewater planning are beneficial not only in guiding new development to the most appropriate areas, but also in establishing wastewater treatment standards based on site constraints, and in making cumulative siting and permitting decisions.

Key Differences

A watershed or aquifer scale approach to wastewater management planning differs from more traditional management efforts as follows:

- Greater attention is given to the environmental impacts of onsite wastewater treatment systems in addition to traditional considerations of site suitability and public health.
- Environmental indicators and other nontraditional measures are introduced to estimate impacts, including those that may be difficult to measure using standard water quality criteria. (For example, water quality criteria have not been established for nitrogen in many coastal waters, even though this is a key nutrient causing over enrichment of poorly flushed areas leading to loss of shellfish habitat.)
- Relative onsite wastewater impacts are compared to other major pollution sources. Documents the need for onsite wastewater improvements and supporting management practices to enhance water quality.
- Results and recommendations integrate onsite wastewater treatment needs with stormwater controls, wetland buffer protection, and other land use considerations.
- Hydrologic units such as watersheds and aquifer recharge areas are used to assess the combined effects of onsite systems and other pollution sources on priority resources. Although detailed analysis may center on the watershed areas within a particular community, the larger watershed may be assessed. This assessment involves at least a review of existing information and preliminary map analysis, possibly with assistance from neighboring communities, regional planning agencies, or county/state agencies.

Initiating a Wastewater Needs Assessment

The overarching goal of the wastewater needs assessment presented in this handbook is to assist communities in selecting the most suitable level of management control based on local conditions, risks, and available resources. In addition, a formalized assessment process creates a proactive way to engage the public and gain community endorsement of the management program selected.

The next chapter of this document provides guidance on initiating and conducting the assessment process, including:

- How to form a wastewater committee
- Who should be involved
- Ways to involve the public
- Where to locate supporting documents, reports, and other relevant information

3 AN OVERVIEW OF THE WASTEWATER NEEDS ASSESSMENT PROCESS

This chapter provides basic recommendations on how to initiate a wastewater planning process at the community level. The recommendations in this chapter cover topics such as how to

- Organize a wastewater needs assessment committee
- Become familiar with community geographic characteristics
- Collect data and supporting documents
- Interpret and synthesize existing data
- Define wastewater assessment objectives
- Work within the community
- Determine roles and responsibilities

The chapter also lists some of the technical resources required for conducting a GIS-based wastewater needs assessment.

Organize a Wastewater Needs Assessment Committee

The first step in initiating a wastewater planning process is to bring together a needs assessment committee. This group should possess sufficient professional standing in the community to articulate the overall objectives of the planning process. Group members should be drawn from municipal departments and commissions, and from community organizations with an expressed interest in land use regulation or environmental management. A wastewater needs assessment committee ideally includes the municipal planner, the water official, the town engineer, town council members, planning board or conservation commission members, a representative from a local watershed group, and other community members possessing knowledge or expertise in fields such as hydrology or soil science.

If the community does not have a town planner with GIS expertise and some experience in environmental planning, a consultant should be hired for this part of the assessment. Once the planning process has been formalized, the objectives of the needs assessment are defined based on existing conditions in the community. Before selecting assessment objectives, a public participation process should be initiated. Public participation should be encouraged at all stages of the planning process (see the *Working Within the Community* section).

In order to arrive at meaningful assessment objectives, assessment participants need to compile and review supporting documentation and data relating to water quality conditions in the community (see Table 3-1). Assessment participants should spend significant time reviewing existing maps of the area, particularly maps showing regional hydrology and land use trends. Although most wastewater management planning occurs within municipal boundaries, it is important to view local water resources as part of larger hydrologic systems and processes.

Become Familiar with Community Geographic Characteristics

Protecting drinking water supplies is a common impetus for adopting wastewater management planning at the local level. Therefore, the needs assessment committee needs to have a thorough understanding of potable water supplies in town, including the names of public suppliers, the extent of their districts, and the population served. It is equally important to identify areas of the community that rely on private wells. Most states do not regulate private well water, which makes it difficult to uncover localized areas of groundwater contamination. The committee will need to identify and describe any groundwater aquifer recharge areas that may supply local drinking water to individual wells or community supply systems. Identifying surface water reservoirs, their tributaries and watersheds is also critical, whether or not the community relies on these supplies for potable water.

Another important reason to become familiar with regional hydrologic systems and processes is that it will make it easier to locate studies that provide critical information on local water resources. For example, a small groundwater recharge area in a town might form part of a larger EPA-designated Sole Source Aquifer system, or a community might lie within the watershed of a protected river, lake, or coastal embayment. Coastal watersheds, for instance, can cover many thousands of acres of land. Most often, people living in inland communities are unaware of their location in a coastal watershed, and the risk that land use activities in their community may pose to coastal waters.

Any number of governmental agencies or university-based scientists could be conducting research or water quality monitoring in the community. A call to the state's USGS office will provide much information on local water resources. Contact information for regional USGS offices is available online at www.water.usgs.gov/local_offices.html. A number of excellent textbooks and manuals are available that introduce basic hydrology and the movement of waterborne contaminants that are written in a clear and straightforward language (Dunn and Leopold, 1978; Winter et al., 1999). Knowing the names of regional hydrologic systems such as groundwater aquifers and watersheds is an important step for locating information and establishing contacts with government and university researchers and resources. Just as importantly, committee members should know the names and locations of surface waterbodies in town, including the tributaries of rivers, ponds, and coastal embayments. The assessment committee, along with assessment volunteers, should identify important habitat and recreational sites in the community, particularly wetland areas, riparian corridors, and community fishing and swimming areas.

It is important for assessment participants to become familiar with soil survey maps of the town. A little time spent with soil survey maps provides considerable insight into local water drainage patterns as well as pollution risk areas in a town. A town land use and land cover map provides essential information on land use patterns and trends as well as the location of development in relationship to surface water and groundwater resources. Information on location and performance of onsite wastewater systems should be obtained from regulatory authorities at this stage. Knowing the location of sewer lines and proposed sewer extension areas is also advised at this early stage of an assessment.

Collect Data and Supporting Documents

A plan is only as good as the research on which it is based. The following section offers practical advice on how to locate and synthesize existing data in support of a comprehensive wastewater management planning approach. Once the planning process has been formalized, the next step is to identify and collect all relevant reports, findings, and data that may have a bearing on water quality issues in the community. The objective at this stage of the assessment process is to develop a thorough understanding of existing conditions and to clearly define water quality problems at the community level. A solid base of understanding assists in the selection of meaningful assessment objectives, and in determining the areas of the community to be assessed and the types of GIS data that will be required (see Chapter 4, *Assembling and Refining a GIS Database*).

Key Reports and Documents

The wastewater assessment committee needs a complete list of all research studies and water quality monitoring programs conducted in the community. Contact a state or regional USGS office, the state department of environmental protection, and state or county department of health for a list of governmental activities in the community and information on non-governmental studies of which they are aware. To start, find out about the state's Source Water Assessment Program. This EPA-funded initiative requires each state to conduct extensive pollution risk assessments for all public water supply areas in the state (USEPA, 1997c). Source Water Assessment reports are available to the public and provide a wealth of information on localized pollution sources and risks to drinking water.

Table 3-1 lists sources of supporting data and information available.

Table 3-1
Sources of Supporting Data and Information

Agency or Office	Information to Request
USGS (State or Regional Office)	• Studies in local groundwater issues • Long-term climate summaries • Long-term rainfall records
NRCS (County Office)	Soil survey—includes information on soil suitability for onsite wastewater disposal
State Department of Environmental Protection	• Wellhead protection Program • Source Water Assessment Program • 305(b) Report – State of the State's Waters • 303(d) List of Impaired Waters • TMDL studies – completed, ongoing, and future • Onsite wastewater permitting/repairs
Municipal, County or State Health Department	• List of government water quality programs • Onsite wastewater permitting/repairs
Municipal Planning Department	• Land use regulations affecting water resources, onsite wastewater systems, stormwater runoff, etc. • Zoning ordinances • Comprehensive plans
Public Water Supplier	• Consumer Confidence Report • Water Quality Protection Plan
University Departments	Water quality monitoring data or related studies

The committee needs to become familiar with all federal, state, and local land use regulations that have a bearing on local water resources protection such as

- Onsite wastewater systems
- Stormwater runoff
- Erosion and sediment control
- Wetlands
- Special area management
- National Pollutant Discharge Elimination System (NPDES) regulations

Municipal planning documents such as zoning ordinances, subdivision regulations, and comprehensive plans provide important information on town goals and efforts to protect water resources. These documents may also cite research studies or monitoring data used in support of local planning decisions.

If the town owns and operates a public water supply system, the assessment committee should work with the water official to obtain information concerning water quality and water quality protection planning. If the public water supply is privately managed, contact the supplier for information. Under the 1986 Amendments to the Safe Drinking Water Act (Section 1428) each state must develop a wellhead protection program. Required protection measures include

- Delineation of wellhead protection areas surrounding public water supply wells
- Identification and management of potential sources of contamination in wellhead protection areas to reduce threats to groundwater

(USEPA, 1999c)

For information on groundwater protection, contact the state's wellhead protection program at www.epa.gov/safewater/source/contacts.html.

Water Quality Monitoring Data

Identifying local waterbodies that are not meeting state water quality standards is an essential component of a wastewater needs assessment. Water quality data includes field monitoring data, drinking water monitoring data (treated water), water quality standards, Total Maximum Daily Load (TMDL) Restoration Plans, beach closures, and other health advisories. Water quality monitoring programs are generally expensive and time-consuming. If a waterbody in the community is not being monitored regularly, look for signs of impairment such as a sudden growth spurt of aquatic vegetation, increased turbidity, development in riparian areas, construction sites, and fishing and recreational advisories.

The best place to locate information on the status of surface waterbodies is to look through the State of the State's Waters 305(b) Report and 303(d) List of Impaired Waters, which are EPA-mandated state reports under the Clean Water Act. For waterbodies that do not meet state water quality standards, find out about TMDL restoration studies and associated schedules. The state's TMDL program should have available to the public results from past studies, information on current studies (including dates for public hearings), and a schedule of future TMDL studies listed by waterbody, contaminants of concern, and anticipated starting dates. EPA maintains a national website for listings of Impaired Waters and TMDLs at www.epa.gov/owow/tmdl/index.html.

The majority of water quality monitoring data in the U.S. is collected by local volunteer monitoring groups. There are roughly 850 such groups working in the U.S. To find out about volunteer monitoring programs around the country go to EPA's Volunteer Monitoring website at www.epa.gov/owow/monitoring/vol.html.

Public water suppliers are the best source of data for groundwater monitoring. Public water suppliers release water quality monitoring results in annual Consumer Confidence Reports. These reports include a list of regulated contaminants as well as levels of contaminant detection and potential sources (USEPA, 2002a).

Federal agencies are also involved in collecting water quality monitoring data. Contact a regional EPA, USGS, or National Oceanic and Atmospheric Administration (NOAA) office for more information.

Annual Precipitation Data

Collect long-term rainfall records from local weather stations. Many county soil surveys have long-term rainfall records. The NOAA, National Climate Data Center website has long-term monthly and annual precipitation records for each state and regions within states available at www.ncdc.noaa.gov/oa/climate/online/coop-precip.html - FILESliterature, use accepted records that are used by state agencies and onsite system and stormwater system designers. This information will be needed later in the assessment to compute hydrologic budgets for study areas (see Chapter 7, *Hydrologic Budget and Nutrient Loading*).

Field Survey Data

Use of a survey requires more time and effort than other forms of data collection; however, the information gained could prove invaluable for developing an educational strategy, determining existing conditions, and identifying the most feasible types of management options. Surveys are a good way to gain greater insight into public attitudes about onsite system care and decentralized wastewater management at the local level. Surveys not only help to gauge public attitudes, they also serve as a public notice that a wastewater management program is being initiated. It is important to note that citizens may not feel comfortable answering questions about onsite system maintenance. At this stage of the assessment, only request information that is deemed necessary by the assessment committee. Public cooperation is a key objective of the assessment process, so it is important to gain and keep a high level of trust.

At this stage of the assessment survey, local engineers working in the onsite wastewater industry and onsite system maintenance providers need to

- Determine the types of problems currently being encountered in the community
- Obtain septic pump-out records from local or regional wastewater treatment facilities to determine the frequency and quantity of sewage being collected
- Utilize neighborhood field surveys to gain information using targeted visual, olfactory, and sampling techniques

Interpret and Synthesize Existing Data

The primary objective at this point is for the assessment committee to develop an in-depth understanding of existing conditions and to clearly define water quality problems in the community—particularly those associated with wastewater disposal practices. Actively involve community volunteers in collecting and interpreting data and information. Ensure that the assessment process is always viewed as a community process and a strategy for increasing environmental awareness and stewardship.

It is important to turn all relevant data into useful information as a guide for future decision-making and public education purposes. The better this information base is, the easier it will be later on to resolve conflicts and concerns over management options and policy decisions (Olson et al., 2002). This information also provides a basis for selecting assessment objectives and techniques as well as follow-up activities once the assessment is complete.

Define Wastewater Assessment Objectives

The assessment methods introduced in this handbook support a wide range of wastewater management planning activities. At the most basic level, use assessment methods to describe existing conditions in the community based on development patterns and landscape characteristics, including problem areas for onsite wastewater treatment. Use assessment results further in selecting wastewater management districts, setting wastewater treatment standards within districts, or identifying areas for sewer line extensions.

It is important to clearly formulate assessment objectives, as they will be the basis for selecting appropriate study area boundaries and GIS database development. For example, if the objective of the needs assessment is to enhance protection of local drinking water supplies, assessment study area boundaries would include wellhead protection areas, groundwater recharge areas, or the watershed of a surface water reservoir and its tributaries. The committee may also choose to focus on enhancing protection of private well water by selecting those areas of town where higher density residential developments have been sited in soils ill-suited for onsite wastewater systems or where higher residential development has been zoned on problematic soils.

Once the assessment committee has become well informed about existing conditions and water quality problems in the community and assessment objectives have been formulated, the next step is to determine which areas of the community to assess and what GIS data is required. The community can choose to perform a GIS risk-based assessment for the entire municipality or select specific areas of the community such as watersheds or groundwater protection areas.

The availability of GIS data may influence where and how to perform the assessment. For instance, if the community is most concerned about protecting a groundwater recharge area, but lacks access to digital groundwater hydrologic data, it may make sense to perform the analysis for an approximate location or area of the town. Chapter 4, *How to Assemble and Refine a GIS Database*, provides detailed instructions on choosing and locating GIS data once assessment objectives have been determined.

Assessment Data and Technology Requirements

This handbook presents environmental assessment techniques that are relatively simple, cost-effective tools for supporting local water resource protection initiatives. Most of the techniques rely on readily available data and require minimal technical expertise, although some level of GIS proficiency is necessary.

A principal benefit of digital mapping technology is that it enables natural resource managers to visually convey the interrelationships between land use decisions and ecosystem structure and response. GIS functionality can also greatly enhance a community's ability to envision future land use scenarios and their potential impact on local natural resources. GIS technology is a powerful tool for appraising the carrying capacity of the land and natural resources on which towns depend. For more in depth instruction on how to obtain and use GIS technology and data for risk assessment purposes, refer to Brice et al. (2000) *Source Water Assessment Using Geographic Information Systems* available online at www.epa.gov/ORD/NRMRL/wswrd/gis.htm.

Software Requirements

This handbook presents assessment methods that require the use of a spreadsheet application and GIS software. Spreadsheets are required for data entry and to calculate hydrologic budgets and nutrient loading rates for the areas under study. The spreadsheets are also used to summarize important land use and soil characteristics. Statistics derived from this data are then used as indicators of the relative health of local water resources.

At least one member of the assessment team will need some expertise in using GIS software for data processing and graphic display. PC ArcInfo software (ESRI, 1997b) is recommended for all geoprocessing functions (Union, Clip, Erase, Buffer). Using ArcInfo ensures that data integrity is maintained. If a GIS technician trained in ArcInfo is lacking, most of the assessment steps can still be conducted using ArcView software (ESRI, 1997a). If ArcView is used, it is recommended that the XTools extension also be used to re-compute the Area, Perimeter, and Acreage fields for any new shapefiles that have been created in ArcView. ArcView software does not automatically re-compute these figures. The Xtools extension is available at http://arcscripts.esri.com/details.asp?dbid=11731.

Work Within the Community

When a town initiates a wastewater management planning process, a timely pubic notification schedule is important. Notification can be through mailings, newspaper advertisements, and postings. Notices should include a statement of purpose, what the assessment will entail, whom it will affect, and how the results will be used. Also include meeting times and places and contact information for further questions. At the first meeting, reiterate the information from the notice along with a visual presentation of what the assessment process will entail and how the results will be displayed. Use this first meeting to solicit public involvement in the planning process and to gain input on community water resources issues and concerns.

Public Participation

This section specifically examines public participation, including

- The importance of local involvement
- Partnering
- Organizing a local assessment group

The Importance of Local Involvement

Design the wastewater management planning process with a strong public outreach and education component. The wastewater management planning diagram shown in Figure 3-1 outlines the assessment approach with activities involving the public in the left column.

Invite community members to participate in each stage of the assessment process. There are many publications now available on initiating a community-based environmental planning program (Arnold and Gibbons, 2001; Olson, et al., 2002; USEPA, 1994; USEPA, 1997a). Not only do community members have a direct stake in public health and environmental decisions, the success of the program will ultimately rest on changing public attitudes and behaviors. A well-integrated public participation process significantly increases community awareness of existing public health and environmental concerns and provides community members with a voice in selecting appropriate wastewater management options. Studies on the success or failure of community wastewater management programs have consistently found that unsuccessful outcomes are often the result of failure to understand the concerns and priorities of community members (Olson et al., 2002).

Partnering

Partnering with local commissions and citizens helps garner trust and local support for the assessment process. The best place to start is the town hall. Organizational structures of town hall staff differ nationwide, but there are several key people who should be directly involved in the wastewater planning process. The planner or planning official, the health agent, and the conservation agent should all have some knowledge of the town's natural resources or be able to steer the committee to those who do.

It is important to enlist the help of people outside of the community, for example federal and state environmental managers or nonprofit organizations. EPA's *A Review of Statewide Watershed Management Approaches* (2002c) notes that the public responds positively to organizations known for promoting ecosystem health. Outside experts often have the advantage of objectivity concerning local political issues. Whether from inside or outside the community, enlist the support of a wide spectrum of individuals and organizations.

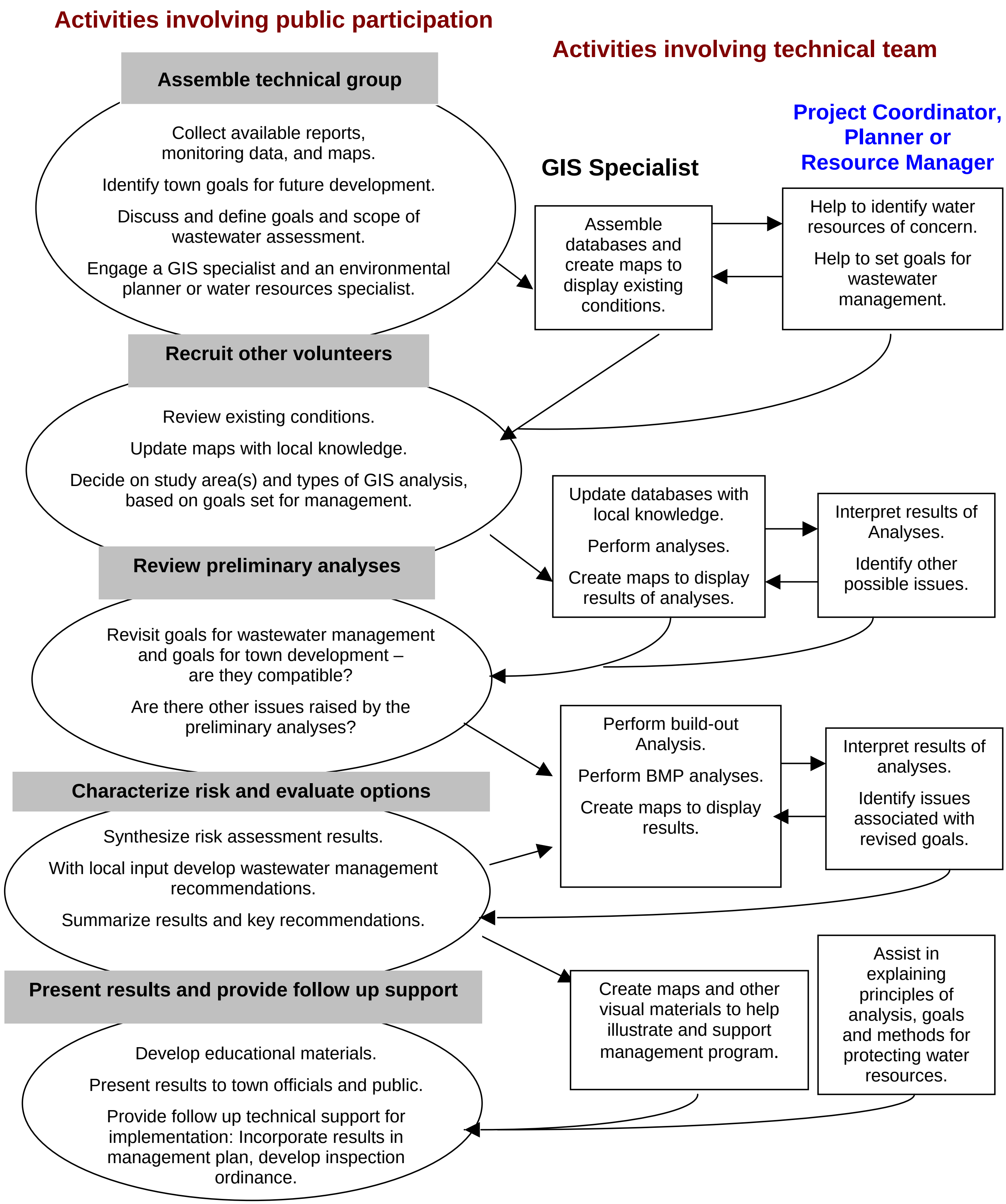


Figure 3-1
A Conceptual Workflow Diagram of the Wastewater Management Assessment Process Showing Tasks for Public Participants, GIS Specialist, and/or Planner

Organizing a Local Assessment Group

Public involvement is a key component in the success of wastewater management programs. One way to involve the public is to have community members' help in the assessment process through a local advisory committee (USEPA, 1991b). This group could be integrated with the wastewater assessment team or work in conjunction with the team. Members of this committee and other citizens can also volunteer to help collect data, conduct inventories, and participate in the review of assessment results. The key to working with volunteers is to minimize their time commitment, while keeping them well informed about progress and decision-making opportunities (Olson et al., 2002).

Determine Roles and Responsibilities

The diagram in Figure 3-1 outlines the roles and responsibilities of the various participants in the assessment process. The left-hand side of the schematic lists a range of activities best suited for public participants, such as identifying town goals, collecting and reviewing available documents and data, deliberating on management recommendations, and presenting assessment results to municipal officials and the public at large. The middle column of the diagram outlines the more technical aspects of the assessment process and recommends that a GIS specialist be hired for these tasks. The activities listed in the far right column are intended for a project manager, planner, or water resources specialist and include responsibilities such as goal setting, interpreting results, and identifying associated issues and concerns.

Assessment Process Objectives and Community Involvement

The objectives of the assessment process go beyond determining the wastewater needs of the community to include education on nonpoint sources of pollution and the potential impacts to public health and the environment. The public outreach and education strategy should also include a focus on water conservation practices. A second objective is to get stakeholders involved in a discussion of resource protection needs. It is important for community members to see the links between wastewater management and water quality conditions in the town. Community members should be actively involved in selecting the water quality indicators used in the assessment. Once community stakeholders understand local threats to water quality and identify significant natural resource protection areas, they can then help to craft appropriate management options.

Typical Work Session Agendas and Outcomes

In order to solicit public participation and input, hold meetings on a frequent basis. The initial meeting should occur prior to the assessment in order to collect information on community perceptions and concerns. For example, anecdotal information on changes in the water quality of local ponds and streams can be collected at the meeting through surveys and open discussion. Field questions to gauge community responsiveness or opposition to local wastewater management programs. Once the overall goals of the assessment are determined, hold a second public meeting to explain these goals, and to encourage additional public participation.

Throughout the assessment process, hold public meetings on a monthly basis to keep participants involved and informed. Also conduct educational workshops to explain land use impacts to water resources and to foster new behaviors, such as restoring riparian buffers, water conservation, and onsite system care.

Presenting Results

Present results to elected officials and the public once the advisory committee has selected management options. Present results to the community in a well advertised public meeting. Lack of public announcements can lead to angry citizens and unnecessary resistance to recommended practices or new policies developed through the assessment process. Present information to the public in plain, non-technical language. If possible, present assessment results visually using large format maps. It is easier for the community to visualize impacted areas if the maps have street names and landmarks (see Chapter 11, *Beyond the Desk Top*).

Once community members have an understanding of the impacts and threats associated with current wastewater management practices, or lack thereof, discuss new management options. Be prepared for citizen concern regarding these options. Use visual aids such as maps, charts, and graphs to show how various management or land use scenarios are expected to improve or further degrade natural resources in the community. For example, a zoning map showing future development potential around a drinking water reservoir or an important local fishery can help direct attention to the need for proactive planning. A chart showing estimated nitrogen loads to groundwater recharge at levels approaching or in excess of advisory standards is also a good way to focus concern.

Continued Technical Support

At the end of the assessment process, community members and municipal officials will ultimately decide on the best level of management effort to address current and future conditions. At this stage, the “outside” assessment team can provide additional information on various management options and, if requested by the town, may continue to work on water resource management concerns. During the decision-making period, and beyond, provide workshops for homeowners, municipal officials, and onsite designers and professionals to ensure the long-term success of the new management program.

4 ASSEMBLING AND REFINING A GIS DATABASE

This chapter focuses on the types of GIS data necessary for conducting an assessment, tips on locating the data, and examples on assembling and refining the data. This chapter also provides a range of assessment options relative to the type of data accessible to users.

Database Development

Most of the GIS map data required for an assessment should be available through a state, county, or municipal GIS database. State and county GIS databases typically include census data, land use and land cover data, roads data, hydrologic data, and soils data to name only a few. Many local communities maintain their own GIS databases, including digitized parcel data, utility districts, zoning, and resource protection overlay districts. In areas where local or regional GIS data is not readily available, hard copy maps or nationally distributed data such as USGS topographical maps, can be used.

Map Scale and Accuracy

Geographic information systems enable users to take several maps created at different scales and compile, overlay, or perform a variety of analyses, all at a common scale. This ease of analysis at a common scale is one of the main advantages of digital maps; however, changing map scales—the ratio of ground distance to map distance— raises the issue of map accuracy.

For example, a scale of 1:24,000 used in 7.5 minute USGS topographic maps implies that one inch on the map is equal to 24,000 inches (2,000 feet) on the ground. To meet national map accuracy standards, 90 percent of the data on a 1:24,000 topographic map must be within 0.033 inches (0.02 inches for map scales smaller than 1:20,000) of where they should be on the map. This means that the actual location may vary up to 40 feet or more in any direction and still meet acceptable accuracy standards. For parcel maps created at a scale of 1:1,200 the on-the-ground deviation is only about three feet. Map scale also determines the smallest mappable unit. For example, the Rhode Island state GIS land use coverage is interpreted from 1:24,000 aerial photographs, identifying 37 land uses as small as one-half acre in area, while the state's wetlands coverage have been photo-interpreted to one-fourth acre units.

Because the original scale at which the geographic data is mapped determines how accurate the map is, working at a larger scale—zooming in to take a closer look at map features—does not result in more detail. Instead, at close view, map errors become relatively more serious than at smaller, more distant views. Because of these map accuracy issues, assessment results are best suited for planning-level analysis at the watershed and subwatershed scale.

Coordinate Systems, Datum, and Projection Parameters

When the user is acquiring GIS data from outside the state (for example, USGS topographical maps), it is essential to determine the coordinate system, datum, and projection parameters of the data being imported so that all data in the GIS database are converted into a common spatial reference system. Data acquired at the town or state level are likely to be in state plane coordinates in a standardized datum—most likely North American Datum (NAD83), and with standardized projection parameters (for example, feet or meters). Every state has its own distinct state plane coordinate system, and many larger states have several different zones. GIS data that do not share the same coordinate system, datum, and projection parameters cannot be viewed simultaneously, and will appear to be tens or hundreds of miles apart, even though the data represent the same geographic area. For a more in depth discussion on coordinate systems and map projections, see www.vterrain.org/Projections/.

If a dataset contains data from different state plane coordinate systems or a combination of Universal Transverse Mercator (UTM) and state plane coordinates, the data will not match up. It is then necessary to “reproject” data from one coordinate system into another. In ArcView, this can be accomplished using the ArcView Projection Utility. To project data, the utility must first be loaded. Then implement the following steps:

1) Under the File menu, choose Extensions. The Projection Utility Wizard is loaded by checking the appropriate box under the Extensions menu.

2) Return to the project. The ArcView Projection Utility is now located under the File menu.

3) Click on the Projection Utility to open a menu where the user can specify a data layer and its coordinate system and select a new coordinate system into which the data will be projected.

This utility enables GIS data in any coordinate system to be “reprojected” to the user’s specified coordinate system, datum, and projection parameters.

Using USGS Digital Maps

USGS digital maps include

- Topographical Map Graphics
- Hydrography

USGS Topographical Map Graphics

For communities that do not have access to local or county GIS data, a 1: 24,000 scale USGS digital topographical map can be used to develop a local GIS database. USGS provides georeferenced digital maps for most of the country that are at a suitable scale for community-based wastewater planning. These maps are in digital raster graphic (DRG) format, and are available online at http://topomaps.usgs.gov/drg/. A DRG is a scanned image of a U.S. Geological Survey standard series topographic map. DRGs display topographic data (such as elevation contour lines), and other natural features such as streams, lakes, and wetland areas. Some land cover characteristics also display such as streets, built-up areas, fields and wooded areas. DRGs can be useful as backdrops for "heads up" digitizing new data layers. For example, a DRG can be used to heads up digitize a watershed boundary (see the example in Figure 4-3), or the DRG can be used to help orient a GIS technician when creating new coverages from hard copy maps (see the section on Land Use and Land Cover).

Major drawbacks of using DRGs for purposes of the assessment include that they

- Are dated, static images
- Lack attribute data, limiting their usefulness in GIS

It is important to note that DRGs are simply georeferenced graphic images; the images are not associated with attribute data the way GIS coverages are. For example, although lakes and streams are depicted on a DRG, the area of a lake or the length of a stream cannot be automatically computed as they can be using a base map derived from a set of individual GIS coverages. In order to obtain data from the graphic, a GIS technician would need to create a new point, line, or polygon coverage and heads up digitize (trace) the data into a new coverage. For each GIS data layer derived in this way, specific attribute data must be manually coded into the attribute table. Once coverages have been added through heads-up digitizing, standard GIS tools can automatically compute attributes such as area, perimeter, segment lengths, and others.

USGS Hydrography

The National Hydrography Dataset (NHD) is a comprehensive set of digital spatial data that contains information about surface water features such as lakes, ponds, streams, rivers, springs, and wells. Within the NHD, surface water features are combined to form "reaches, " which provide the framework for linking water-related data to the NHD surface water drainage network. These links enable the analysis and display of these water-related data in upstream and downstream order. While initially based on 1:100,000-scale data, the NHD is designed to incorporate and encourage the development of higher resolution data required by many users (USGS, 2003).

If state- or county-level hydrographic data are unavailable (contact regional USGS office or state EPA), users should download data from the NHD. Alternatively, a GIS technician can heads up digitize hydrography from a 1: 24,000 scale USGS DRG as described previously.

GIS Data Requirements

GIS data requirements involve:

- Assessment study areas
- Land use and land cover data
- Soils data
- Land use and soils coverage
- Wetland data
- Riparian area data
- Sewer and onsite system data
- Point source pollution data
- Zoning
- Protected lands
- Parcel data
- Roads and utilities
- Orthophotography
- Cultural features and resources
- Natural resources and rare species
- FEMA flood maps

Assessment Study Areas

Natural hydrologic boundaries such as watersheds, aquifer recharge areas, and wellhead protection areas are highly recommended for use in conducting the analyses. If hydrologic boundaries are obtained from a state or federal resource agency, assessment results can be used more readily in support of regulatory or management programs. Although the assessment techniques presented in this handbook are intended for screening-level risk assessments, they should be conducted and documented as formally as possible. The legitimacy of assessment results will depend, in some measure, upon the thoroughness of the analyses.

The first step is to either locate or create the study boundaries. Study area boundaries should reflect well-defined assessment objectives. Once selected, a study area boundary becomes the “clip” coverage for deriving other data layers such as land use, soils, riparian area, and sewer districts.

Modifying Study Boundaries

Hydrologic boundaries such as watersheds and groundwater recharge areas do not follow political boundaries. When selecting assessment study boundaries, the wastewater needs assessment committee must decide whether or not to include areas that extend into other municipalities or states.

The map in Figure 4-1 shows a watershed boundary (in yellow) that extends into an adjacent town. A wastewater assessment was conducted for the entire watershed using the boundary to “clip” GIS data for both towns. The aquifer recharge area shown in purple in Figure 4-2 also extends into adjacent towns. However; only the area within the municipal boundary (the town’s groundwater protection overlay district) was used for assessment purposes. If hydrologic boundaries are modified to reflect political boundaries, or if these boundaries are created based on approximate locations, they might not be suitable as regulatory or management boundaries, though they are still useful for screening-level assessments.

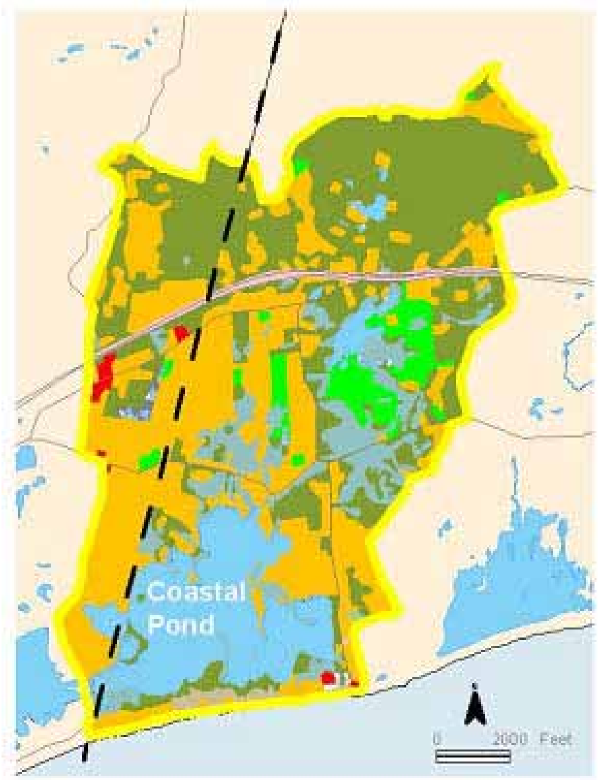


Figure 4-1
Watershed Study Area Boundary

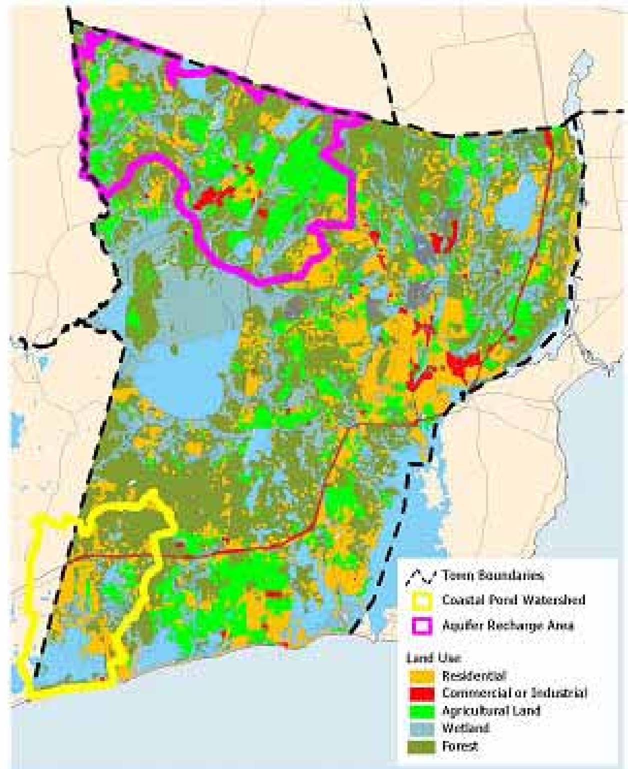


Figure 4-2
Modified Hydrographic Boundaries

Once selected, the watershed boundary becomes a clip coverage for all of the other GIS coverages required for the assessment. In the example shown in Figure 4-1, the watershed of a coastal pond was selected as a study boundary for a wastewater management program being conducted by two adjacent towns. The map shows land use and land cover within the watershed for the coastal pond. The dashed line is the municipal boundary.

Watershed Boundaries

If the community does not have access to GIS coverages of watershed and/or sub-watershed areas, a GIS technician can create the boundary coverage by heads up digitizing from a USGS DRG (Figure 4-3). The outer boundary of a watershed or drainage divide is formed by the ridges and hills surrounding a waterbody and is the location selected as the downstream outlet. The watershed of most lakes and rivers consists of a network of intermittent drainages, man-made channels and storm drains, streams, wetlands, and the surrounding upland. At any point in the watershed, precipitation runs off the land surface and collects in these natural and man-made drainage pathways, following the lay of the land or topography. Because water flows down gradient, watersheds are defined by topography. To draw a watershed boundary, simply connect high points and ridges shown on a topographic map (Figure 4-3).

Figure 4-3
Watershed Delineation

Delineating Watershed Boundaries

For instructions on delineating watershed boundaries, see: *The National Newsletter of Volunteer Water Quality Monitoring*, Volume 6, No. 2, Fall 1994. Available online at www.epa.gov/volunteer/fall94/index.html.

Groundwater Protection Areas

Groundwater reservoirs have their own watersheds, known as recharge areas. The boundaries of a surface watershed and groundwater recharge area can, but do not always coincide. If the goal of the assessment is to protect drinking water resources, aquifer recharge areas and wellhead protection areas (Figure 4-4) should be selected as study area boundaries for areas relying on groundwater supplies. GIS coverages of aquifer recharge areas or wellhead protection areas should be available through a state wellhead protection program (www.epa.gov/safewater/source/contacts.html) or possibly a regional USGS office. In some cases, committees might decide to cut a hydrologic boundary to correspond to a political boundary, for instance when conducting the assessment for a municipal groundwater protection area. However, if a wellhead protection area is used as a study area boundary, the boundary should not be modified. Wellhead protection areas are regulatory boundaries that should be assessed and protected in their entirety.

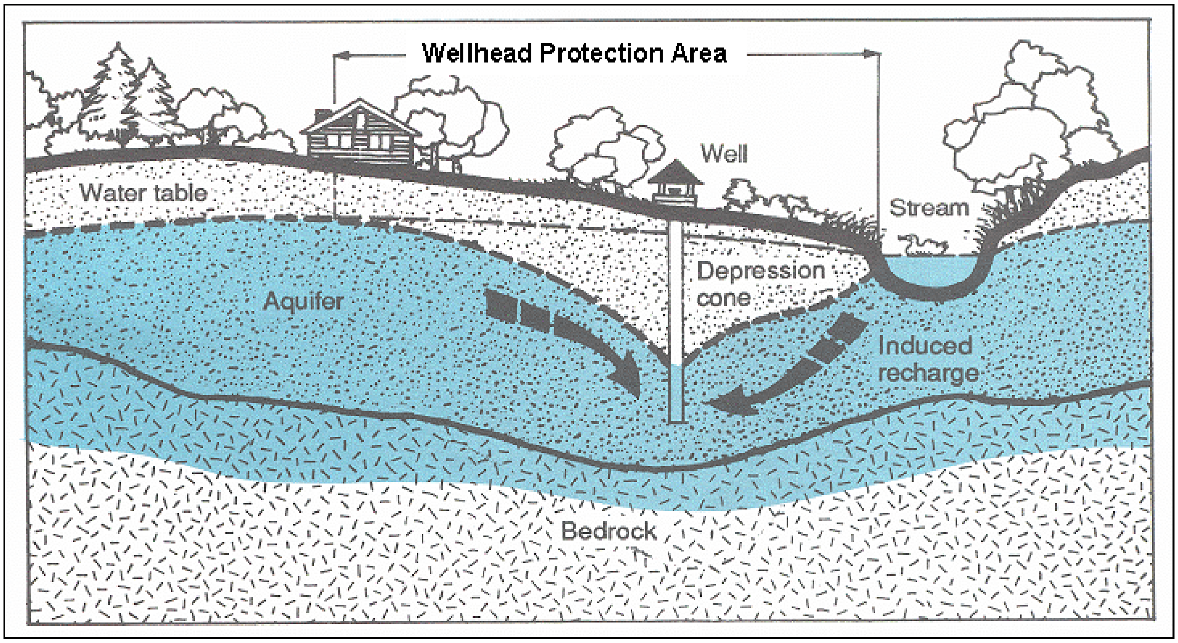


Figure 4-4
Groundwater Recharge Area and Wellhead Protection Area (source: R.S. Lyle, 1991. Cornell University)

Land Use and Land Cover Data

Current land use and land cover data are required to conduct the assessment. Unfortunately, most states only update their land use and land cover data every decade. In areas undergoing suburbanization, a decade of land use change can have significant bearing on assessment results.

If the town does not have access to a state or local land use and land cover GIS data layer, a national land use/land cover data (NLCD) is available through USGS. The NLCD is based on 1990–1993 Landsat TM satellite imagery at 30-meter resolution. In addition to satellite imagery, researchers used a variety of supporting data including topography, census, agricultural statistics, soils, wetlands, and other land use and land cover maps to arrive at 21 land cover classes.

NLCD data is not recommended for purposes of the assessment for the following reasons:

4) The NLCD is not recommended to characterize areas smaller than approximately 25 km (United States Geological Survey, 2001)

5) The NLCD is in digital raster format and would need to be converted into vector data

6) Refining the NLCD would further reduce its accuracy

If the assessment is to be conducted for a large watershed or groundwater recharge area, NLCD data can be obtained from the USGS website at edc.usgs.gov/products/landcover/nlcd.html.

If the community lacks detailed (large-scale) land use and land cover data, there are a number of options for purchasing or creating the data. With access to recent orthophotography (digitally corrected aerial photographs), a GIS technician can fairly easily create a new land use and land cover polygon coverage by interpreting and heads up digitizing data directly from the orthophotographs, using GIS software such as ArcView. Photointerpretation is a standard method for creating land use and land cover data.

If the community does not have access to orthophotography, data can be derived from hard copy aerial photographs or parcels maps, which enables a digital USGS topographical map to be used as the base map on which the new land use polygons are drawn. A topographical map provides basic information such as the location of streams, ponds, and roads that will help orient the GIS technician. Municipal or county assessors maps can also be digitized to derive land use information.

Updating Land Use Maps

If the community does have access to large-scale data, the data should be refined or updated for assessment purposes. There are a number of different ways to update or refine land use and land cover data, depending on what additional data is available. A simple way to update land use maps is by having assessment volunteers conduct windshield surveys of assessment study areas (usually no greater than 500 acres in size). Assessment volunteers can assist in map updates with minimal training, and the aid of a land use map and orthophotograph of the same area. If land uses do not correspond with the color-coded areas on the land use map, volunteers can note changes or discrepancies (see Figures 4-5 and 4-6 and Table 4-1).

Using volunteers to update land use maps is an excellent public education strategy. In the process, volunteers will learn to read maps, learn about the importance of watersheds or groundwater protection areas, and become more familiar with land use impacts to water resources. A local planning department can also provide assistance in updating or refining this data.

In the example shown in Figure 4-5 and 4-6, volunteers were able to identify misclassified land use as well as land use changes. A GIS technician can then use the information to recode the land use attribute table to reflect changes or corrections. This simplified technique only provides generalized changes in acreage. No new polygons are created in the process. For example, in the updated map below, only a portion of the pastureland polygons could be recoded to medium density residential. This is due to the size of the polygons. For a more accurate land use update, an experienced GIS technician can use ArcEdit software to edit existing coverages.

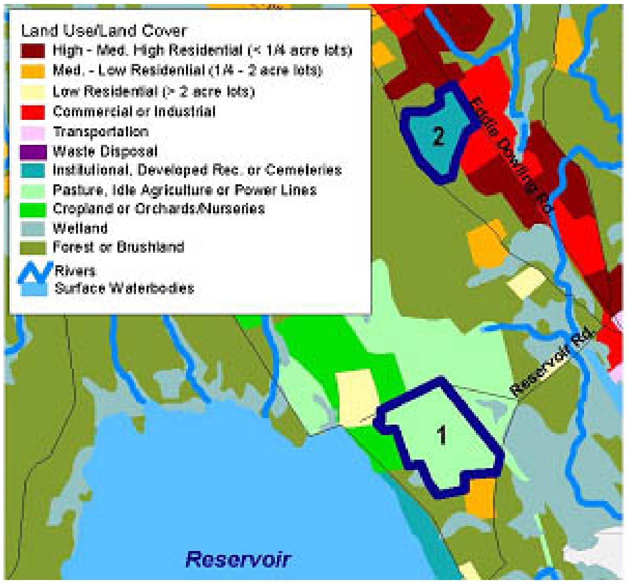


Figure 4-5
Existing Land Use

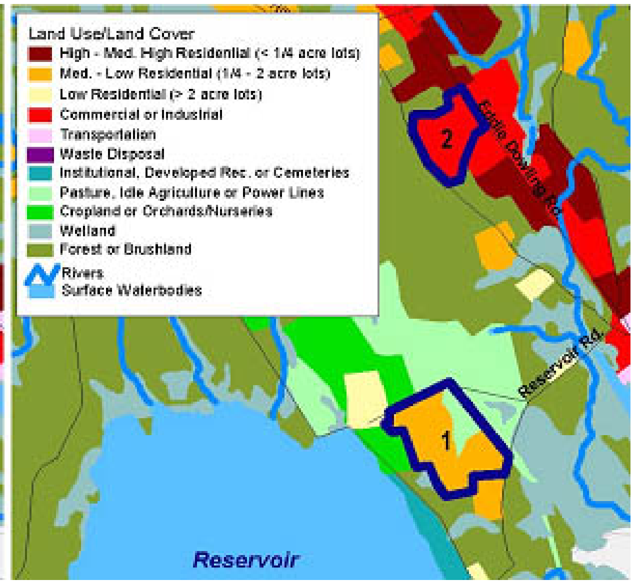


Figure 4-6
Updated Land Use

Table 4-1
Tracking Land Use Change

Map ID Number (Land Use Map)	Change in Land Use	Approximate Location
Use numbers 1, 2, 3… to track changes.	Describe current land use and changes (see below).	Provide actual address or a description of proximity to roads and other clearly marked features.
1	Mapped as pastureland—change to account for new medium density residential subdivision (22 houses on 20 acres). Horses are grazing on adjacent pastureland.	Site is between Reservoir Road and the reservoir itself.
2	Mapped as developed recreational. The area is actually commercial development.	Site is along Eddy Dowling Road.

The most accurate way to update land use maps is by using digitized parcel data. A land use and land cover map (Figure 4-7) provides important information that a parcel map does not, such as the extent and type of agricultural land uses and vegetation cover. However, the parcel-based land use map (Figure 4-8) provides a much more accurate count on the number of onsite systems and also provides estimates on the age of those systems.

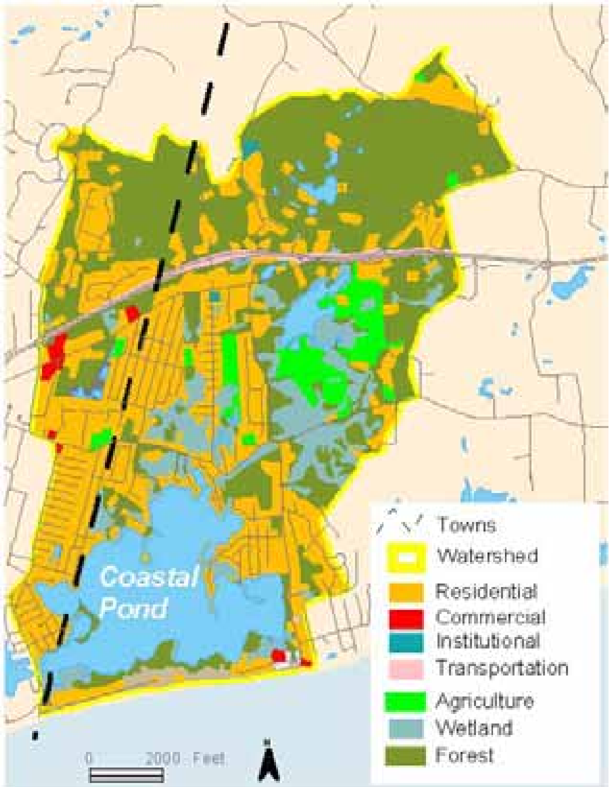


Figure 4-7
Land Use and Land Cover Map

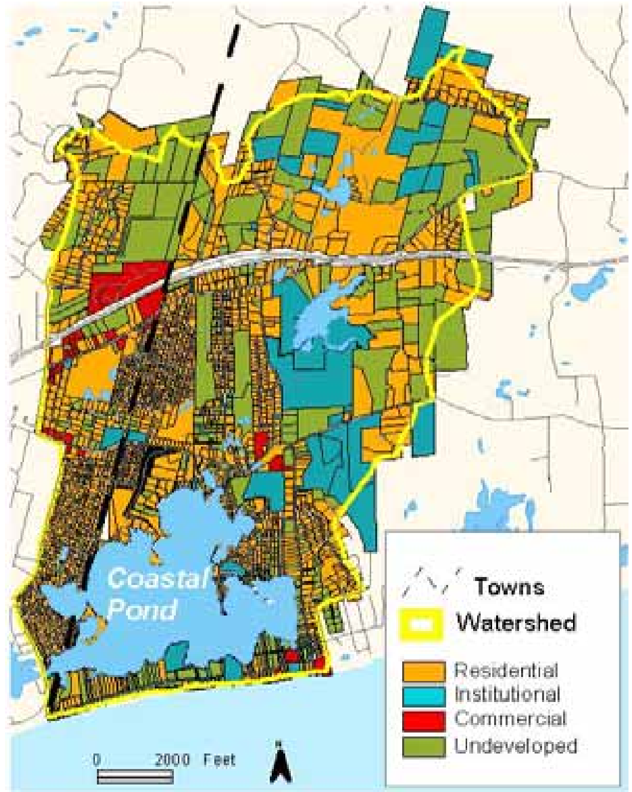


Figure 4-8
Parcel Land Use Map

If the town or county has digitized parcel data (assessor's maps), it is probably more current than county or statewide land use data. Parcel data generally includes property codes for different types of land uses, including vacant (undeveloped) land. To update the land use and land cover GIS data, simply overlay the parcel data to identify any changes or corrections to the land use and land cover data. For example, if a large tract of land has been recently subdivided into house lots, the land use code should be changed from an undeveloped state (for example, forest or agriculture) to an appropriate residential land use category. The parcel dataset can also be used later in the assessment to help refine estimates of nutrient loading from onsite systems (see Chapter 7, *Hydrologic Budget and Nutrient Loading*).

Using Land Use Data

An important part of the assessment involves using the land use data to estimate population and onsite system densities. Most land use data uses the Anderson Level Classification system to code land uses interpreted from satellite images or aerial photographs. For more information on this classification system, go to http://landcover.usgs.gov/pdf/anderson.pdf. Most land use classification systems divide residential development into broad density categories (see Table 4-2).

Table 4-2
Description of Rhode Island Residential Land Use Categories

Rhode Island Residential Land Use Categories	Description
High density residential	Greater than 8 dwelling units per acre
Medium high density residential	4 to 7.9 dwelling units per acre
Medium density residential	1 to 3.9 dwelling units per acre
Low density residential	Less than 0.5 dwelling units per acre

To estimate the number of onsite systems, first estimate the average number of dwelling units in the study area. Because the range of densities within each residential land use category is so broad, the dwelling unit estimate will vary widely. For example, areas mapped as medium density residential can have densities ranging from one dwelling unit per acre to almost four dwelling units per acre. In this category, lot sizes would range from about one-fourth acre to one acre per dwelling.

For more accurate estimates, site-specific information is needed to select the density closest to the zoning categories in the study areas. Consult with a town planner to determine appropriate residential land use densities. If the town lacks basic GIS capacity, it is possible to derive the necessary land use statistics from a hard copy parcel map and a tax assessor's database (refer to Chapter 1, *Introduction, Overcoming GIS Limitations*).

Soils Data

County Soil Survey Geographic (SSURGO) data, developed from county soil surveys, is recommended for conducting the assessment. For more information on obtaining SSURGO data go to www.ftw.nrcs.usda.gov/ssur_data.html.

The assessment method presented in this handbook primarily focuses on soil permeability, depth to water table, restrictive layers, and erosion potential. Soil permeability is classified using four major hydrologic soil groups (see Table 4-3). These broad categories describe the potential for soil to allow water to seep into the ground or to run-off the surface and convey stormwater pollutants.

The assessment method also considers depth to water table in conjunction with permeability. Mapping these two characteristics together reveals hydrologic dynamics in the study area. Knowing the proportion and location of soils with these characteristics is also a good indicator of water quality risks. Higher water table soils generate more runoff than well-drained soils, presenting more of a potential threat to surface water. Excessively permeable soils, on the other hand, present a potential threat to groundwater due to rapid pollutant infiltration.

Table 4-3
Soil Hydrologic Group Descriptions

Soil Hydrologic Group	Basic Description	Typical Depth to Seasonal High Water Table	Water Quality Risk When Developed
A	Deep water table, high infiltration, and low runoff	Greater than 6 feet	• Highest pollutant movement to groundwater from onsite systems and fertilizers. • Largest increase in runoff with impervious cover. • Greatest loss of groundwater recharge with impervious cover.
B	Well-drained, moderate runoff	Greater than 6 feet or 1.5 to 3.5 feet	• High potential for pollutant movement to groundwater from onsite systems in sandy subsoils. • Moderate increase in runoff and loss of recharge with impervious cover. • Potential loss of prime farmland soils with new development.
C	Slowly permeable, collection areas for runoff, typically high water table, high runoff	1.5 to 3.5 feet or 0 to 1.5 feet	• High pollutant movement to surface waters from onsite systems, fertilizers, and land disturbance. • High potential for hydraulic failure of onsite systems, with surfacing or lateral movement of effluent. • High potential for wet basements, temporary flooding.
D	Very high water table, essentially wetlands	0 to 1.5 feet	• Highest pollutant movement to surface waters. • Loss of pollution treatment potential with disturbance of wetland buffers. • Wetland habitat encroachment.

For the assessment, it is necessary to create a new attribute field in the soils coverage that combines information on soil drainage (hydrologic group) and depth to water table (such as Hydrologic Group C, 1.5–3.5 feet). If a SSURGO data set is used, the attribute fields for hydrologic group and depth to water table will be located in the same data table. If the GIS soils data does not include both attribute fields, either enter the information manually from a hard copy version of a state or region’s United States Department of Agriculture (USDA) Soil Survey, or map only one of these features. Mapping the two features together is highly recommended. See Figure 4-9 for an example of a soil map legend that shows both soil drainage and depth to water table.

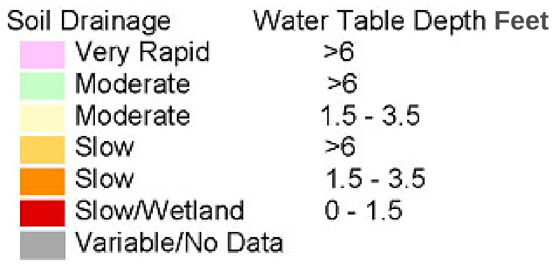


Figure 4-9
Soil Map Legend Showing Soil Drainage and Depth to Water Table

If a SSURGO dataset is not available for the county or region, it may be possible to modify State Soil Geographic (STATSGO) data, available for all states through USDA, Natural Resources Conservation Service. However, STATSGO data is designed for large-scale planning activities and is not recommended for regulatory purposes at the county or local level. Alternatively, hard copy soil survey maps can be digitized for study area boundaries, or critical information can be directly entered into the land use and land cover dataset (see the Land Use and Soils Coverage section that follows).

Land Use and Soils Coverage

Land use and soils coverage is created by "unioning" the land use and land cover data with the soils data for the study area using ArcInfo software or the XTools extension in ArcView. This new coverage enables identification of areas of concern by querying the data set for the co-occurrence of selected land uses and problematic soils (Table 4-4). For example, one can select all unsewered high-density residential development occurring on high water table soils to identify areas with a higher risk of onsite system failure.

The unioned land use and soils coverage is also necessary for modeling estimated nutrient loads to groundwater and surface water resources, and for identifying priority protection areas and monitoring sites.

Table 4-4 is an example of a portion of the attribute table for the new land use and soils GIS data, showing both land use type and underlying soil conditions.

NOTE: Table 4-4 data does not correspond directly to Figure 4-10.

Table 4-4
Land Use and Soils ArcView Attribute Table

Land Use Code	Land Use/Land Cover	Soil Name Code	Soil Characteristics	Acres
170	Institutional (schools, hospitals, churches, etc.)	MmB	A- Excessively Permeable	2.33
210	Pasture (agricultural not suitable for tillage)	MmB	A- Excessively Permeable	0.41
113	Medium Density Residential (1 to 1/4 acre lots)	CB	B- Well Drained, SHWT >6'	0.21
320	Evergreen Forest (>80% softwood)	Ss	B- Mod. Well Drained, SHWT 1.5'-3.5	1.12
310	Deciduous Forest (>80% hardwood)	Ss	B- Mod. Well Drained, SHWT 1.5'-3.5	3.08
161	Developed Recreation (all recreation)	Wa	C- Silty & Wetter, SHWT 0'-1.5'	0.29
113	Medium Density Residential (1 to 1/4 acre lots)	Wa	C- Silty & Wetter, SHWT 0'-1.5'	0.08
600	Wetland (not to be classified)	Wa	C- Silty & Wetter, SHWT 0'-1.5'	2.53
120	Commercial (sale of products and services)	Wa	C- Silty & Wetter, SHWT 0'-1.5'	0.95
161	Developed Recreation (all recreation)	Ba	D- Very Wet, SHWT 0'-1.5'	0.73
113	Medium Density Residential (1 to 1/4 acre lots)	Ba	D- Very Wet, SHWT 0'-1.5'	2.11
310	Deciduous Forest (>80% hardwood)	W	Variable or Unknown	1.23
400	Brushland (shrub and brush areas, reforestation)	UD	Variable or Unknown	1.42

Figure 4-10 shows an example of GIS data from unioning land use and soils coverage data. Each polygon in the new land use and soils coverage will be coded with data from both of the parent coverages. For example, the land use polygon coded 220 in the lower left-hand corner of diagram A will be split into two with one new polygon having the Efa soil code name and the other having the EfB soil code name. This will enable a query of the data for both land use and soil characteristics.

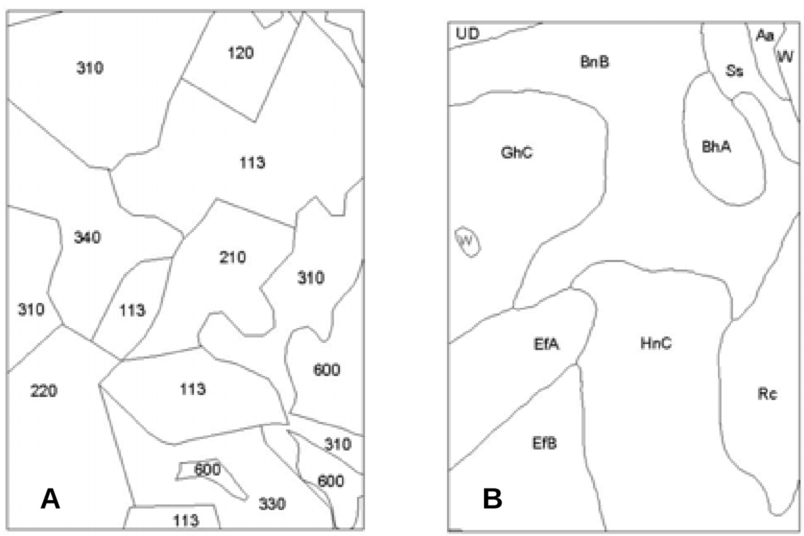


Figure 4-10
Unioning Land Use (A) and Soils (B) GIS Data

Wetland Data

Wetland data is available from the National Wetlands Inventory (NWI). The NWI of the U.S. Fish & Wildlife Service produces information on the characteristics, extent, and status of the nation's wetlands and deep water habitats. The NWI has mapped 90 percent of the lower 48 states, and 34 percent of Alaska. About 44 percent of the lower 48 states, and 13 percent of Alaska are digitized. Wetland data can be downloaded from www.nwi.fws.gov/downloads.htm.

Riparian Area Data

A riparian area is loosely defined as the land area within a specified distance of surface waterbodies. In undisturbed shorelines, the riparian area is a vegetated ecosystem along a waterbody through which energy, materials, and water pass. Riparian areas have a high water table and are subject to periodic flooding and influence from the adjacent waterbody. Encompassed within the riparian area are wetlands, uplands, or a combination of both.

GIS data of surface waterbodies should be available through a state environmental protection agency. The riparian area data can be obtained by using GIS software to buffer the HYDROLINE and HYDROPOLY coverages, and then unioning the two buffer coverages. Once the riparian buffer coverage has been created, use it to clip the new land use and soils coverage. The new clip coverage describes land use and soils characteristics in riparian areas.

Before creating a buffer coverage, review state regulatory buffer requirements and local land use regulations to determine an appropriate buffer distance to surface waterbodies.

The riparian land use and land cover map in Figure 4-11 shows land use and land cover data within a 200-foot buffer of all surface waterbodies in the study area boundary. Assessing the conditions of riparian areas is an important component of the assessment. The data is used to derive risk indicators such as the percent of development and impervious surface area within riparian zones. Mapping riparian areas also provides a quick screening-level assessment of potential high-risk pollution areas.

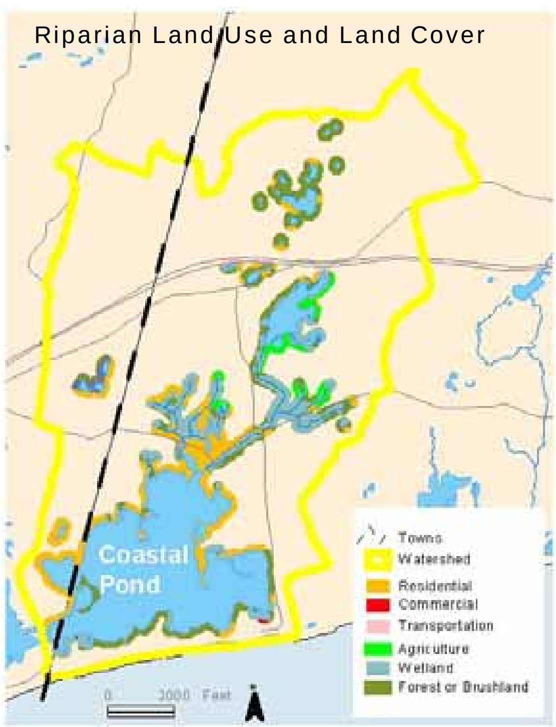


Figure 4-11
Riparian Land Use

Sewer and Onsite System Data

Determining the number of onsite systems in a study area becomes an important component of the assessment process when determining nutrient loads to groundwater resources (Chapter 7, *Hydrologic Budget and Nutrient Loading*). Location of sewered districts should be available through a local or state GIS database. If the data is not available, a GIS technician can easily create the coverage with input from a local planner or water official using a GIS coverage of area roads since sewer lines follow roads. The sewer line coverage should then be buffered to account for the sewered district, or consult with the town or county sewer and water official to create a more accurate sewer district boundary. Whenever possible, determine how many homes or businesses within the sewer district are currently not connected to the service.

There are a number of different ways to determine the number of onsite systems in a study area. The most accurate way is to use town parcel data. If parcel data is digitized, simply overlay each data layer (parcels, sewer district, and study boundary) in ArcView and count the built parcels. If a hard copy parcel map is used, print out a copy of the study area boundary at a scale equivalent to the parcel map, and trace the boundary line onto mylar.

If town parcel data is not available, use an updated land use coverage to estimate the number of onsite systems in the study area. To perform this analysis a new land use and soils coverage map should be created with the area falling within the sewer district subtracted out (see Figure 4-12). Use the “Erase” function in XTools to subtract the sewered area. The remaining data provides land use and soils characteristics for only the unsewered portion of the study area.

The map in Figure 4-12 shows land use and land cover in a groundwater protection area minus the sewer district in that area. A GIS coverage of this data is only necessary for the assessment if parcel data is unavailable for determining the number of onsite systems within a study area.

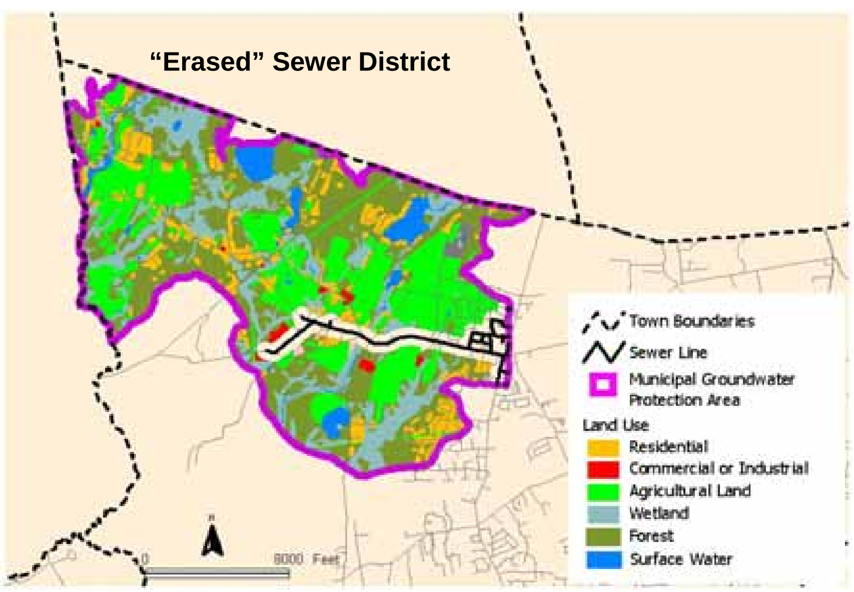


Figure 4-12
Subtracting Sewer Districts From Land Use Data

Point Source Pollution Data

State departments of environmental protection and public health are the primary sources of point source pollution data. Point sources of pollution include underground storage tanks, National Pollutant Discharge Elimination System (NPDES) permit sites, Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites, hazardous facilities sites, and other potential pollution sources. Some of this data should be available in digital form through a state department of environmental protection. Towns or counties often maintain databases listing the names and addresses of industrial sites in the community. Further information on point source pollution inventory activities is provided in EPA's *Guide for Conducting Contamination Source Inventories for Public Drinking Water Supply Protection Programs* (1991a).

If required, data concerning drinking water supply, toxic releases, and underground storage tank leaks can be found at www.epa.gov/Compliance/cleanup/federal/superfund.html. EPA's CERCLA website currently lists the location of hazardous waste sites within communities in Enviromapper. Although this data is not in digital form, coordinates can be obtained for these sites. Specific pollutant releases can be found on EPA's TMDL 303(d) listed waters website www.epa.gov/waters/data/downloads.html. This site contains GIS data on the locations of TMDL listed pollutants.

Zoning

Town zoning ordinances detail how a town will be developed in the future. By combining data on current land use, protected areas, and town zoning, it is possible to envision the town once all developable land has been built upon. This is done through a "build-out" analysis using GIS data. Estimates of future water use, runoff, and other nonpoint source pollution can be obtained from a build-out map. Zoning data is usually available through a municipal GIS database, or a regional planning agency. If this data is not available digitally, use hard copy maps to identify development potential, and manually code the information into a new land use and soils GIS coverage (see Chapter 5, *Envisioning Future Growth*).

Protected Lands

Use protected lands data in the assessment to identify areas where development is prohibited. Data concerning protected areas may be available through local or state GIS databases. Nonprofit organizations such a local land conservancy or a local chapter of The Nature Conservancy should also be consulted.

Parcel Data

Parcel data is useful for refining land use data and for estimating the age and density of onsite systems. This dataset may be available through a municipal planning department or regional planning agency. Hard copy parcel maps can also be useful, particularly when users also have access to a parcel databases (refer to Chapter 1, *Introduction, Overcoming GIS Limitations*).

Roads and Utilities

Road and utility data should be available through a state or county GIS database. Topologically Integrated Geographic Encoding and Referencing (TIGER) road data can be obtain from the U.S. Bureau of the Census at www.census.gov/geo/www/maps.

Orthophotography

In a digital format, orthophotography can be used as a spatially accurate base map for assessment purposes. Orthophotography combines the graphic qualities of an aerial photograph with the geospatial qualities of a map. Unlike an aerial photograph, distortions due to relief displacement, lens angle, and the altitude of the aircraft are geospatially rectified so that features on the ground adhere to map accuracy standards. An orthophotograph can be used to interpret land use and land cover, and local hydrologic features such as small streams, wetlands, and ponds.

Cultural Features and Resources

The National Park Service is currently conducting a cultural resource mapping project involving battlefields, buildings, landmarks, landscapes, and tribal communities. Other cultural features include archeology sites, heritage landmarks and vegetation of societal significance. Exact locations may not be available in GIS; however, knowledge of these areas when determining high-risk areas and for developing management strategies is important.

Natural Resources and Rare Species

Several states have natural resource and endangered and rare species inventories available. Other potential sources of this information include The Nature Conservancy and Audubon Society. Communities with rare species should consult the state environmental agency in order to identify high-priority protection areas.

FEMA Flood Maps

The Federal Emergency Management Agency (FEMA) is currently conducting a Modernization Plan that provides flood maps in digital format. Flood data can help differentiate soil types and areas where onsite systems should not be installed. FEMA map products are available at www.fema.gov/maps.shtm.

Database Development and Analysis Process

Figure 4-13 provides an illustration of integrating GIS mapping into a wastewater needs assessment process. The information on land use acreages by soil type is brought into a spreadsheet for summary and to develop watershed indicators and estimate nutrient loads. More extensive mapping is done for visual aid in presenting results to the public. This approach works well when several study areas must be evaluated or when repeated analysis is envisioned.

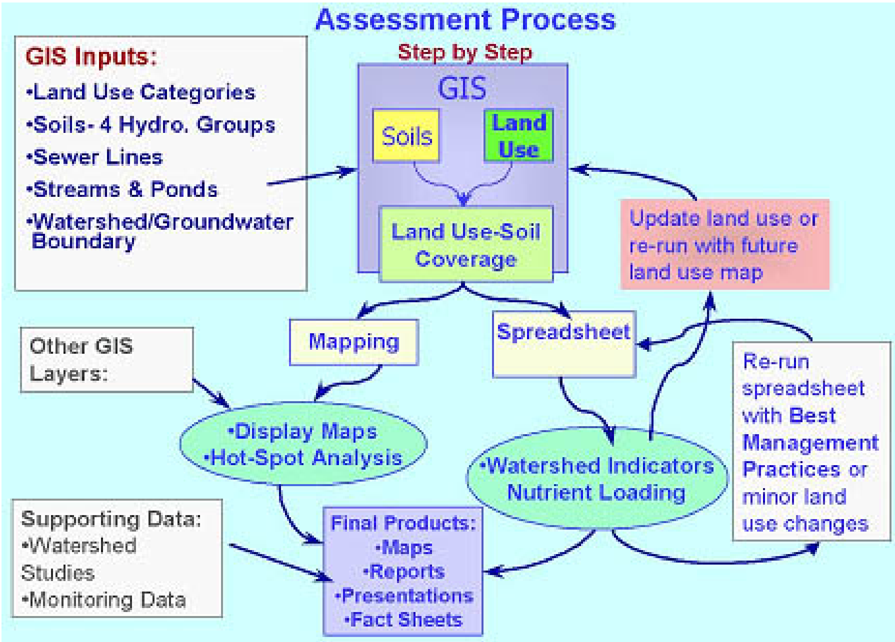


Figure 4-13
Database Development and Analysis Process

GIS Technical Note

Figure 4-13 is an example of a "loosely linked" GIS model where GIS software is used to collect the initial spatial information and develop GIS coverages. Data on land use and landscape characteristics are derived from GIS coverages, and then are brought into a separate spreadsheet application to calculate watershed statistics and nutrient loading estimates. A "linked" GIS model would perform these calculations within GIS rather than exporting them to an outside spreadsheet.

Selecting Assessment Techniques

The next four chapters of this handbook comprise the more technical sections of the assessment process, and provide step-by-step instruction on how to conduct a comprehensive screening-level risk assessment. Users can select one or all of the techniques outlined in the four chapters.

Chapter 5, *Envisioning Future Growth*, provides step-by-step instructions on how to perform a GIS "build-out" analysis using data such as land use, soils, zoning, and protected land. The objective of conducting a "build-out" analysis is to enable the community to view future land use scenarios and to gain a more informed understanding of the potential cumulative impacts of current land use trends and management practices.

5 ENVISIONING FUTURE GROWTH

This chapter provides information on envisioning future growth through the use of build-out analysis. It provides step-by-step instructions for performing a simple build-out analysis and a build-out analysis using parcel data.

Build-Out Analysis

A build-out analysis is a standard land-use planning tool that enables local decision makers to envision full development of the community or an area within the community under current zoning regulations. A build-out analysis is typically used to determine total developable land area, and to identify potential impacts to natural resources such as forest fragmentation and changes in hydrology due to increased impervious surface area. As a planning tool, a build-out analysis enables local decision-makers to view current growth patterns, determine the compatibility of these development trends with community comprehensive plan goals, and make changes that will improve future outcomes.

GIS Data Coverages Needed

The following GIS data is required for build-out analysis:

- Study Area Boundaries
- Land Use and Land Cover
- Soils
- Unioned Land Use and Soils
- Protected Land
- Zoning
- Surface Water
- Riparian Buffer

Part One: Simple Build-Out Analysis

A simple build-out analysis can be performed without parcel data; however, the count for new residential units will not be as accurate as a parcel-based analysis. To conduct the simple build-out analysis, first “union” a land use GIS coverage map and a soils GIS coverage map using ArcInfo software or Xtools.

Simple build-out analysis is a six-step process:

- **Step One**—Select Study Boundary
- **Step Two—**Identify all Undeveloped Land

- **Step Three**—Code for Protected Lands
- **Step Four**—Code Development Constraints
- **Step Five**—Code Undeveloped Land Based on Current Zoning
- **Step Six**—Determine Approximate Number of Potential Future Units

Step One—Select Study Boundary

The first step in simple build-out analysis is to select study area boundaries. If the analysis is being performed in multiple areas, it is a good idea to conduct the GIS build-out for the whole town, and then later "clip" the larger coverage with each study area boundary. This will prevent having to recode the GIS data multiple times for each study area.

Figure 5-1 shows an example of a GIS build-out analysis that was conducted for an area encompassing three sub-watersheds. The first step entailed creating a boundary coverage in order to clip statewide coverages such as land use (A) and soils (B).

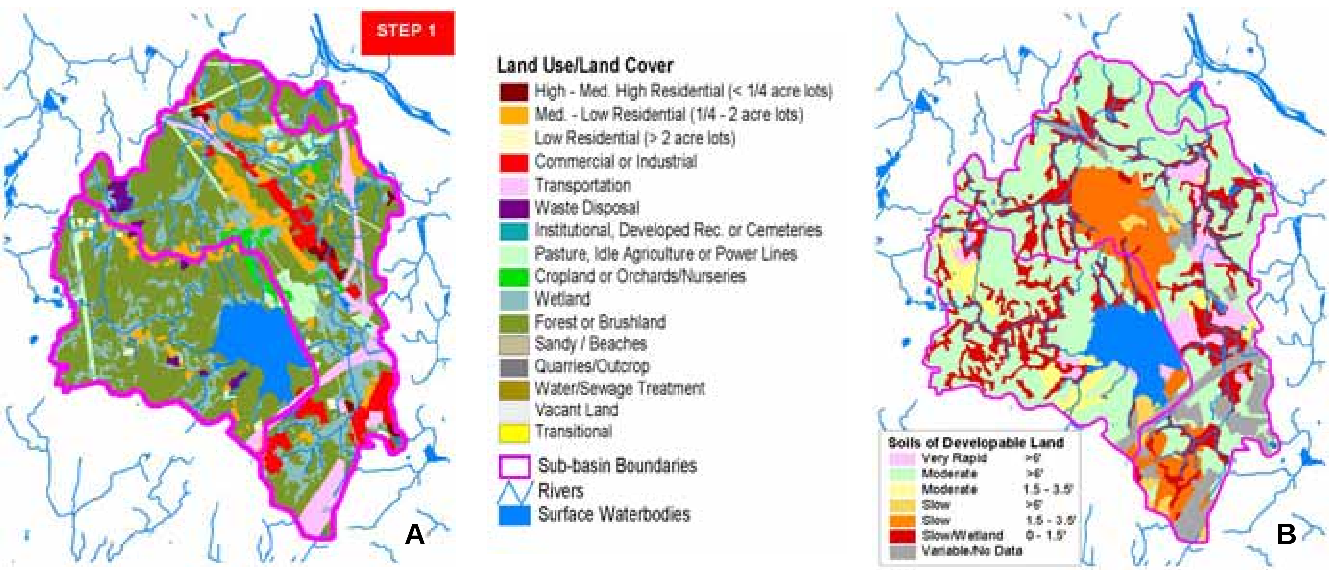


Figure 5-1
Build-Out Analysis Step One

Once the study area boundaries have been selected, and the land use and soils GIS coverages have been clipped, the two coverages should be unioned to create a new land use and soils coverage map.

Step Two—Identify all Undeveloped Land

The next step is to identify and code remaining undeveloped land. This is an easy process using ArcView. Simply create a new attribute field in the new land use and soils coverage. Select and code all brushland, forest, wetlands, agricultural lands, or other selections to differentiate undeveloped from developed land (for example, 0, 1).

Step Three—Code for Protected Lands

Either a municipal planning office or state environmental protection agency should have a hard copy map or GIS coverage of protected land. Municipal zoning maps will often include this land as open space. Create a new attribute field in the land use and soils coverage, and then code all undeveloped land that is permanently protected. To perform this query, first select all land that has been coded as undeveloped in Step Two, and then select from this set all land that is protected. Give these land use and soils polygons an identifying code (for example, 0, 1).

Figure 5-2 shows all land color-coded based on development status. Figure 5-3 shows developed versus undeveloped land, with permanently protected land removed from the undeveloped land category (as shown in white).

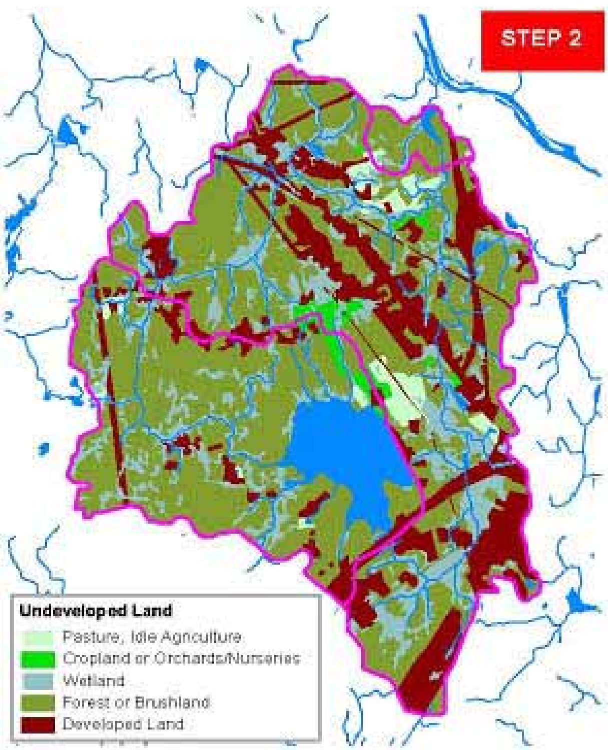


Figure 5-2
Build-Out Analysis Step Two

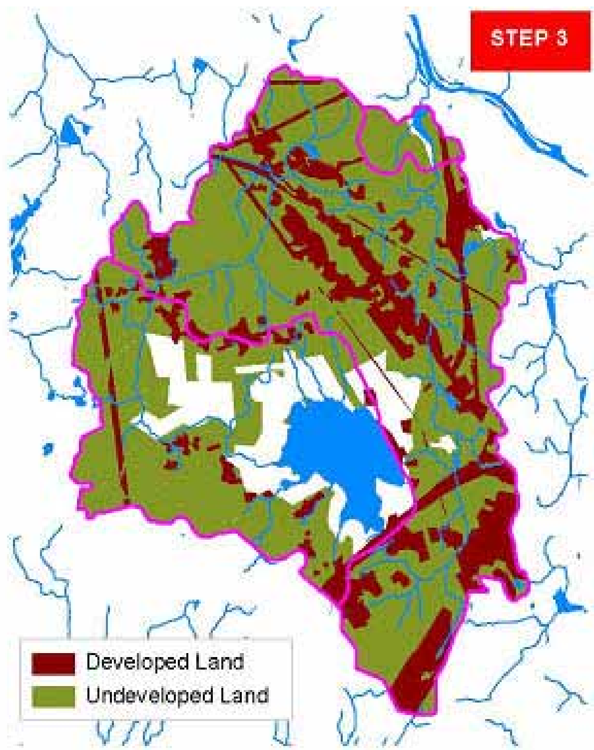


Figure 5-3
Build-Out Analysis Step Three

Step Four—Code Development Constraints

Begin this step by first identifying significant development constraints in the community. In some parts of the country, high water table soils may be a significant constraint, while in other parts of the country, steep slopes may be the primary constraint to development. Check local land use regulations and state environmental regulations to determine significant constraints to development. Make sure that the soils data includes the necessary attribute fields and ranges for soil constraints. For example, if high water table soils are being used as a constraint, the data should be coded based on a range of depth to water table.

Next, create a new attribute field for constraints. Then select all land previously coded as undeveloped that is on high water table soils and give it an identifying code (for example, 0, 1). Also, be sure to code all wetlands as constrained. The land use and land cover data may include a wetlands category or the soils data may include a field identifying hydric soils (hydrologic group D).

All undeveloped land within riparian buffer zones should also be constrained (check state and local regulations to determine setback requirements). The easiest way to identify land in riparian buffers is to first create a buffer coverage of all surface waterbodies (such as streams, ponds, and reservoirs). Once the buffer coverage is created, union it with the new land use and soils coverage. Then select all undeveloped land within the buffer and assign an identifying code.

Figure 5-4 shows land within a 200 foot riparian buffer and undeveloped land on high water table soils coded as constraints to development. It also shows constrained land as well as protected land coded as undevelopable (B—shown in white).

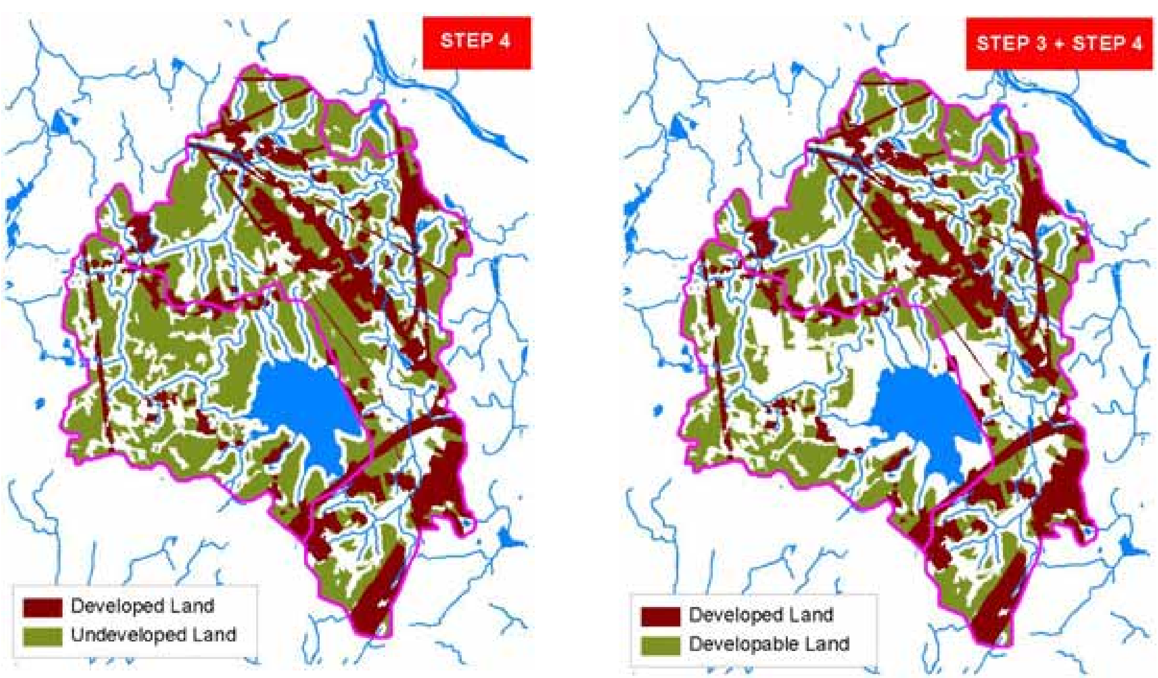


Figure 5-4
Build-Out Analysis Step Four

Step Five—Code Developable Land Based on Current Zoning

To complete the GIS component of the simple build-out analysis, give all undeveloped land that is not constrained or protected a new land use code based on current zoning. If a digital zoning map is unavailable, work from a hard copy map to assign new land use codes. Create a new attribute field for future land use, which includes land use codes for existing developed land, undeveloped constrained land by current land category (such as agriculture and forest), and the new land use codes for developable land based on zoning regulations (see Figure 5-5).

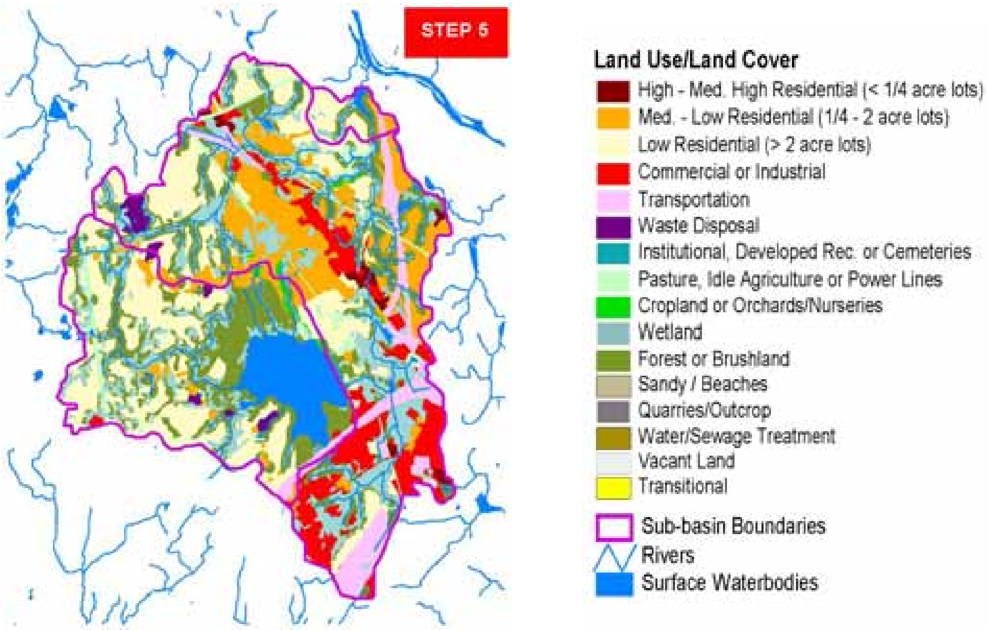


Figure 5-5
Future Land Use Map

The map in Figure 5-6 shows the soil characteristics of developable land in the study areas. Knowing the location and types of soils that will be built upon is useful information when determining appropriate wastewater treatment standards for new onsite systems.

For example, in Figure 5-6 soils are primarily moderately well drained with a depth to water table greater than 6 feet. There are a few problematic areas, however, close to the community’s surface water reservoir that have slowly drained soils with a depth to water table within 3.5 feet of the ground surface.

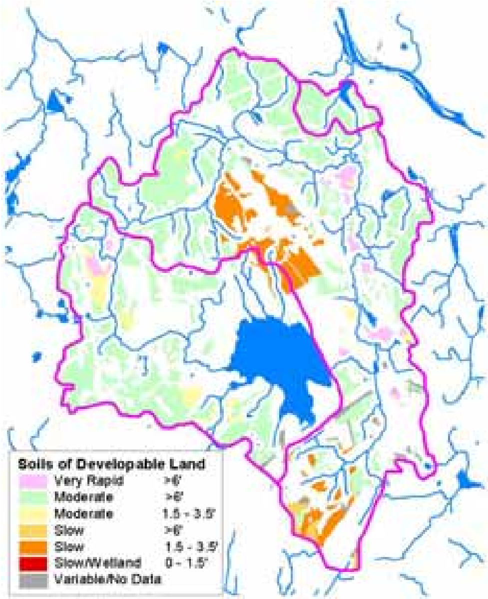


Figure 5-6
Soils of Developable Land

Step Six—Determine Approximate Number of Potential Future Units

The last step in the simple build-out analysis is to determine the number of potential future onsite systems in the town or study area.

Using Table 5-1 as an example, export the attribute table of the land use and soils coverage as a database (.dbf) file into a spreadsheet application. Sort the data based on new land use categories for developable land and total square footage for each land use category. Then, multiply this number by 0.85 or 0.80 to include area for streets and utilities, and divide by the minimum lot size requirements for each zoning district. This procedure will provide a rough estimate of potential future dwelling units in the study area.

Table 5-1
Calculating Future Onsite Systems

Zoning District	Minimum Lot Size (Sq. ft.)	Developable Area in Sq. Ft. for Each Zone (Sq. ft. = Acres × 43560)	Area Less Street/Utility Area (Area multiplied by 0.85 or 0.80)	Number of Potential Future Units (Area less street/utility divided by minimum lot size)
Medium Density R-40	40,000	14,592,600	12,403,710	310
Low Density R-80	80,000	22,651,200	19,253,520	240
Commercial	Floor Area Ratio	84,000	—	Sq. ft. of development
Industrial	Floor Area Ratio	146,000	—	Sq. ft. of development

Part Two—Build-Out Analysis Using Parcel Data

The parcel build-out analysis provides a much more accurate estimate of the number of onsite systems likely at full development. This is because the simple build-out analysis is based on generalized residential densities and does not take into consideration infill development. Implement parcel build-out analysis in conjunction with simple build-out analysis in order to derive land use and soils data for the indicator analysis (see Chapter 6, *Watershed Indicators: Linking Land Use to Water Quality*).

The methodology for the parcel build-out analysis also provides valuable information on the wastewater pollution risk posed by current development. Coding parcel data by size and soil constraint facilitates later planning and management activities such as the establishment of appropriate inspection schedules and onsite system design and treatment standards for new or replacement systems.

Limitations

Because of the scale of the analysis, the accuracy of the data, and the complexity of land subdivision and development, build-out figures are only estimates based on the following assumptions:

- Parcels coded as vacant are developable
- Parcels with easements are not developable
- Developed parcels with lot areas greater than the minimum lot area requirements may have future development potential
- Parcels with major environmental constraints will not be developed

Environmental Constraints

Wetlands are the primary environmental constraint used in the example that follows. Computerized selection and visual judgment are used to fully or partially exclude parcels that contain wetlands.

Slope and rockiness may be considered in more advanced analysis. These constraints are more important in some geographic areas than others, and it adds an additional level of complexity to the build-out analysis. These constraints are also easier for the developer to overcome in most cases through either creative development or engineering solutions.

Definitions

The following definitions apply to parcel build-out analysis:

Grandfathered Vacant Parcels—Legally-platted lots that are smaller than current zoning allows. They typically range from 5,000 to 30,000 square feet and require special planning considerations for septic system placement.

Standard Vacant Parcels—Parcels that can accommodate one or more units if developed.

Built Parcels that Can Accommodate Further Units—Parcels that have been built upon, but have ample room for further development. It is important to gauge the development potential of these parcels.

Build-out analysis using parcel data is a seven-step process:

- **Step One—**Trim Parcel Coverage to Extent of the Study Area
- **Step Two—**Code for Town Zoning
- **Step Three—**Code Development Constraints
- **Step Four—**Code Protected Lands
- **Step Five—**Identify Vacant Parcels
- **Step Six—**Identify Grandfathered Parcels
- **Step Seven—**Determine Number of New Units from Vacant Parcels

Step One—Trim Parcel Coverage to Extent of the Study Area

Select parcels that lie within the study area (that is, watershed, sub-basin, or wellhead protection area) as follows:

1. Use the Select by Theme command in ArcView to select all of the parcels that have *their center* in the study area boundary or use the Selection Tool.

2. Visually inspect the edges of the selected parcels—it may be necessary to manually select or de-select some parcels near the edge using best judgment.

   Convert the selected area into a shapefile and use it in the rest of the analysis (see

3. Figure 5-7).

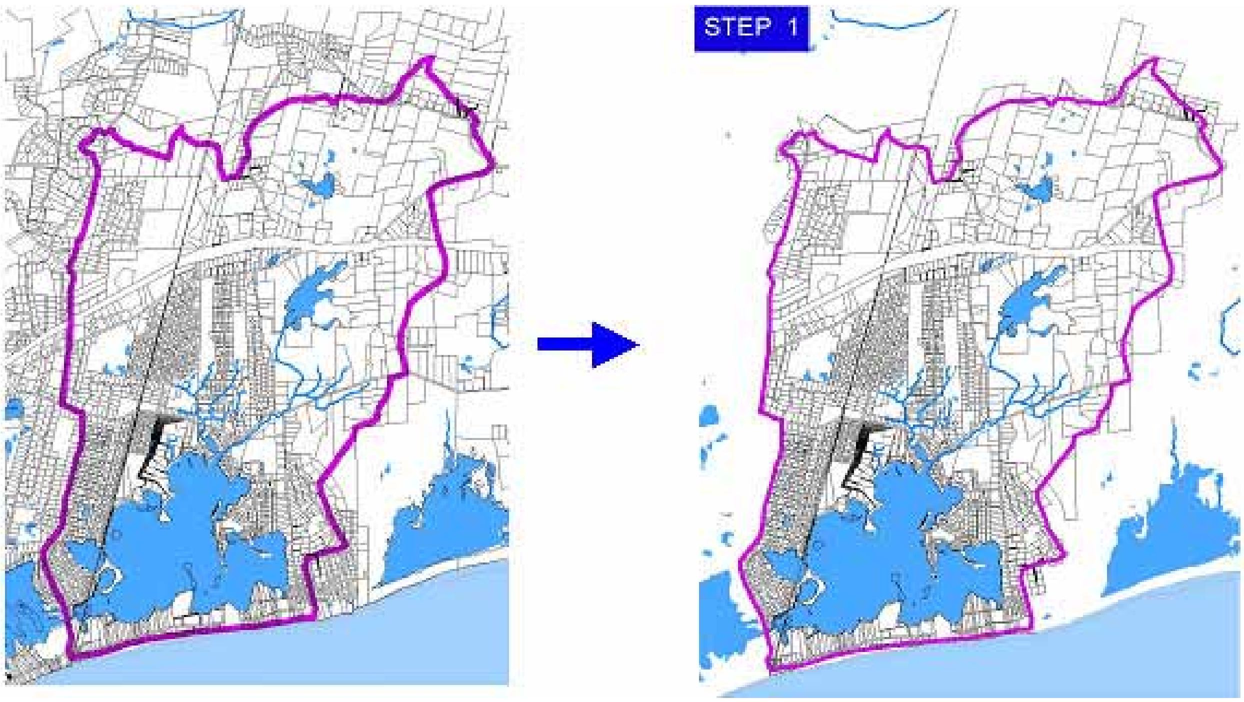


Figure 5-7
Parcel Build-Out Step One

Step Two—Code for Town Zoning

The parcel data may already be coded with town zoning. Sometimes, parcel coverages contain a zoning field that is numerically coded. Check with the town's tax assessor or planner for an explanation of the coding scheme. If the parcel coverage is not already coded based on zoning, create a new attribute field and code the parcels based on zoning designation. If a digital zoning coverage is not available, use a hard copy map to identify the zones, which usually follow streets.

Figure 5-8 shows all the parcels in the study area by zoning category. In many cases, both developed and undeveloped lots are smaller than the zoning requirements in that district. These are "grandfathered" lots that were platted prior to adoption of current zoning regulations. To address this issue, towns can adopt ordinances requiring owners of adjacent small lots to merge parcels.

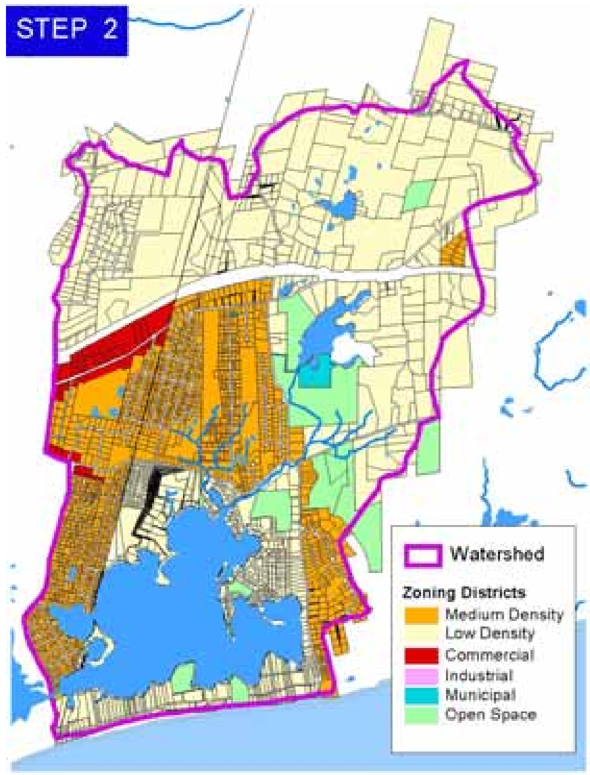


Figure 5-8
Parcel Build-Out Step Two

It is more difficult to prevent development on substandard lots if a neighboring property owner does not own the parcel. In such cases, the town can require reductions in house sizes and impervious surface areas, and the use of alternative onsite wastewater treatment systems. If a parcel is already developed, the town can require that an alternative treatment system be installed if and when the current system fails. Alternative treatment technologies should not be permitted until the town has adopted adequate oversight for system design and maintenance.

Step Three—Code for Development Constraints

There are a number of ways to code for development constraints. Either use the Select by Theme feature in ArcView to identify these areas, or graphically overlay wetlands and soils data with the parcel data and manually-select and code parcels that are severely constrained (see Figure 5-9). As a rule of thumb, soils with water table depths of 0–1.5 feet should be considered wetlands. Deciding how constrained a lot is will depend on local and state land development regulations. Because this is a screening-level analysis, when in doubt, rely on best judgment and be consistent.

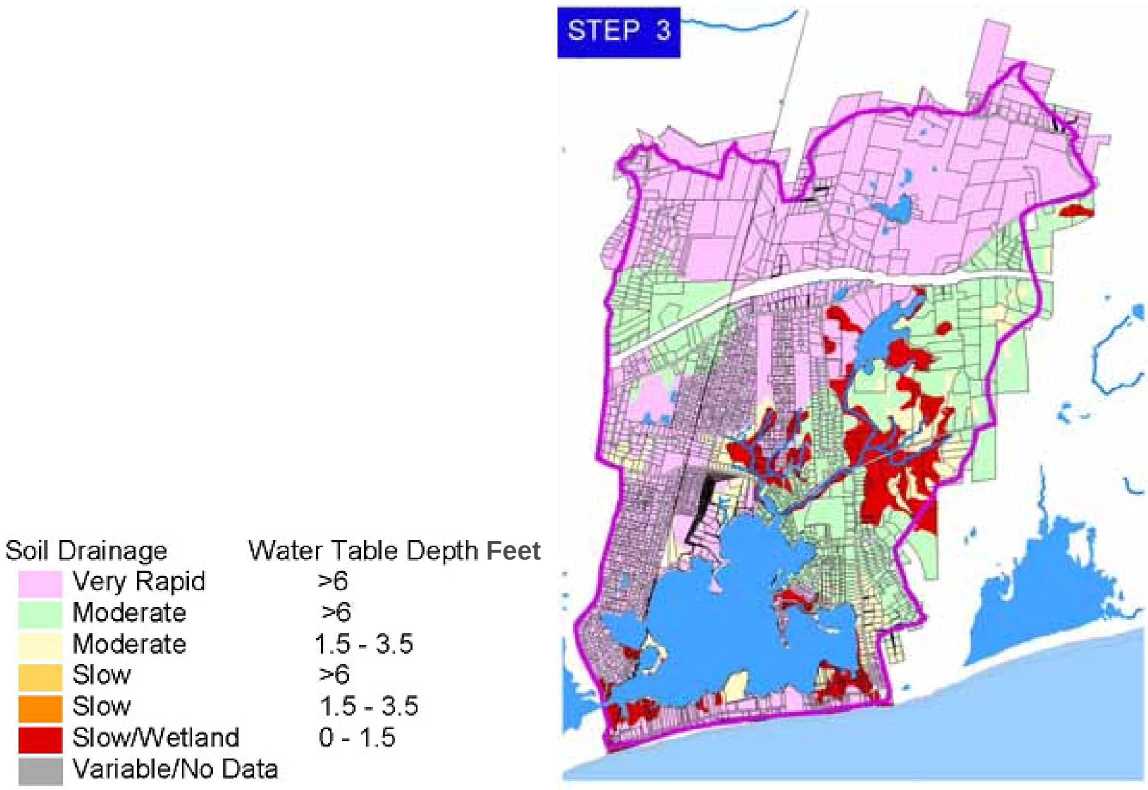


Figure 5-9
Parcel Build-Out Step Three

Knowing the number and location of parcels with size and soil constraints is an ideal basis for establishing wastewater treatment standards, maintenance, and inspection requirements. Areas of the town can be divided into wastewater management districts, and regulations can be tailored to each district based on a risk analysis.

There are two types of onsite system failures to be aware of when evaluating overall soil conditions in a study area:

- **Hydraulic failure—**occurs when wastewater effluent is unable to seep into the ground because of system damage, clogged soils, a solids-filled septic tank, high usage, or high water table in the leach field. Indications of failure are pretty apparent including ponding, backups in the plumbing, and odor.
- **Treatment failure—**Occurs when wastewater reaches groundwater without adequate purification. Treatment failure is most common in sandy soils where rapid infiltration short-circuits natural treatment. System failure in sandy soils is often hard to detect given the lack of above ground indicators such as ponding or odor.

Step Four—Code for Protected Land

Code all parcels that are protected (see Figure 5-10). Protected lands may be owned by the town or by private individuals with a conservation or utility easement, or right-of-way. They may also be owned by the federal government (Fish & Wildlife) or organizations such as the Audubon Society or the Boy Scouts (which are unlikely to sell for development). The tax assessor's property code should include this information; however, check the parcel owner field for additional information. Also, review an open-space map to identify any additional protected parcels. Because data sets will vary in age and purpose, it is a good idea to consult multiple sources. A town or state environmental planner should be consulted to update information on protected lands in the community.

Figure 5-10
Parcel Build-Out Step Four

Step Five—Identify Vacant Parcels

Identify all vacant parcels in the study area (see Figure 5-11). The easiest way to do this is by using the property code in the parcel attribute table. The name of the field may be different from town to town, however, most tax assessors use a standard two-digit property code. Vacant parcels are usually coded by land use; in other words, vacant residential parcels will have a code different from vacant commercial parcels, and other types of vacant parcels. Recode vacant parcels with severe development constraints as undevelopable rather than as vacant. Give all vacant land an identifying code.

Figure 5-11
Parcel Build-Out Step Five

Step Six—Determine Potential Number of Units from Vacant Parcels

Calculations of future development potential must be conducted separately for grandfathered and non-grandfathered parcels. To perform calculations, export the parcel attribute table as a .dbf file into a spreadsheet program. Then sort the parcel data by zoning district requirements (see Table 5-2).

Table 5-2
Parcel Area Calculations

Zoning District	Lot Area (sq. ft.) Needed Per Dwelling Unit (including area for roads and utilities)
R200	210,000 (5% added)
R80	86,400 (8% added)
R60	66,000 (10% added)
R40, R40A	46,000 (15% added)
R30	34,500 (15% added)
R20	24,000 (20% added)
Commercial	—
Industrial	—

Grandfathered Vacant Parcels

Grandfathered vacant parcels are all platted lots that do not meet zoning district lot area requirements. It is possible that a large percentage of vacant parcels will fall into this category. Once the data has been sorted by zoning district and lot size, select out the parcels that are smaller than zoning requirements. The calculation of units for grandfathered vacant lots is simply a count of individual lots.

Standard Vacant Parcels

Standard vacant parcels are all those meeting zoning lot size requirements. Determine the number of potential future units by dividing parcel area by minimum lot size requirements, allowing area for roads and utilities.

When parcels are subdivided, a certain percentage of land must be set aside for roads and utilities. Different zoning categories will require different percentages of land for this purpose. The easiest way to deal with using different road and utility percentages for different zoning categories is to add the extra area required on a per-lot basis (see local ordinance for percentages).

For example, for medium density residential, R-40 zoning:

$40{,}000 \times 1.15 = 46{,}000$

For a six-acre parcel that is 261,360 sq. ft.
261,360/46,000 = 5.68

This parcel can accommodate five dwelling units.

Step Seven—Determine Yield from Built Parcels that Can Accommodate More Units

Some parcels in the parcel database that have been built upon might have ample room for further development. It is important to gauge the development potential of these parcels. In the parcel attribute table compare parcel size and lot area requirements for developed residential parcels. Select all developed residential parcels with lot areas more than double the zoning requirements. Export this data into a spreadsheet application and calculate the number of potential future units. Be sure to account for utility and road area requirements.

Table 5-3 shows an example summary of parcel analysis that includes potential units from vacant parcels and from built parcels that can accommodate more units.

Table 5-3
Example Summary of Parcel Analysis

Parcel Type	Minimum Lot Size in Square Feet	Additional Future Units
Grandfathered Vacant Parcels		
R-30	—	62
R-40	—	2
R-80	—	83
R-200	—	7
	Subtotal:	**154**
Standard Vacant Parcels		
R-30	30,000	73
R-40	40,000	6
R-80	80,000	25
R-200	200,000	15
	Subtotal:	**119**
Built Parcels that Can Accommodate Further Units		
R-30	30,000	82
R-40	40,000	1
R-80	80,000	27
R-200	200,000	6
	Subtotal:	**116**
	New Onsite Systems:	**389**

Using Assessment Results

At the completion of the build-out analysis, users should have a set of land use and soils data for current conditions and a duplicate dataset for future conditions. Although the results of the build-out analysis are valuable simply as map images for envisioning future growth, the data in the GIS attribute tables for land use and soils are required for computing watershed statistics, hydrologic budgets, and nutrient loading estimates.

The next assessment technique, computing watershed statistics (Chapter 6, *Watershed Indicators: Linking Land Use to Water Quality*), requires the land use and soils datasets to be imported into a spreadsheet application. To bring the data into a spreadsheet either export the GIS coverage attribute table from ArcView as a .dbf file and save it with a new name, or locate the .dbf file for the GIS coverage in Windows and save it with a new name. Next, open the .dbf file in a spreadsheet application and organize the data by land use and soils. (See Appendix A for examples on how to organize the data once it is brought into the spreadsheet.)

6 WATERSHED INDICATORS: LINKING LAND USE TO WATER QUALITY

Watershed indicators can be used to link land use to water quality. A watershed indicator is simply an indirect measure that relates an environmental feature of a watershed to its overall water quality. Environmental scientists research and use environmental indicators as surrogates and integrative measures of human impacts on ecosystems. (EPA, 1998; Karr, 1999; EPA, 2000; EPA, 2001). One of the most widely used indicators of watershed health is the percentage of watershed imperviousness (Arnold and Gibbons, 1996).

Using GIS Data to Derive Water Quality Indicators

The use of indices enables communities to identify trends and evaluate onsite wastewater management strategies in a timely and economical manner. Watershed risk indicators offer a relatively rapid and cost-effective means of assessing the cumulative impacts of land use on water resources. The indicators chosen will vary according to the characteristics of the study area and the type of assessment being conducted. This chapter provides step-by-step instructions on how to derive indicator measurements using GIS coverages and a spreadsheet program (see Appendix A).

Indicators used in this assessment include:

- The presence of likely pollution sources based on the percent of high-intensity land use
- Percent of impervious surface area and surface water runoff
- Natural landscape features that promote pollution movement to ground and surface waters, such as the percent of highly permeable soils and the percent of forest and wetland cover in riparian buffer zones
- The vulnerability of water resources to identified pollutants based on aquifer characteristics and current water quality monitoring data

Indicators presented in this handbook can be used to:

- Characterize current and future conditions and identify trends
- Identify data gaps and the need for additional monitoring or specialized modeling
- Compare differences among study areas
- Red flag areas already in high risk categories
- Identify the type(s) of pollution threats to better focus management actions

Risk Factors

Features evaluated in a wastewater needs assessment are itemized in the following list. Some or all may be considered when evaluating risk. The sign in parentheses following the indicator signifies the nature of the relationship with risk (that is, "+" implies that a higher value increases risk and "–" implies that a lower value increases risk).

Study area land use

- High-intensity land use (+)
- Impervious cover (+)
- Forest and wetland (–)

Riparian area

- High-intensity land use (+)
- Impervious cover (+)
- Forest and wetland (–)

Soils

- Groundwater risks
  - Excessively permeable (+)
  - High water table (+)
  - Restrictive layer (–)
  - Erodible (–)
  - Wetland soils with high potential for nitrogen removal (–)
- Surface water risks
  - Excessively permeable (–)
  - High water table (+)
  - Restrictive layer (+)
  - Erodible (+)
  - Wetland soils with high potential for nitrogen removal (–)

Hydrologic budget estimates

- Groundwater risks
  - High surface runoff (–)
  - High groundwater recharge (+)
  - Nitrogen inputs to groundwater (+)

- Surface water risks
  - High surface runoff (+)
  - High groundwater recharge (–)
  - High phosphorus inputs to surface runoff (+)

Water resource characteristics

- Groundwater risks
  - Unconfined aquifer (+)
  - Confined aquifer (–)
  - High withdrawal rates from pumping wells (+)
- Surface Water Risks
  - High flushing rate (–)
  - Deep depth (–)

Selecting and Interpreting Indicators

Select indicators based on the objectives established for the wastewater needs assessment, modified by possible data limitations. Indicators are best used to compare the relative change in risk among study areas or between different land use scenarios. Indicator analysis is particularly useful in comparing current and future land use impacts as well as the relative effectiveness of implementing various management options.

Risk Ranking System

To make the assessment more useful for onsite wastewater management decisions, results for many indicators are ranked along a scale from low to high or extreme risk. These thresholds are general guidelines designed to serve as a frame of reference in interpreting results. They should be considered points along a continuum, as opposed to rigid categories with distinct boundaries. Thresholds are based on the following factors:

- Literature values
- Risk threshold levels
- Indicators
- Percentile ranking of assessment results

Literature Values

Literature values relating water quality to presence or extent of watershed features. Each indicator is a standard, widely accepted measure of watershed health. The relationship between percent impervious cover and stream habitat is probably the best documented. Numerous studies show that stream habitat is likely to be impaired if the average watershed impervious cover exceeds 10 percent, with severe impacts likely when impervious cover exceeds 25 percent of the watershed area (Schueler and Holland, 2000; Arnold and Gibbons, 1996; Booth and Jackson, 1997).

Risk Threshold Levels

Supporting data for risk threshold levels for other indicators is more limited compared to literature values. Tolerance limits are set low as an early warning of potentially hazardous conditions before adverse impacts occur. This reflects the predisposition presented in this handbook towards pollution prevention as the most cost-effective approach to protect 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. For example, in drinking water supply areas, only shoreline areas with no high-intensity land use are ranked as a low risk to water quality. This ranking is based on the assumption that any high-risk land use within this critical zone is a potential threat and should be investigated.

Indicators

Indicators focus on situations of highest pollution risk and may not detect circumstances where a variety of factors combine to magnify pollution potential. For example, medium-density residential development (1 to 3.9 dwellings per acre) is not considered a high-intensity land use. But even this relatively low-density development could affect water quality depending on site specific features such as soil suitability, proximity to surface waters, level of onsite system maintenance, and landscape care practices.

Percentile Ranking or Assessment Results

When a large, representative database is available, risk thresholds may be set using statistical breakpoints to rank assessment results. Assessment results for 74 Rhode Island watersheds and aquifer recharge areas were compiled using current land use conditions. The percentage of forest and wetland in riparian areas, number of onsite systems per acre, nitrogen loading to groundwater, phosphorus loading to surface runoff, and other variables were ranked individually using results from all 74 study areas. Percentiles (25^{th}, 50^{th}, 75^{th} and 95^{th}) were then calculated for each indicator, and a corresponding rank of low, moderate, high, and extreme risk was assigned to the ranked scores. This method provided an objective ranking based purely on comparative results where literature values on risk thresholds was weak or unavailable.

For example, the risk levels for the number of onsite systems per acre and phosphorus loading to surface waters were established in this way. Although this method generates an objective ranking, it does not necessarily provide a better relationship to actual water quality unless indicator levels are also correlated with monitored data. Although the assessment areas covered a wide range of rural and urban watersheds, most of the study areas are not highly developed, resulting in more conservative ranking than if the range of rural, suburban, and urban watersheds were equally distributed.

Assumptions

A number of assumptions are used in the calculations of watershed and aquifer risk indicators to conform with accepted protocols. For example, when the percentage of impervious surface is used to reflect watershed health, it is assumed that the watershed study area is no larger than 100 square miles. (Shueler and Holland, 2000, p.154). This assumption is based on studies in watersheds of varying sizes where impervious surface estimates were found to be relevant only in smaller (less than 100 mi^2) watersheds. There are numerous assumptions that must be considered for any indicator used to gauge watershed health.

Assumptions should always be reviewed for consistency and appropriateness to any analysis. The assumptions presented in this handbook are based on published research, field data, research studies performed at the University of Rhode Island, and best professional judgment. Before beginning an analysis, assumptions should be modified to reflect local conditions through the use of local data sets. When local data is unavailable, adapt the assumptions from examples given in this handbook, using best judgment. Assumptions carry a level of uncertainty and should be modified to reflect a conservative estimate.

Both groundwater and surface water quality are directly related to land use within a groundwater recharge area or watershed (for example, Frink, 1991; Weiskel and Howes, 1991; Tufford et al., 1998). Consequently, land use is one of the most important factors in evaluating pollution risks and forms the basis for other watershed indicators such as nutrient loading and remaining forested areas. Land use indicators, or risk factors, used in this assessment include the following:

- High-intensity land use
- Impervious surface area
- Reduced wetland and forest cover

These indicators are calculated within the study area as well as within the riparian area. The riparian area indicators focus attention on land use practices that are closest to surface water resources and thus may present the most immediate risk for surface water contamination. Nitrogen and phosphorus as pollution indicators and soil types as risk factors are also considered.

Indicator—High-Intensity Land Use

High-intensity land use activities use, store, or generate a wide range of pollutants that have the potential to contaminate nearby water resources. Both sewered and unsewered areas are included in this indicator based on evidence that densely developed areas generate pollutants regardless of the presence of public sewers. Some of the risks associated with high-intensity land use include leaking underground storage tanks, pollutants deposited or spilled on pavement and subsequently transported with surface runoff, and leaking sewer lines or malfunctioning pump stations (Pitt et al., 1994).

Possible impacts to water resources from high-intensity land use include:

- Groundwater contamination by fuel products from leaking underground storage tanks
- Groundwater and/or surface water contamination by solvents and other toxic materials from accidental spills or improper disposal, especially at industrial sites
- Alterations to natural hydrology that generate increased surface runoff, which carries petroleum products and heavy metals from roads, parking lots, and other impervious surfaces
- Increased nutrients delivery to groundwater and surface water from fertilizers applied to crops, home lawns, parks, and golf courses
- Nutrient and bacteria delivery to groundwater and surface water from leaking sewer lines or malfunctioning pump stations, and from onsite systems in densely developed unsewered areas
- Surface water contamination from storm drains and agricultural tile drains that direct surface runoff to streams and other open waters instead of to a treatment structure such as a retention basin

Calculations and Assumptions for High-Intensity Land Use Indicator

Study Area Calculations

$$\text{\% High-Intensity Land Use in Study Area} = \frac{\text{Total Area High Intensity Land Uses}}{\text{Total Study Area}} \times 100$$

Riparian Area Calculations

$$\text{\% High-Intensity Land Use in Riparian Area} = \frac{\text{Total Acreage High-Intensity Land Uses in Riparian Area}}{\text{Total Riparian Area}} \times 100$$

To derive this indicator for riparian areas using GIS software, create a riparian “buffer” coverage. Use the buffer coverage to “clip” study area land use and land cover using Xtools or ArcInfo software.

Assumptions

The following land uses are considered high intensity:

- Extreme risk
  - Commercial and industrial
  - Highways, railroads, and airports
  - Junk yards or landfills
- High risk
  - High- and medium-high density residential (greater than 4 units/acre)
  - Schools, hospitals, and other institutional uses
  - Intensively managed cropland (such as corn, potatoes, and nursery crops)

In a recent USGS study conducted in Rhode Island, researchers (DeSimone and Ostiguy, 1999) verified that groundwater underlying industrial land use is more likely to contain toxic contaminants. They also found that elevated nitrogen (greater than 1 mg/l nitrate-N) in groundwater was associated with urban land uses whether or not the area was sewered, due to leaking sewers and fertilizers from home lawns, parks, golf courses, and institutional lands. Based on this research, thresholds were established for the high-intensity land use indicator (Table 6-1).

Table 6-1
Thresholds for High-Intensity Land Use Indicator

Indicator—Land Use	Low Risk	Medium Risk	High Risk	Extreme Risk
High-Intensity Land Use in Study Area	<10%	10 – 14%	15 – 25%	>25%

At a more detailed scale, ranking the intensity of development or its potential to pollute surface and groundwater resources must also take into consideration the soil suitability as well as the proximity of development to riparian areas. For example, although medium-density residential development (1 to 3.9 dwellings per acre) is not considered a high-intensity land use, it could have a significant impact on water resources depending on proximity to surface waterbodies, soil conditions, and topography.

Indicator—Impervious Cover

Impervious cover is a catch-all term for pavement, rooftops, cement, and other impermeable surfaces that prevent rainwater from seeping into the ground. Because nearly two-thirds of all impervious cover is automobile-related (such as parking lots, roads), it is generally a good measure of development associated with suburban sprawl. 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). Increased imperviousness alters the natural hydrology of the landscape by dramatically increasing the rate and volume of stormwater runoff and reducing critical groundwater recharge.

Areas with high levels of impervious cover are subject to more frequent flooding events due to the higher volume and faster flow of stormwater runoff (Figure 6-1). Increased erosion and sedimentation in streambeds, higher stream temperatures, and diminished stream flow because of lower groundwater levels during critical summer low-flow periods are some of the possible effects of increased impervious cover in a watershed. These effects translate to loss of high-quality stream habitat, reduced biodiversity, and chemical changes in water quality. In groundwater recharge areas, impervious cover reduces recharge to deep groundwater supplies.

Figure 6-1
Stream Bank Erosion Due to Rapid Stormwater Runoff (source: Jonson, Baltimore County DEPRM at http://chesapeake.towson.edu/landscape/impervious/habitat.asp)

According to recent studies, 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 (Shueler and Holland, 2000; Azous and Horner, 1997). At greater than 25–30 percent imperviousness, the extent of flooding and stream water quality impacts can become severe (Figure 6-2). It is important to note that in areas where impervious cover is below 10 percent but where other non-impervious land uses, such as cropland, are abundant, stream degradation is still possible. Booth (1991) recommends that in addition to low-impervious cover, forest cover should be maintained at 65 percent or more of a watershed area in order to preserve stream quality.

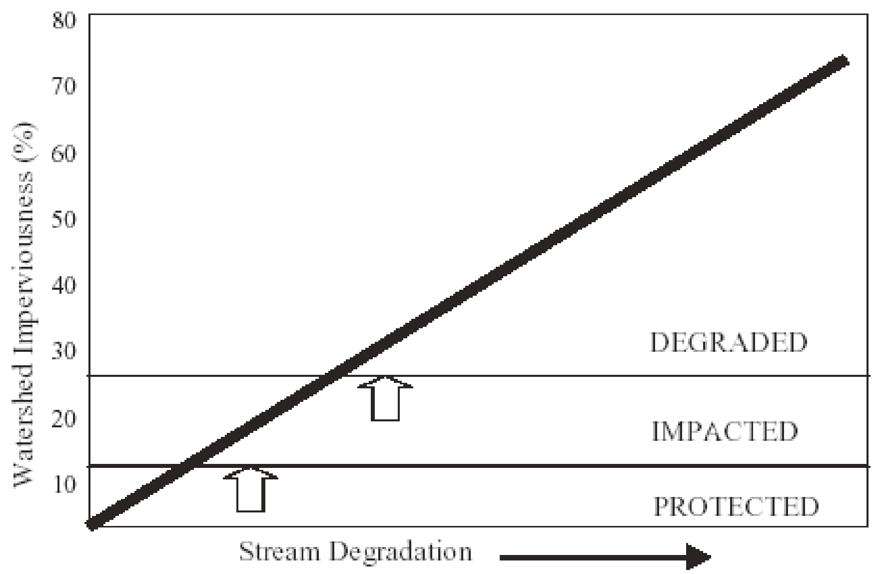


Figure 6-2
Watershed Imperviousness and Stream Degradation
(source: NEMO after Schueler, 1994)

Though intended to reduce onsite system pollution, sewering associated with increased urbanization can have a negative impact on groundwater recharge and stream flow. Studies on Long Island have shown that sewering has caused a significant reduction in aquifer recharge (Sulam, 1979). This loss of recharge can also reduce stream baseflow (Pluhowski and Spinello, 1978).

For a more in-depth look at the effects of impervious surface cover, the Stormwater Center's Impervious Cover Model at www.stormwatercenter.net examines 26 watershed indicators that reflect the impacts of impervious surface cover. Several of the indicators used to depict the extent of impervious cover impacts are listed in Table 6-2.

Table 6-2
Watershed Indicators as They Relate To the Extent of Imperviousness
(source: Impervious Cover Model at www.stormwatercenter.net

Watershed Indicator	Finding for Impervious Impacts
Aquatic habitat	Decrease in woody plants at 10% impervious cover (Booth et al., 1996)
Fish, habitat, and channel stability	Decline at 10% impervious cover (Booth, 1991)
Stream temperature	Increases with increase in impervious cover (Galli, 1991)
Aquatic insects	Significant decline with 8–9% impervious cover (Hicks and Larson, 1997)
Insects, fish, habitat water quality, riparian zone	Steep decline after 6% impervious cover; 45% impervious cover = 50% biotic integrity (Horner et al., 1996)
Fish spawning	Decline in fish eggs and larvae with >10% impervious cover (Limburg and Schmidt, 1990)
Wetland water quality	Decrease in quality when impervious cover exceeds 3.5% (Taylor et al., 1995)

Calculations and Assumptions for Impervious Cover Indicator

This section provides calculations and assumptions for estimating impervious surface area.

Calculations

Assign a percent impervious value to each land use (Table 6-3). Sum the acres for each land use in the study area (LU_x) and multiply by the corresponding percent impervious value. Sum across all land uses and divide by the total watershed area:

$$\%\ \text{Impervious for } LU_x \text{ in Study Area} = \frac{\text{Area } LU_x}{\text{Total Study Area}} \times \%\ \text{Impervious for } LU_x$$

Table 6-3
Estimated Average Percent Impervious Cover by Land Use

Land Use Category	TR55 USDA	New Jersey DEP	Mass GIS	URI MANAGE	Center for Watershed Protection	Town of Holliston, MA
HD Res (1/8 acre lot)	65	59		55	33	
MHD Res (1/4 acre lot)	38	39	57	36	28	19
MHD Res (1/3 acre lot)	30	34				
MHD Res (1/2 acre lot)	25	27	13	25	21	14
MD Res (1 acre lot)	20	18	10	14	14	12
MLD Res (2 acre lot)	12	12		11	11	
LD Res (3–5 acre lot)		8		8		
Agriculture			1		2	1.2
Open urban			1		9	23
Townhouse					41	
Multifamily			80		44	47
Commercial	85		90	72	72	45
Industrial (light)	72		75	54	53	60
Roads	72		75	72	80	54
Airports	72		75	72		54
Railroads	72		75	72		54
Junkyards	72		1	72		0.4
Recreation	10		2	10		7
Institution	50			34	34	
Sources	USDA 1986	Hoffman and Canace, 2002	Mass GIS	Kellogg, Joubert, and Gold, 1997	Center for Watershed Protection, 2002	Roberts, 1999

HD = High Density
MHD = Medium-High Density
MD = Medium Density
MLD = Medium-Low Density
LD = Low Density

Data Source Assumptions

There is considerable variation in estimates of impervious surface cover for different land uses, depending on the region of the country and on the area over which the estimates were averaged (for example, state versus town). The average annual estimates provided in Table 6-3 are estimated values modified in some cases using measured impervious cover. Estimates listed under Center for Watershed Protection are based on the Center for Watershed Protection's Simple Method (Schueler, 1987), updated using impervious cover measured from GIS orthophotos of suburban land uses in the Chesapeake Bay watershed (Capiella and Brown, 2001). The Town of Holliston, MA values are measured from a sampling of homogenous land uses using GIS one-meter orthophotos. These values include only roads and large rooftops, excluding driveways, outbuildings, and other impervious surfaces and may under-represent actual impervious cover. The URI MANAGE estimates are based on a combination of estimates using USDA Technical Release 55 (1986) and Center for Watershed Protection (2002), adjusted to reflect local parcel characteristics.

Example of Impervious Cover Area for Commercial Land Use

Table 6-4 shows an example of how to calculate percent impervious area for commercial land.

Table 6-4
Example of Percent Impervious Calculation for Commercial Land

Land Use Category	Total Acres	% Impervious	% Area
HD Res (1/8 acre lot)	0.1	65	0
MHD Res (1/4 acre lot)	15.8	38	1
MD Res (1 acre lot)	46.8	20	2
MLD Res (2 acre lot)	9.7	12	0
LD Res >2 acre lot	9.4	8	0
Commercial	15.1	72	2
Industrial (light)	0	72	0
Roads	0	72	0
Airports	0	72	0
Railroads	0	72	0
Junkyards	0	72	0
Recreation	5.2	10	0

Land Use Category	Total Acres	% Impervious	% Area
Institution	3	50	0
Total Developed Areas	105	—	—
All Other Pervious Areas	435.9	—	—
Total Watershed Area	541	—	5%

$$\text{\% of commercial watershed impervious area} = \frac{15.1 \text{ acres}}{541 \text{ acres}} \times 72$$

% of commercial watershed impervious area = 2%

The variation in impervious estimates is likely due to differences in population density. Prisloe et al. (2000) found increases in impervious surface in four Connecticut towns closely correlated with population density. The data suggests that in more densely populated areas a larger percentage of each land use is impervious compared to more rural areas.

For example, high-density residential land use in Connecticut has three different values, depending on the overall population density in the area (Table 6-5).

Table 6-5
Percent Impervious Values for High-Density Residential Land Use as a Function of Local Population Density (source: CT NEMO)

Population Density	High	Medium	Low
% Impervious for High-Density Residential Land Use	59.5	39.1	30.2

These values should be considered when calculating land use coefficients. Researchers at Connecticut Nonpoint Education for Municipal Officials (CT NEMO) and the NOAA Coastal Services Center have developed a tool that estimates impervious surface area and water quality conditions within a study area. The Impervious Surface Analysis Tool can be found at www.csc.noaa.gov/crs/is/index.html. While this tool enables users to plug in specific coefficients for the appropriate population densities, there are still several assumptions to consider:

- Stream quality is a function of the percentage of impervious area
- Each watershed operates independently of upstream watersheds
- Watershed characteristics such as soils, topography, stream density, and others are not considered
- No distinction is made between total (all) and effective (directly impacting a waterbody) impervious area
- The spatial distribution of impervious surface and its proximity to drainage systems is ignored

Example of Impervious Cover Analysis

Impervious cover analysis provides a useful measure to evaluate potential risks among different subwatersheds and to compare current with future land use. In this example, only slight increases in impervious surface are expected with future development (Figure 6-3). Since key water supply areas (Carr, Watson, and Jamestown WHPA) are expected to remain below 10 percent, these areas are considered to have a low risk of contamination from runoff.

Jamestown Shores is a concern due to currently high-risk levels and a slight increase expected in the future. Given that flooding is already a problem in this area, these high-risk levels suggest remediation and runoff prevention is necessary. The Jamestown graph bars on the left of the chart provide a comparison to the town as a whole. The largely undeveloped Watson Pond and Carr Pond subwatersheds provide reference watersheds close to natural undeveloped conditions.

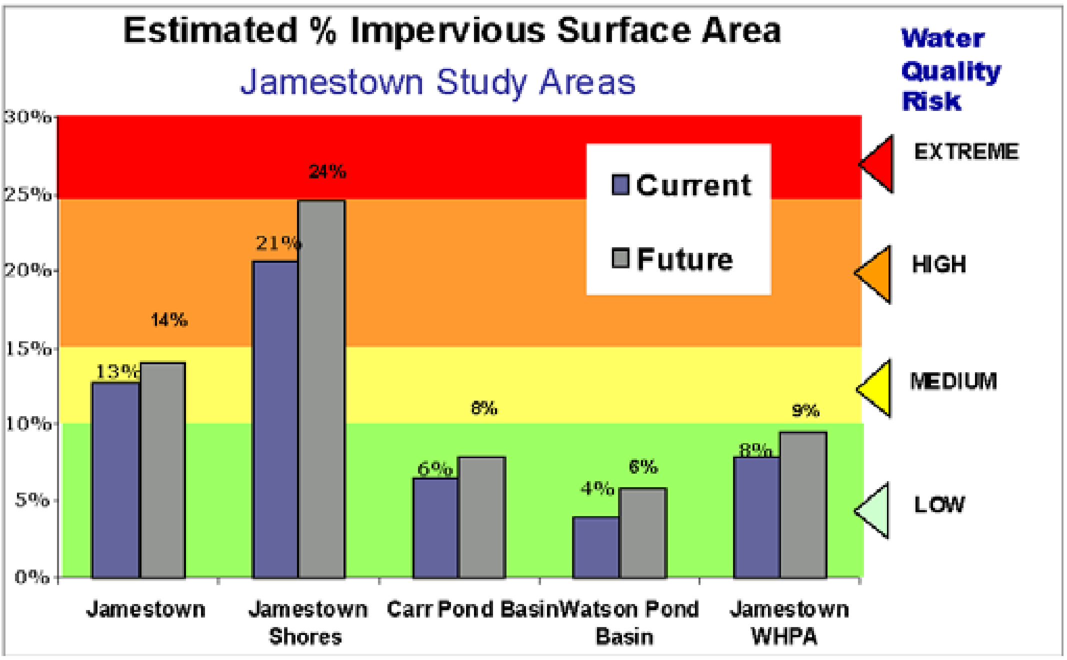


Figure 6-3
Example of Impervious Cover Analysis for Jamestown, RI

Indicator—Forest and Wetlands Area

The extent of forests and wetlands in a watershed is directly linked to water quality (USEPA, 1999b). Forests and wetlands serve as ecosystem treatment systems, helping to preserve and maintain watershed health. Unlike the other risk factors presented in the assessment, there is an inverse relationship between the area of these undeveloped lands and risk to water quality.

Forested watersheds have the capacity to intercept, store, and infiltrate precipitation, thereby recharging groundwater aquifers and maintaining baseflow in streams. Undisturbed forest soils tend to store organic matter and nutrients, including atmospheric pollutants associated with acid rain. Forested riparian areas also provide shade to surface waters, stabilize stream banks, and filter sediment. Many watershed assessment methods utilize the percentage of forest cover as a primary indicator of watershed health (Chesapeake Bay Foundation, Stormwater Center—Rapid Stream Assessment Technique, Rapid Bioassessment, MD DEP, Southern Rockies Ecosystem Project).

Wetlands are a vital link between land, groundwater, and surface water. Wetland ecosystems can protect water quality and control flooding. The extent of wetlands within a watershed can be used as a measure of the potential for sediment trapping, pollutant storage, and nutrient transformation. Wetland functions are highly variable, however, depending on factors such as seasonal variation, location within the watershed, and storage capacity. Despite this variability, the extent of wetlands within a watershed is strongly correlated with healthy ecosystems (Hicks and Larson, 1997; Amman and Stone, 1991; Azous and Horner, 1997). Watersheds with less wetland area have less opportunity for pollutant treatment, less storage capacity to moderate changes in hydrology brought about by urbanization, and a higher potential for direct pollutant delivery to surface waters. Wetland loss has been noted to be a primary cause of degraded water quality (Barbour et al., 1999). Wetland indicators range from wetland area (such as wetland loss—EPA, Chesapeake Bay Foundation), to condition of habitat (such as species at risk—EPA), or species present (such as fish, shellfish, benthic organisms—Chesapeake Bay Foundation, Stormwater Center, Benthic Index of Biological Integrity, Rapid Bioassessment, MD DEP).

Wetland indicators often used for watershed assessments include:

- Annual or total percent wetland loss
- Wetland area percent

Calculations and Assumptions for Forest and Wetlands Indicator

This section provides calculations and assumptions for estimating forest and wetlands areas.

Calculations

$$\text{\% Forest and Wetland in a Study Area} = \frac{\text{Forest + Wetland Area}}{\text{Total Study Area}} \times 100$$

To calculate percent forest and wetlands using GIS, sum the area in the land use and land cover data in each category and divide by the total study area. If the land use and land cover data does not include a wetlands code, use a wetland coverage, if available, and use the Select By Theme function in ArcView to estimate the wetlands within the study area.

Assumptions

The following land use categories are included in the percent forest and wetlands calculation:

- Forest
- Brush
- Wetlands
- Unfertilized pasture

Brush and unfertilized pasture are included because they provide similar ecological functions in the hydrologic cycle.

Water quality in wellhead protection areas or watersheds that have a combined forest and wetlands cover of 80 percent or more are considered, in this study, to be at low risk. Alternatively, wellhead protection areas or watersheds with less than 20 percent forest and wetlands cover have little capacity to protect against pollutant movement, and also have a higher proportion of developed land use that can generate contaminants (Table 6-6).

Table 6-6
Thresholds for Percent Forest and Wetlands Indicator

Indicator	Low Risk	Medium Risk	High Risk	Extreme Risk
% Forest and Wetlands	>80%	50–80%	20–49%	<20%

Example of Forest and Wetlands Analysis

Percent forest and wetlands was calculated for the different study areas within Jamestown, RI (see Figure 6-4). Current forested area was compared with future forested area based on a build-out analysis (see Chapter 5, *Envisioning Future Growth*).

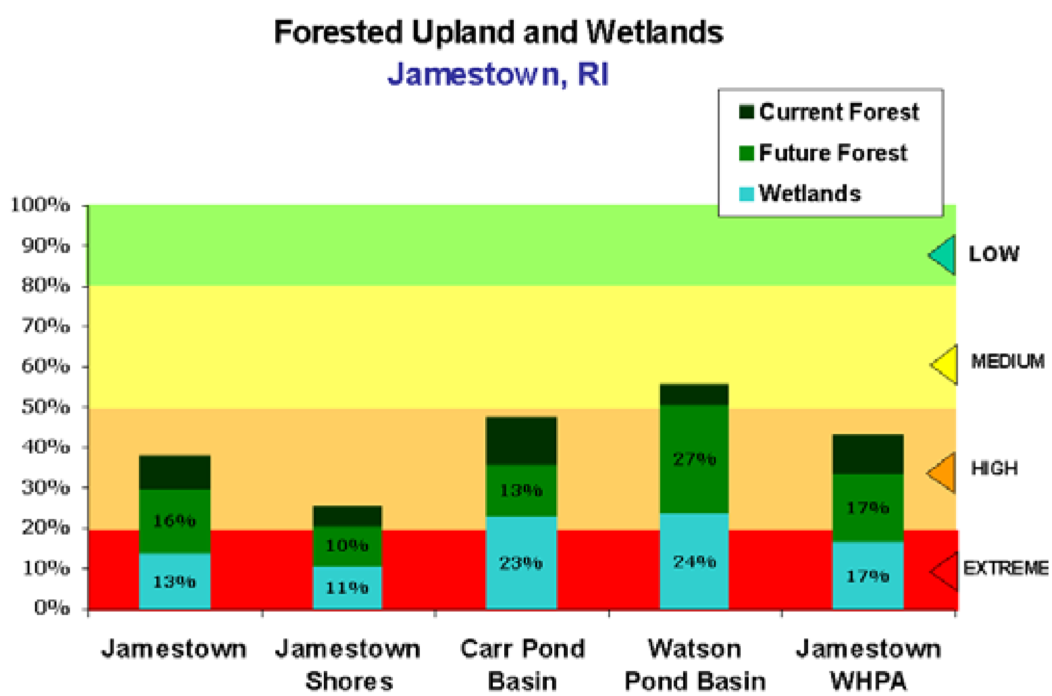


Figure 6-4
Example of Percent Forest and Wetlands Analysis for Jamestown, RI

Riparian Land Use Indicators

The same indicators that are used to evaluate the study area as a whole can also be used to evaluate more immediate risks to surface water by applying them to the riparian area. Riparian areas are defined as the land adjacent to surface waters. Contaminants that are likely to move with surface runoff pose a more immediate threat when they originate within the riparian area. In addition, riparian areas can serve as pollutant sinks when left undeveloped. High-intensity land use and increased imperviousness have the compounded effect of bringing possible contaminants in close proximity to surface water as well as reducing the ability of riparian areas to act as pollutant sinks. Because high intensity land use, imperviousness, and the loss of forest and wetlands are all important to surface water quality, the following land use indicators are used in the riparian area:

- Percent high-intensity land use
- Percent impervious
- Percent forest and wetlands

The relevant width of the riparian zone depends on the riparian function being considered. Because soils and hydrology vary, and because different riparian functions (such as sediment and pollutant trapping, nutrient transformations, stream bank stability, habitat protection) depend on different riparian characteristics, the width of interest is variable.

Surface waters included in this analysis are all surface waters (streams, rivers, lakes, ponds, coastal waters) depicted on a 1:24,000 USGS topographic map. The distance used for analyses done in Rhode Island is 200 feet; in many states, a 150-foot buffer is considered to be a reasonable and defensible *minimum* distance for preventing major water quality impacts from small-scale development (Welsch, 1991; Desbonnet et al., 1994; Herson-Jones et al., 1995). Depending on local regulations, freshwater and coastal wetlands may be buffered as well.

NOTE: Mapping errors are most pronounced when dealing with small slivers such as riparian areas, especially when overlaying data layers produced from various sources at different scales. All map analyses, and particularly shoreline data, are suitable for planning level analysis only. Awareness of these limitations and caution in interpreting results is especially important in analyzing riparian area characteristics at the parcel level. In all cases when using GIS data, field inventory is needed to verify boundaries and pollution risk.

Riparian Function

Riparian areas have the potential to function in two ways:

- Vegetated buffers can serve as water quality treatment zones, maintaining ecosystem health by filtering pollutants (for example, phosphorus and other sediment-borne pollutants) carried with surface runoff and removing nitrogen through biochemical processes.
- Disturbed riparian areas can become high-risk pollutant delivery zones, especially when intensely developed. Vegetated buffers should be considered the last line of defense for pollutants reaching surface waters.

Vegetated riparian buffers also serve other functions that enhance water quality including:

- Store floodwaters and infiltrate runoff, particularly with porous forest soils
- Stabilize stream banks
- 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—a critical function on smaller streams (greater than 100 feet wide)
- Provide open space, recreation, scenic views, and wildlife habitat and/or travel corridors

Calculations and Assumptions for Riparian Land Use Indicators

This section provides calculations and assumptions for riparian areas.

Calculations

Calculations for percent high-intensity land use, percent impervious, and percent forest and wetlands are done using the same approach as for the whole study area. The only difference is that the study area is replaced by the riparian area.

Assumptions

A lower indicator threshold for percent high-intensity land use and percent impervious and a higher threshold for percent forest and wetlands is used when considering the impacts of development in riparian areas because of their proximity to surface water (Table 6-7). In addition, percent high-intensity land use is even more important if the surface water is a drinking water supply.

Table 6-7
Riparian Land Use Rating System

	Drinking Water Supplies	All Other Waters		
Rating	**% High Intensity**	**% High Intensity**	**% Impervious**	**% Forest and Wetland**
Extreme	>15%	>15%	>5%	<60%
High	5–15%	10–15%	10–15%	60–79%
Medium	<5%	5–9%	5–9%	80–95%
Low	0%	<5%	<10%	>95%

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 (Frimpter et al., 1990; Hantzsche and Finnemore, 1992; Gorres and Gold, 1996; Valiela et al., 1997). 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 of nitrogen is 10 mg/l. The drinking water action level of 5 mg/l triggers increased monitoring.
- Nitrogen is associated with human inputs such as agricultural and residential fertilizers and onsite systems, and is a recommended water quality indicator for both groundwater and surface water by EPA (1996).
- Nitrogen moves easily in surface water and groundwater, and can indicate the presence of other dissolved pollutants such as bacteria and viruses, road salt, and some toxic chemicals.
- Nitrogen fertilizes coastal waters, leading to excessive growth of nuisance seaweed and algae, low dissolved oxygen events, loss of eelgrass, and declines of shellfish beds. Coastal ecosystems are generally nitrogen limited and are, therefore, sensitive to nitrogen loading (National Research Council, 2000).

Phosphorus as a Pollution Indicator

Phosphorus loading to surface waters is a widely-used component of lake assessment studies (Holdren et al., 2001). Phosphorus is the limiting nutrient in most freshwater systems (Vollenweider, 1968), and is one of several surface water indicators recommended by EPA (1996). While phosphorus is essential for algal and aquatic plant productivity, even minute increases in phosphorus loading can trigger tremendous increases in growth followed by significant oxygen demands as algae blooms die off. Low oxygen levels increase the potential for fish die-off and for further release of nutrients and other elements from anoxic sediments. The negative effects of this accelerated growth, also referred to as "eutrophication," are especially critical when managing drinking water reservoirs. Because phosphorus tends to adsorb to soil particles and be transported with sediments, it is also a useful indicator for sediment-borne pollutants. In summary,

- Land use activities have significant, measurable impacts on phosphorus levels in surface waterbodies.
- High phosphorus levels in freshwater systems are often associated with:
  - Phosphate-based detergents
  - Lawn and garden fertilizers
  - Leaking sewers
  - Urban stormwater runoff
  - Improperly sited and maintained onsite systems
  - Agricultural drainage
  - Pet waste

- Phosphorus tends to be associated with sediment and is a useful indicator of other sediment-borne pollutants such as metals and bacteria.

Soil Types as Risk Factors

The ability of pollutants to move through various soil types is a critical factor in estimating the vulnerability of a water resource. Highly permeable soils allow water and soluble contaminants to move towards an aquifer and pumping wells. Less permeable soils promote surface runoff to nearby surface waters. The location of potential pollution sources on highly permeable soils within groundwater protection areas or on less permeable soils near important surface water resources is an important component of the assessment process. Other relevant soil characteristics include the depth to the seasonal high water table, restrictive layers such as “hardpan” where downward infiltration is very slow, and erosion potential (based on slope and texture) where controlling erosion from construction sites and other land disturbance may be difficult.

When mapped together, hydrologic soil groups and seasonal high 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, fine-grained soils with slow permeability have lower infiltration rates and often have a higher water table. High water table areas are almost always connected to small streams, wetlands, and intermittent drainage ways that form an extended drainage network. As a result of these connections, pollutants generated in these areas can move rapidly to surface waters or to shallow groundwater. Onsite systems constructed in these slowly permeable soils are also more likely to experience hydraulic failure, especially where a dense compacted hardpan soil layer restricts downward flow of water. Characteristics of the four hydrologic soil groups are described in Chapter 4, *Assembling and Refining a GIS Database*, Table 4-3.

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. The effect of soil type in estimating pollutant runoff impacts is less important in urban areas with extensive drainage improvements. Stormwater drainage systems, channelized streams, and artificially drained fields and building sites all bypass natural rainfall storage and infiltration processes and quickly divert runoff to downstream discharge points. These artificial improvements are not identified in this map-based assessment and must be field-inventoried. Developed watersheds with highly permeable soils may be better suited for stormwater retrofitting because of their higher capacity for natural infiltration.

Synthesizing and Displaying a Multiple Indicator Analysis

For an in depth discussion on how to synthesize and display a multiple indicator analysis, refer to Chapter 9, *Evaluating and Ranking Pollution Risk Indicators*. Chapter 7, *Hydrologic Budget and Nutrient Loading*, provides instruction on how to use land use and soils data to compute estimated nutrient loads to both surface water runoff and groundwater recharge, which are also important water quality risk indicators.

7 HYDROLOGIC BUDGET AND NUTRIENT LOADING

Local decision-makers often require information on the importance of onsite wastewater contamination relative to other sources. This chapter outlines a step-by-step method for estimating surface water runoff and groundwater recharge, and introduces simple modeling calculations for estimating cumulative nutrient loads and loading derived from onsite wastewater systems to both surface water runoff and groundwater recharge. In order to conduct this part of the assessment, land use and soils data, annual average precipitation data, population estimates, and the estimated number of onsite systems in each study area are required.

Using Models to Evaluate Land Use Impacts

Modeling and field monitoring are vital tools used to help assess both current conditions and future impacts of land use on water quality. While field monitoring can characterize the current condition of water resources, monitored data alone cannot give a sufficient indication of future conditions. Models are used to estimate the possible range of future conditions as a result of changes in land use and management. Models are also used to estimate the relative importance of various sources of nutrients or other pollutants, especially when field data is sparse or inconclusive. As an alternative to project-by-project impact review, modeling can provide a big picture perspective that is needed to evaluate cumulative impacts. Modeling is also a valuable tool for comparing relative effects of different land use scenarios or management practices.

Models are as diverse in approach and implementation as the people who create and use them. This diversity creates a great deal of confusion. In order to provide a common logic and language, relevant modeling terminology is provided in Table 7-1.

Maps are one form of models people use every day, as are weather models used in weather forecasting and economic indicators used to predict economic performance, such as the consumer confidence index. Models are a representation of our understanding of relationships (physical, biological, chemical, economic) using images, logic trees, or mathematical expressions. People use models to gain additional information about something that would otherwise be difficult or impossible to measure directly.

With these models, predictions are often made about how these systems will behave in the future. Every model makes assumptions or establishes certain ground rules. For example, calculating the consumer confidence index makes assumptions about the number of people surveyed or the questions asked and how their responses are used to compute the index.

Similarly, environmental models make assumptions about pollutant delivery from different land uses or pollutant attenuation on the landscape.

Table 7-1
Common Modeling Concepts and Terminology

Term	Definition	Example
Space		
Lumped	Aggregates spatial characteristics	Sums the forested area in a watershed
Distributed	Recognizes one-, two-, or three-dimensional spatial relationships	1-D: depth below soil surface 2-D: plan view of stream network 3-D: groundwater aquifer
Time		
Steady-state	Averages over a given time period	Season; year
Dynamic	Steps through time	Daily
Input-Output Linkage		
Empirical (also referred to as Functional or Statistical)	Uses equations derived from observed relationships without modeling the processes themselves. These equations are often developed using regression techniques.	Estimates the nitrogen load from a forested watershed based on the measured nitrogen load from other forested areas
Mechanistic (also referred to as Process-based or Process-level)	Uses equations that describe the mechanisms that control the processes. Generally much more complex and requires more detailed input data.	Estimates the nitrogen load from a forested watershed based on the nitrogen cycling and hydrologic processes within the watershed
Hybrid	Uses a combination of empirical and process-based relationships. Many models fall in this category, with mechanistic relationships being used where they are well understood, such as hydrologic processes, and where input data is available and reliable.	Estimates the nitrogen load from a forested watershed based on the observed nitrogen load from other forested areas combined with equations representing the hydrologic processes within the watershed
Input Data		
Parameters	Assigned values characterizing the system being modeled. Remains constant throughout the analysis.	Watershed area; soil properties
Variables	Assigned values characterizing the scenarios within the system being modeled. Changes with each scenario.	Land use

Table 7-1
Common Modeling Concepts and Terminology (Cont.)

Term	Definition	Example
Input Data		
Parameters	Assigned values characterizing the system being modeled. Remains constant throughout the analysis.	Watershed area; soil properties
Variables	Assigned values characterizing the scenarios within the system being modeled. Changes with each scenario.	Land use
Output		
Deterministic	One outcome for one set of input values.	Sediment load prediction from a possible land use scenario
Stochastic	Probability distribution calculated for a set of input probability distributions.	Monte Carlo simulation providing a probability distribution of possible sediment loads from a probability distribution of possible pollutant attenuation factors.
Purpose		
Decision Support	Provides a relatively quick and inexpensive analysis to aid in planning and directing more detailed analyses or data collection. Usually more empirical models.	—
Research	Provides a framework within which to explore processes in need of refinement and clarification. Generally more process-based models.	—

Issues Common to All Modeling Analyses

It is helpful to keep in mind the following issues when deciding when and how to use a model:

- Output from both simple and complex models are estimates based on a set of assumptions or hypotheses and dependent upon the quality of both those assumptions and input data.
- Reckhow (1994) argues that, "limited observational data and limited scientific knowledge are often incompatible with the highly-detailed model structures of the large pollutant transport and fate models." At the local level, communities often possess limited data and lack assessment funds that preclude the development and evaluation of sophisticated models. Nevertheless, local decision makers can benefit from approaches that use available data to identify relative risks and guide subsequent research and monitoring that will further management programs.

- Model caveats must always be considered when interpreting model output including:
  - What is assumed?
  - How uncertain is the input data?
  - How does the uncertainty influence the decision-making process?
- Before using any model, consider the intended goals of an analysis and weigh the costs in time, input data, and computer expertise against the uncertainties.

Calibration, Validation, and Verification

A model can encompass any combination of time/space/linkage/outcome characteristics. It follows that input data required by a model can vary from extremely detailed and spatially explicit to spatial and temporal averages over the study area and over monitored time periods. Data availability and the cost in both time and money of obtaining quality input data ought to be a primary factor in determining the usefulness of a model. No one type of model is inherently superior to another. Rather, different forms suit different purposes.

For example, a mechanistic or process-based model that attempts to represent all of the processes a nitrate molecule might encounter on its travels through a watershed is well-suited to research objectives that identify and explore processes that are poorly understood or are missing entirely (for example, Reckhow, 1994; Oreskes et al., 1994; Honachefsky, 2000). These models are also referred to as “heuristic”. Input data for a mechanistic model is generally difficult to obtain because it is usually detailed and site-specific. In addition, implementing a model that uses mechanistic representations is usually more challenging and time-consuming than implementing a simpler empirical model. The misconception that complexity translates to accuracy has led to a great deal of waste in time and money over the years. When detailed, high resolution data are lacking, a simple model may be able to provide important management insights more quickly and inexpensively than a complex model.

The use of models raises questions concerning calibration and validation. Honachefsky (2000) provides a good overview of models and their uses and limitations in environmental planning. Calibration refers to the process of adjusting model parameters to obtain the best fit of model output with monitored data. This process assumes that the model can account for most, if not all, of the factors that contribute to a sample taken at a given point in time. Many sources of local data do not have the resolution necessary to calibrate complex models. For example, most municipal well data values represent water that is a combination of ages and subject to various biological and physical processes. The municipal well data capture a generalized picture of groundwater quality that actually reflects a host of interacting hydraulic factors and demands an extensive field-verified database for proper validation. The modeling approaches within this handbook rely on accepted, widely used indicators that connote relative risks, rather than developing specific output that is oriented towards calibration and validation.

The MANAGE Approach

The MANAGE model, developed by URI Cooperative Extension, is an example of a simple mass balance model that generates nutrient loading as an additional indicator of pollution risk. This approach is intended as a screening-level tool to help decision makers quickly and efficiently assess possible water quality issues associated with changes in land use, and to help direct future monitoring, research, and follow-up investigations to management decisions. This approach builds on the experience of many field researchers, modelers, and planners.

Using the terminology in Table 7-1, MANAGE is a decision-support model, and is steady-state, lumped, empirical, and deterministic. However, it also accounts for some spatial relationships in that it modifies nutrient loading based on the land use and soils characteristics of the riparian area. The “hot spot” mapping is another tool used in the MANAGE assessment that recognizes critical spatial relationships.

The nutrient loading component uses a simple mass balance method. This method calculates a general water budget based on water inputs (precipitation and onsite system discharge) and outputs (evaporation and plant transpiration, surface 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, incorporating accepted input values from published literature. The estimates of nitrogen leaching to groundwater are improved by the use of input values derived from research done within Rhode Island.

Outputs are average annual estimates of runoff, infiltration, and nutrient loading for the study area. These estimates are useful in comparing relative differences in pollution risk among various land use scenarios or among subwatersheds. This approach does not calculate any nitrogen removal once the nitrogen reaches the groundwater or surface water. There is still enormous uncertainty associated with nutrient (particularly nitrogen) sinks at the watershed scale. The nutrient loading should be used as a relative measure and viewed as a worst-case estimate. Also for this reason, comparisons with monitored data should be made with this caveat in mind. Monitored samples represent water that is an aggregate of ages, and therefore of land use scenarios, and of interactions with biological and physical processes (Focazio et al., 2002).

MANAGE uses a spreadsheet to calculate a hydrologic budget and nutrient loading estimates. The input data is generated from GIS data layers using a macro in ArcInfo to extract the total area of each Land Use (LU)/Hydrological Soil Group (HSG) category within the:

- Study area
- Riparian area of study area
- Unsewered portions of both the study area and the riparian area

Hydrologic Budget

Using a mass balance approach, MANAGE calculates average annual surface runoff and groundwater recharge using precipitation as an input and estimated evapotranspiration as an assigned model parameter (Frimpter, et. al., 1990). Evapotranspiration is difficult to measure and is often estimated through the direct measurement of every other term in the mass balance equation. For example, watershed studies conducted by the USGS typically estimate evapotranspiration by subtracting long-term stream runoff, which includes groundwater discharging to streams, from long-term precipitation. Since precipitation and evapotranspiration rates can vary greatly based on climate and rainfall within a county or watershed, site-specific data should be obtained where possible.

MANAGE uses average annual precipitation and evapotranspiration estimates from USGS investigations conducted locally (Johnston and Dickerman, 1985). Long-term rainfall records and average annual evaporation measured by evaporation pans may also be obtained from the NOAA, National Weather Service. State and county cooperative extension offices may also be able to provide information on local evapotranspiration rates.

All input values for the hydrologic budget must be adjusted for different regions of the country, depending upon climate and rainfall. The hydrologic mass balance equation can be written as

Inflow = Outflow + Change in storage

or

$$PPT = SRO + ET + GW_{recharge} \quad \textbf{(Eq. 7-1)}$$

where

PPT = Average annual precipitation (depth $\times$ study area)
SRO = Average annual surface runoff (depth $\times$ area; discussed below)
ET = Evapotranspiration (evaporation + plant transpiration; assigned at start of analysis)
$GW_{recharge}$ = Recharge to groundwater

The SRO is calculated first, and the groundwater recharge is then calculated as the remainder after SRO and ET are subtracted from PPT.

Annual surface runoff is calculated from assigned runoff coefficients for each LU/HSG using the approach described by Adamus and Bergman (1993). Low and high values for surface runoff coefficients are assigned for each LU category (Appendix B). Coefficients for each HSG are then interpolated for each LU category using the following formula:

$$SRC = LLC + (ULC - LLC) \times X \quad \textbf{(Eq. 7-2)}$$

where

SRC = Surface runoff coefficient for a given LU
LLC = Lower limit of coefficient
ULC = Upper limit of coefficient
X = Value associated with each HSG (Table 7-2)

Table 7-2
Weighting Factors (X) Used for Different Hydrologic Soil Groups in Equations 7-2, 7-6, and 7-7

Hydrologic Soil Group	Value of X
A	0
B	1/3
C	2/3
D	1

Essentially this formula divides the range evenly into thirds, with the high end assigned to hydrologic soil group A (high infiltration rate) and the low end assigned to hydrologic soil group D (very slow infiltration rate). This is based on the approach developed by Adamus and Bergman (1993).

Appendix B gives runoff coefficients used by MANAGE. These may need to be adjusted for the study area. This approach is comparable to the Simple Method, which estimates average annual runoff and pollutant loads based on typical pollutant concentrations from different land uses (Center for Watershed Protection, 2002). The runoff from each land use category is the sum of runoff from each LU/HSG combination.

Runoff volume from LU_i =

$$(A_A \times SRC_A + A_B \times SRC_B + A_C \times SRC_C + A_D \times SRC_D) \times PPT \quad \textbf{(Eq. 7-3)}$$

where

A_x = Area of LU category *i* falling on A, B, C, or D soils
SRC_x = Surface runoff coefficient for LU_i falling on A, B, C, or D soils
PPT = Depth of average annual precipitation

The total runoff from the study area is then the sum of runoff from each land use category:

$$SRO = RO_1 + RO_2 + \ldots + RO_y \quad \textbf{(Eq. 7-4)}$$

where

SRO = Total average annual surface runoff volume
RO_1 = Runoff volume from land use category 1
RO_2 = Runoff volume from land use category 2
y = Total number of land use categories

Groundwater recharge is the sum of recharge from precipitation plus inputs from onsite systems:

$$GW_{recharge} = \text{Recharge from PPT} + [\text{Onsite system inputs}]$$

$$GW_{recharge} = PPT - SRO - ET + [\text{Onsite system inputs}] \quad \textbf{(Eq. 7-5)}$$

The more impervious surface area in a study area, the more surface runoff will be generated and less recharge to groundwater. This approach integrates over time (one year) and space (study area).

Figure 7-1 shows that groundwater recharge decreases with land development as impervious cover and surface runoff increase. As a result, only 50 percent of rainfall is estimated to recharge to groundwater in Jamestown Shores compared to 74 percent in the Carr Pond watershed.

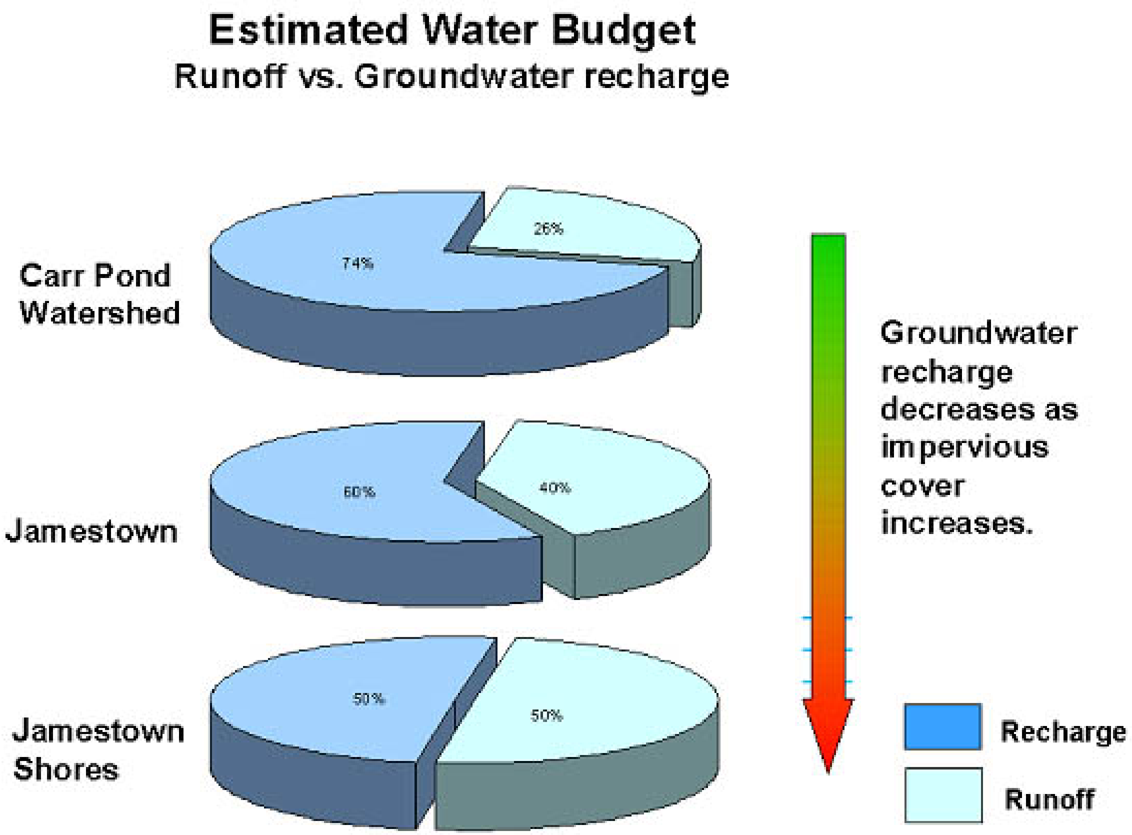


Figure 7-1
Comparison of Runoff and Infiltration with Watershed Development

After the hydrologic budget has been calculated, the nutrient loading indices can be estimated.

Nutrient Loading Indices

Nutrient loading indices apply to

- Groundwater
- Surface Water

Groundwater

The long-term water quality of an aquifer can be inferred from the estimated quality of the recharge water (Frimpter et al., 1990; Weiskel and Howes, 1991; Hantzche and Finnemore, 1992). Estimating the nitrogen loads to the groundwater is a useful indicator for long-term groundwater quality. An estimate of nitrogen loading to groundwater is calculated by summing the contributions from each potential nonpoint nitrogen source. Phosphorus loading to groundwater is not estimated because phosphorus tends to bind to soil grains, limiting its mobility in groundwater.

The MANAGE approach accounts for the following nonpoint nitrogen sources:

- Onsite systems
- Lawn fertilizers
- Agricultural fertilizers
- Pet waste
- Stormwater infiltration largely from atmospheric sources

These nonpoint nitrogen sources are illustrated in Figure 7-2. Large animals, such as cows and horses, can be significant sources of nutrients and bacteria, depending on management practices, such as siting of manure piles away from surface waters or exclusion of animals from streams or ponds. Because management of large animals is site specific, a field visit is helpful.

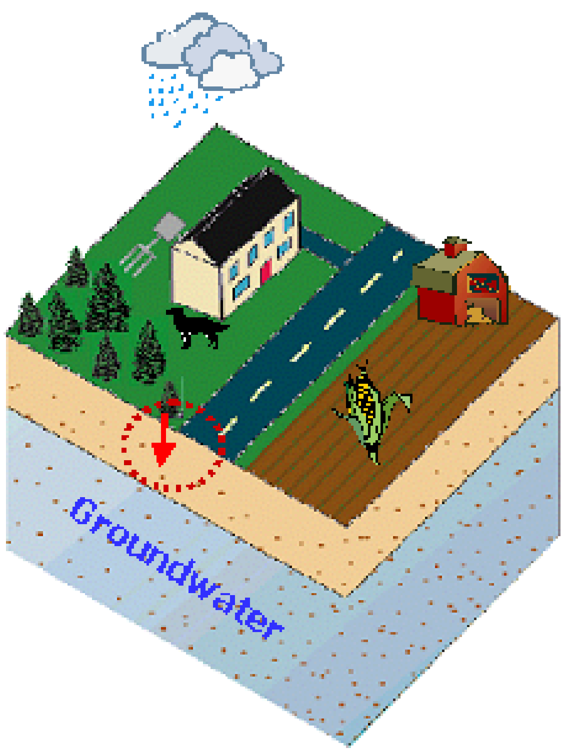


Figure 7-2
Sources of Nitrate-Nitrogen to Groundwater

Groundwater Nitrate-Nitrogen (N) Loading Assumptions

Onsite systems

- 7 lb N/person/year
- 80% leaching to groundwater

Lawn fertilizer

- 175 lb N/acre/year
- 6 to 20 % leaching to groundwater

Agriculture (cropland)

- 175 to 215 lb N/acre/year
- 20% leaching to groundwater

Pet waste

- 0.41 lb N/person/year

Unfertilized pervious area

- 1.2 lb N/acre/year

Total nitrate-nitrogen loading to groundwater is estimated by summing the contributions from each land use (Frimpter et al., 1990). The number of onsite systems is estimated using residential land use densities or from parcel data. An occupancy rate must be estimated as well. The total area of lawn is calculated and multiplied by the fertilizer loading rate, the leaching rate, and the percentage of homeowners assumed to apply fertilizer. The total area of cropland is calculated and multiplied by the fertilizer loading and leaching rates. Pet waste is accounted for using population as a surrogate for the number of pets. All of these contributions can be modified depending on changes in fertilizer rates, crop management practices, or the type of onsite systems being used or proposed.

In the study shown in Figure 7-3, the densely developed Jamestown Shores area was identified as being at highest risk, especially shallow wells. Field monitoring (Veeger, 1996) found that wells on lots less than an one acre in size had a higher likelihood of contamination by bacteria and nitrogen.

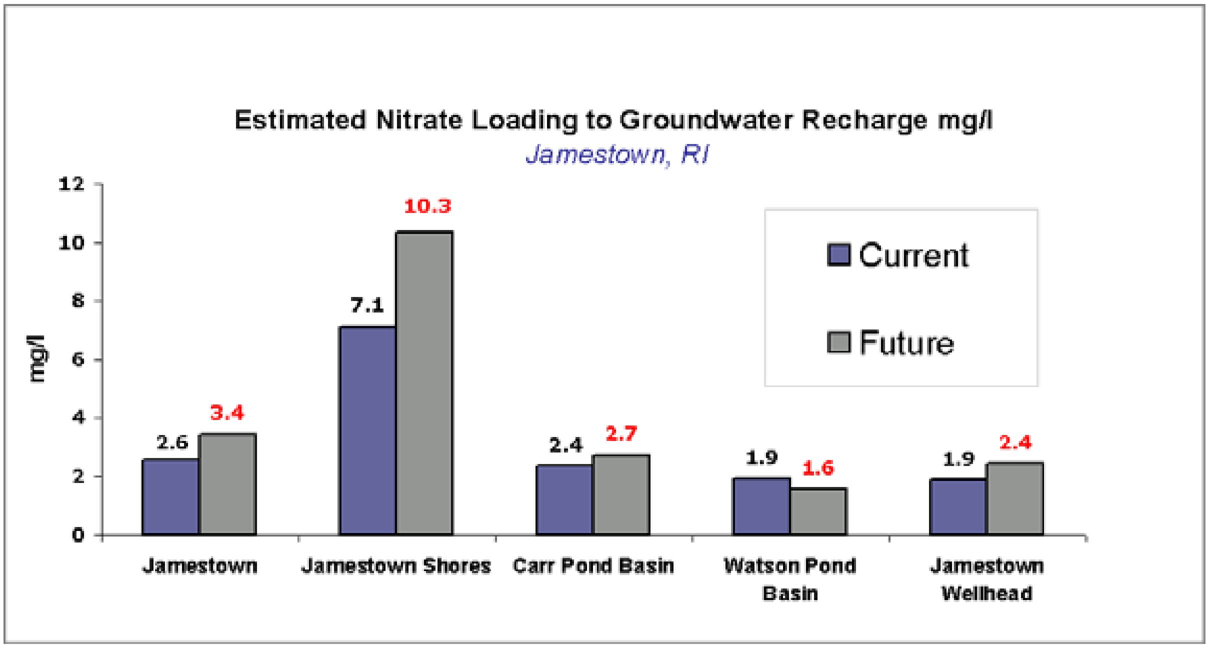


Figure 7-3
Identifying Areas at Risk for Groundwater Contamination and Increased Loading to Nitrogen-Sensitive Coastal Areas

The mean annual concentration of nitrate in recharging groundwater within the study area is estimated by summing all nitrate sources and dividing by the volume of recharge. This approach assumes that recharging water is well-mixed within the study area, which is rarely the case. Monitored data from wells within the study areas are also an important part of the analysis. However, when comparing monitored data with estimates of concentration in recharge taken as an annual average, several issues are important to keep in mind.

Because natural processes vary over time, nitrate concentrations in groundwater vary both seasonally, due to variations in nitrogen cycling, and annually due to variations in precipitation and recharge. These natural variations are reflected in the natural variability of monitored data over time. Long-term monitoring datasets are extremely valuable because they clarify natural variability as compared to actual trends that are the result of changes in land use or management. In addition, monitored data varies spatially. Recharge mixes with shallow groundwater, which may be a mixture of both newer and older groundwater, though there is enormous uncertainty regarding the extent of mixing. The model assumes complete mixing, so the estimates represent an average over time (one year) and space (the study area).

For these reasons, comparing the monitored data with model estimates is most useful for the purpose of comparing study areas. By ranking the study areas according to their estimates and comparing their rankings according to monitored data, differences can be identified and investigated. The source of the difference may be an error in the land use data, soils data, or loading assumptions, or there may be other anomalies within the study area. The purpose of using this comparative approach is to assist decision-makers in identifying priority areas for further study, and in comparing current conditions with the possible effects of future development (Figure 7-3).

Surface Water

Nitrogen and phosphorus are useful surrogates for other pollutants because of their mobility patterns and co-occurrence with other pollutants. Both nitrogen and phosphorus are present in wastewater effluent and fertilizers. Nitrogen is extremely mobile as nitrate (NO_3^-), a dissolved inorganic form of nitrogen, and is a useful indicator of dissolved pollutant transport. Phosphorus tends to sorb to soil particles in its inorganic form of orthophosphate (PO_4^+) and can serve as a surrogate for other pollutants that are transported with sediment.

A mass balance approach is again used to estimate nutrient (nitrogen and phosphorus) loading to surface water (Adamus and Bergman, 1993). Again, upper and lower limits are assigned for nitrogen and phosphorus delivery to surface water from each land use category (Appendix C) in lb/acre/yr or kg/ha/yr. As in the surface runoff calculations, HSG is used to determine the value of the pollutant delivery coefficient:

$$PC = LPC + (HPC - LPC) \times X \quad \textbf{(Eq. 7-6)}$$

$$NC = LNC + (HNC - LNC) \times X \quad \textbf{(Eq. 7-7)}$$

where

PC or NC = Most likely export coefficient for phosphorus (P) or nitrogen (N)
LPC or LNC = Lower limit export coefficient for P or N
HPC or HNC = Upper limit export coefficient for P or N
X = Value associated with each HSG (see Table 7-2)

The nutrient load from each land use is the sum of nutrient loads from each HSG within each land use:

$$P \text{ from } LU_i = A_A \times PC_A + A_B \times PC_B + A_C \times PC_C + A_D \times PC_D \quad \textbf{(Eq. 7-8)}$$

and

$$N \text{ from } LU_i = A_A \times NC_A + A_B \times NC_B + A_C \times NC_C + A_D \times NC_D \quad \textbf{(Eq. 7-9)}$$

where

A_x = Area of LU category *i* falling on A, B, C, or D soils
PC_x or NC_x = Nutrient export coefficient for LU_i falling on A, B, C, or D soils

The total nutrient load to surface water from the study area is then the sum of nutrient loads from each land use category:

$$\text{Total } P = P_1 + P_2 + \ldots + P_y \quad \textbf{(Eq. 7-10)}$$

and

$$\text{Total } N = N_1 + N_2 + \ldots + N_y \quad \textbf{(Eq. 7-11)}$$

where

P_1 or N_1 = P or N load from land use category 1
P_2 or N_2 = P or N load from land use category 2
y = Total number of land use categories

Also included in loading to surface water runoff is an estimation of contributions from malfunctioning onsite systems, the loading rate depending upon proximity to surface water and soil characteristics. If the soil has a restrictive layer within six feet of the soil surface, a higher loading rate from ponded effluent is assumed. Systems that are located within the riparian area are also given a higher loading rate.

The number of onsite systems is estimated from residential land use data, or more accurately from parcel data. Because soil characteristics differ widely with geographic location, local estimates should be made with respect to both their ability to treat wastewater (leaching rate of nitrogen and phosphorus to groundwater) and their potential for failure and transmission of ponded effluent (delivery rate of nitrogen and phosphorus to surface water).

Note on Nutrient Loading Estimates

The nutrient loading estimates do not take into account point sources, which may be important in a study area. In addition, the assessment assumes the use of common management practices. However, inputs may be much higher where lawns are over-fertilized and over-watered or where fertilizers are spilled on impervious surfaces and can wash into storm drains. Commercial and industrial activities vary widely in both the volume and quality of surface runoff generated. For a more accurate estimate, these should be estimated individually to determine average flows, flow variability, and concentration of wastewater inputs.

8 MAPPING HIGH-RISK AREAS FOR POLLUTANT MOVEMENT

A major question for decision makers is where to initiate onsite wastewater improvements. Mapping high-risk areas for pollutant movement, frequently referred to as “hot spot mapping,” is a simple, inexpensive technique that can be used to visually identify areas in the watershed or groundwater protection area that present a high risk of pollutant movement to surface water and groundwater resources. Hot spot mapping utilizes standard GIS functionality to select and isolate variables of interest in the data such as the presence and extent of a certain soil type or land use activity. GIS software is then used to overlay or combine spatial data in ways that enable users to view possible interactions between land use activities and the physical characteristics of the landscape.

When data layers are combined, users can select and map unique combinations of variables to help identify wastewater needs areas, resource protection areas, or to select sites for additional assessment and monitoring. This chapter provides a general overview of landscape features and land use activity commonly associated with water quality impairments, and provides graphical examples on how to conduct specific hot spot analyses.

Map Analyses of Pollution Risks

GIS data layers that are useful for map analyses include:

- Land Use
- Soils
- Unioned Land Use and Soils
- Surface Water
- Aquifers
- Topography (Land Contours and Elevations)
- Parcel Data[1]
- Onsite System Repair Data[1]

A simple example of hot spot mapping for wastewater management purposes would be to overlay watershed land use data with soils data. Then select all unsewered residential development that occurs on problematic soils such as those with a seasonal high water table.

[1] For refined wastewater needs assessment

This information is particularly useful when viewed along with hydrologic data showing the location of ponds, streams, and groundwater aquifers. Isolating the co-occurrence of onsite systems on problematic soil types in close proximity to water resources is a quick and easy way to target priority areas for wastewater management planning or monitoring studies.

For a more refined GIS assessment, use parcel data coded with onsite system repair information to provide more site-specific types of information, such as the name and address of property owners, age and repair information for onsite systems, as well as statistics on failure rates. The user can then overlay this information with data on soil characteristics to uncover possible relationships between the two. For example, onsite systems with high failure rates might be sited more frequently in certain problematic soils. This information can then be used for public education and notification purposes or for wastewater planning studies in the watershed or town.

NOTE: It is important to emphasize that this is a rapid, screening-level analysis. The soils and land use information used are suitable for planning-level analysis only and are less accurate for small areas and locations at boundaries of mapped data layers created at different scales, such as the overlay of soil types and parcel data. In addition, mapped high-runoff areas are often overshadowed by man-made drainage alterations. Follow-up field investigations are needed to verify land use, soil conditions, and the presence of potential pollution sources.

Mapped Risk Factor—Pollution Source Hot Spots

Contrary to popular belief, pollutants from land use activities, also called “nonpoint source pollution,” are not diffusely spread throughout the landscape in random or unpredictable patterns. Onsite systems are not evenly distributed across a watershed or recharge area, but are often clustered in subdivisions and neighborhoods and intermixed with open space or other land uses. In fact, most nonpoint source pollution can be traced to:

- High-intensity land use activities that generate the most pollutants
- Natural features such as soil types and shoreline areas that promote pollutant movement, either to surface waters via stormwater runoff or to groundwater with infiltration

High-intensity land use activities use, store, or generate pollutants that have the potential to contaminate nearby water resources. Both sewered and unsewered areas should be assessed based on evidence that densely developed areas generate high levels of pollutants regardless of the presence of public sewers. Some of the risks associated with high-intensity land use activities include:

- Leaking underground storage tanks
- Pollutants deposited or spilled on pavement and transported in runoff
- Leaking sewer lines or malfunctioning pump stations
  (Pitt et al., 1994)

Ranking the intensity of development (including high densities of onsite wastewater systems) or its potential to pollute water resources also requires consideration of the suitability of the land to accommodate development as well as the proximity of development to surface water. For example, riparian areas can either act as pollution removal zones (with forested shoreline buffers) or pollutant delivery zones (with developed shorelines).

Overlaying high intensity land use data with soils data can 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 contribute the majority of pollutants entering the environment. Directing management actions to the most serious problem sites can be a cost-effective way to prevent or remediate pollution problems.

Wastewater Pollution Hot Spots

For purposes of wastewater management planning, hot spots consist of any area that has a high potential for wastewater contamination of water resources. Wastewater hot spots are typically found in areas that have a higher density of older onsite systems and where systems are sited in problematic soils or riparian areas. When looking at maps, some tips for identifying potential wastewater hot spot areas are as follows:

- Identify areas with onsite wastewater systems.
- Identify higher density residential developments.
- Determine the relative age of onsite systems either through parcel data or by determining the age of subdivisions. Systems installed prior to 1980 are considered at higher risk of failure than are newer systems.
- Determine if nearby water resources are listed as impaired for pathogens or nutrients.
- Determine if the area has seasonal high water table soils or restrictive soil drainage.
- Identify any surface water pooling that occurs.

Soils and Onsite System Suitability

Soils data are useful to predict water flow and pollutant pathways from onsite systems (see Chapter 4, *Assembling and Refining a GIS Database*, Table 4-3).

- In rapidly permeable soils (hydrological group A) effluent often moves too rapidly through the soil to allow proper treatment.
- Restrictive soils are those with slow permeability, generally less than 0.2 inches per hour. These often include soils designated as hydrological groups C or D. Soils with slow permeability or impermeable layers can cause effluent to pond on the ground's surface, which is a public health threat. The ponded effluent can then flow untreated directly into a surface waterbody via overland flow or discharge to a storm drain.
- High water tables exacerbate the effect of excessive and restrictive permeability on onsite system functioning.

Hot Spot Mapping

In order to perform the hot spot mapping techniques presented in this chapter, create a new attribute field in the soils GIS data that combines information on soil drainage (hydrologic group) and depth to water table (for example, C-SHWT 1.5'-3.5'). If a United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) data set is used, the attribute fields for hydrologic group and depth to water table will be located in the same data table, though in separate data fields.

Combining these two attributes in one field enables soil drainage networks and likely pathways of water and pollutant movement to be viewed simultaneously (Figures 8-1 and 8-2). Soil permeability (as indicated by hydrologic soil groups) and water table depth are often useful in identifying hydrologically active areas where runoff and shallow subsurface flow is likely to occur. This concept of partial hydrology, whereby slowly permeable soils with a seasonal high water table form extended drainage networks, has been clearly documented by Dunne and Leopold (1978) and others. Information on slopes can be obtained from topographic maps or soil surveys to determine overland flow direction.

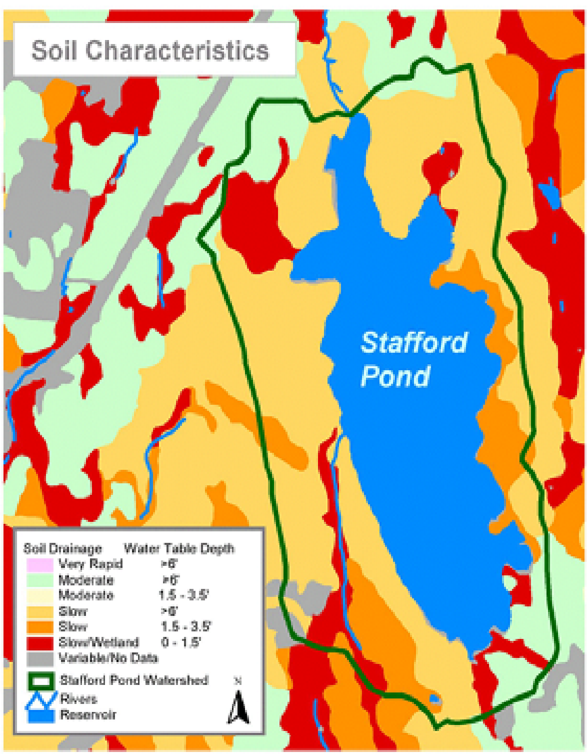


Figure 8-1
Example of a Soils Map With Combined Soil Drainage Class and Depth to Water Table

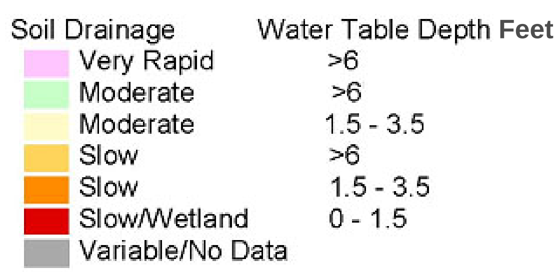


Figure 8-2
Example of a Soils Map Legend with Combined Soil Drainage Class and Depth to Water Table

If the GIS soils data used for the assessment does not include both attribute fields, it may be possible to manually enter the missing data from a hard copy version of the County Soil Survey. If planning-scale soils GIS data is unavailable, a simplified soils map can be created for the study area. To generate a simplified soils map, create a new polygon coverage using a base map. Then, “heads up” digitize information directly from the County Soil Survey.

An alternative to GIS soils data is a digital USGS surficial geology map, which can provide indications of soil drainage patterns. For example, sand and gravel deposits often correspond to rapid drainage associated with hydrologic groups A and B soils, till and bedrock corresponds mostly to moderate or slow drainage associated with hydrologic group C soils, and alluvium to the slow drainage of hydrologic group D soils. In addition, a GIS wetlands coverage can be used to identify hydrologic group D soils (see Chapter 4, *Assembling and Refining a GIS Database*, Wetland Data section). A sophisticated map reader can use a USGS topographic map graphic (digital raster graphic or DRG) to obtain excellent insights into the location of swales and natural drainage networks that can be overlaid with other GIS data by creating a new coverage and then heads up digitizing the information.

Hot Spot Mapping—Step 1

Using GIS software, "clip" SSURGO soils data and land use and land cover data using the watershed or groundwater protection area boundary (Figure 8-3). An additional option is to create a riparian "buffer" coverage to clip the land use and land cover and soils data in order to collect information about land use and soils within a specified distance from surface water.

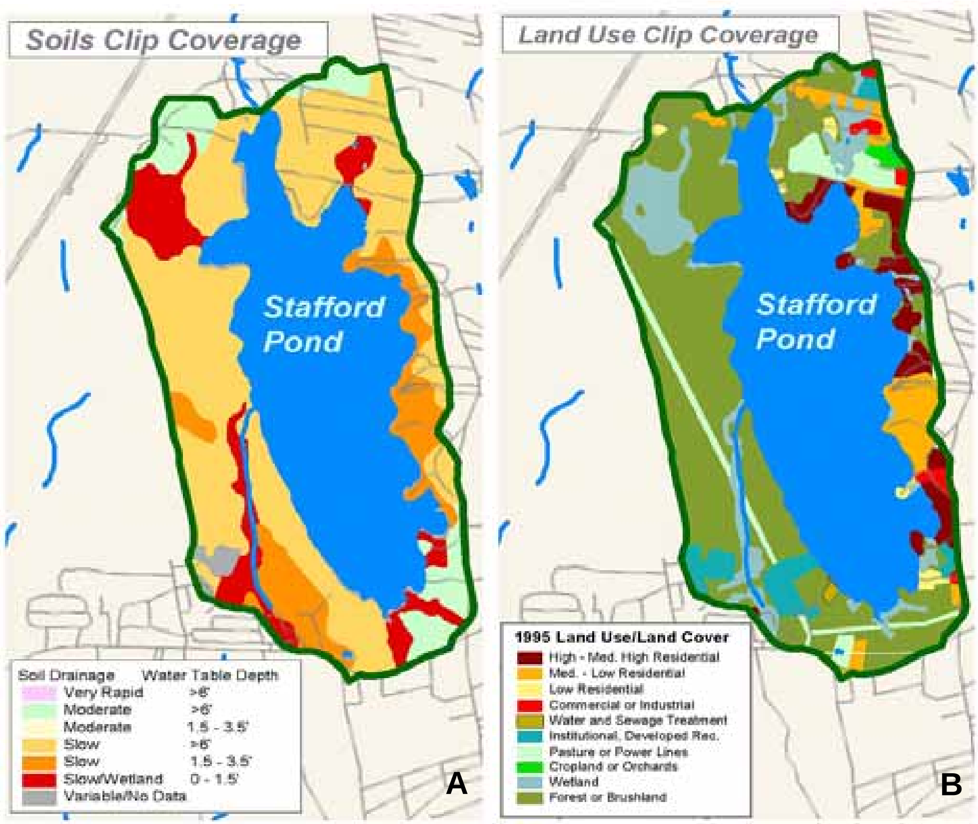


Figure 8-3
(A) Soils and (B) Land Use Coverages Clipped with the Study Area Boundary

Modify the GIS attribute data associated with the clipped coverages. For example, create a new field in the soils clipped coverage for soil drainage characteristics, or lump or refine land use categories in the land use coverage.

Hot Spot Mapping—Step 2

Using GIS software, create a new coverage with the combined attributes of both land use and soils data. With this new coverage, identify areas of concern by querying the dataset for the co-occurrence of selected land uses and soil characteristics. For a preliminary hot spot analysis, select all high-intensity land uses (Appendix D) occurring on high water table soils (see Figure 8-4 (A), Surface Water Hot Spots) or on excessively permeable soils (groundwater hot spots). Further refine this kind of analysis by considering land use and soils within a specified distance from surface water (see Figure 8-4 (B), Riparian Hot Spots).

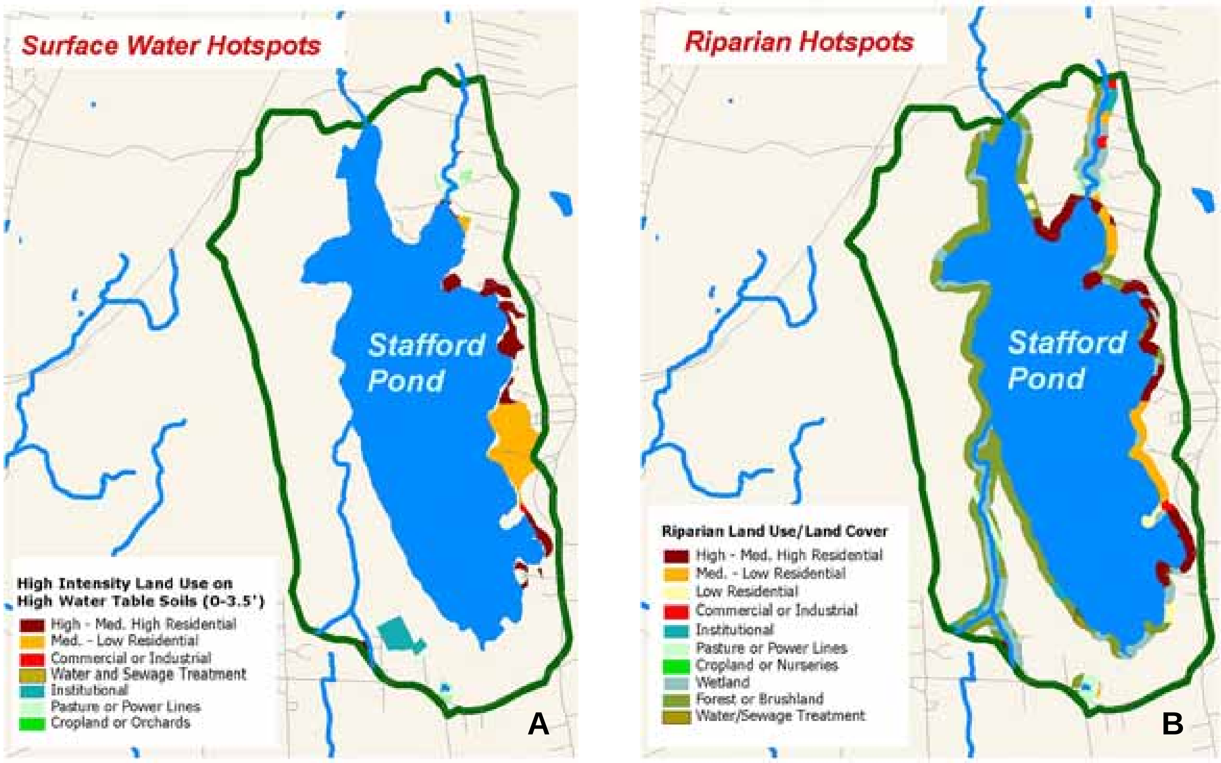


Figure 8-4
Examples of Hot Spot Mapping for Pollution Movement to Surface Waters Using High-Intensity Land Use and Soils with a High Water Table that Are Likely to Generate Surface Runoff

The hot spot analysis shown in Figure 8-4 targets high-risk areas for stormwater runoff, onsite system failure, and nutrient movement from active agriculture. Map A shows that higher density residential development sited on high water table soils is a primary concern. This pond is a drinking water reservoir that has been placed on Rhode Island’s 303(d) List of Impaired Waterbodies for dissolved oxygen and total phosphorous. Map B shows riparian zone analysis that highlights additional land use activities of concern within 200 feet of the reservoir or one of its tributaries.

Example—Hot Spot Mapping for a Coastal Pond

In a coastal pond community, protecting private wells from wastewater contamination is a significant concern. High nitrogen levels in the coastal pond threaten the estuary ecosystem—an important spawning habitat. Due to the sandy soils common in this area, the coastal pond is susceptible to contaminant transport to groundwater, which then flows into the pond. Therefore, highly permeable soils are considered high risk in this setting Figure 8-5, Map A).

In the coastal community example shown in Figure 8-5, many onsite systems were initially designed for one or two bedroom summer cottages. As the community continues to grow, summer cottages are being converted to year-round use without any corresponding improvements to onsite systems (Figure 8-5, Map B).

By overlaying soils and land use coverages, hot spots for pollutant movement to groundwater and the coastal pond are identified (Figure 8-5, Map C). Non-conforming lots of record are an additional problem in this community. In many instances, a lot is too small for the construction of a conventional onsite system, and/or it has multiple site constraints such as proximity to a critical resource, high water table, and soils that percolate either too slowly or too rapidly. Note that many of the small residential lots are situated on excessively permeable soils. However, owners of these lots hold a “grandfathered” right to construct a dwelling unit and onsite system.

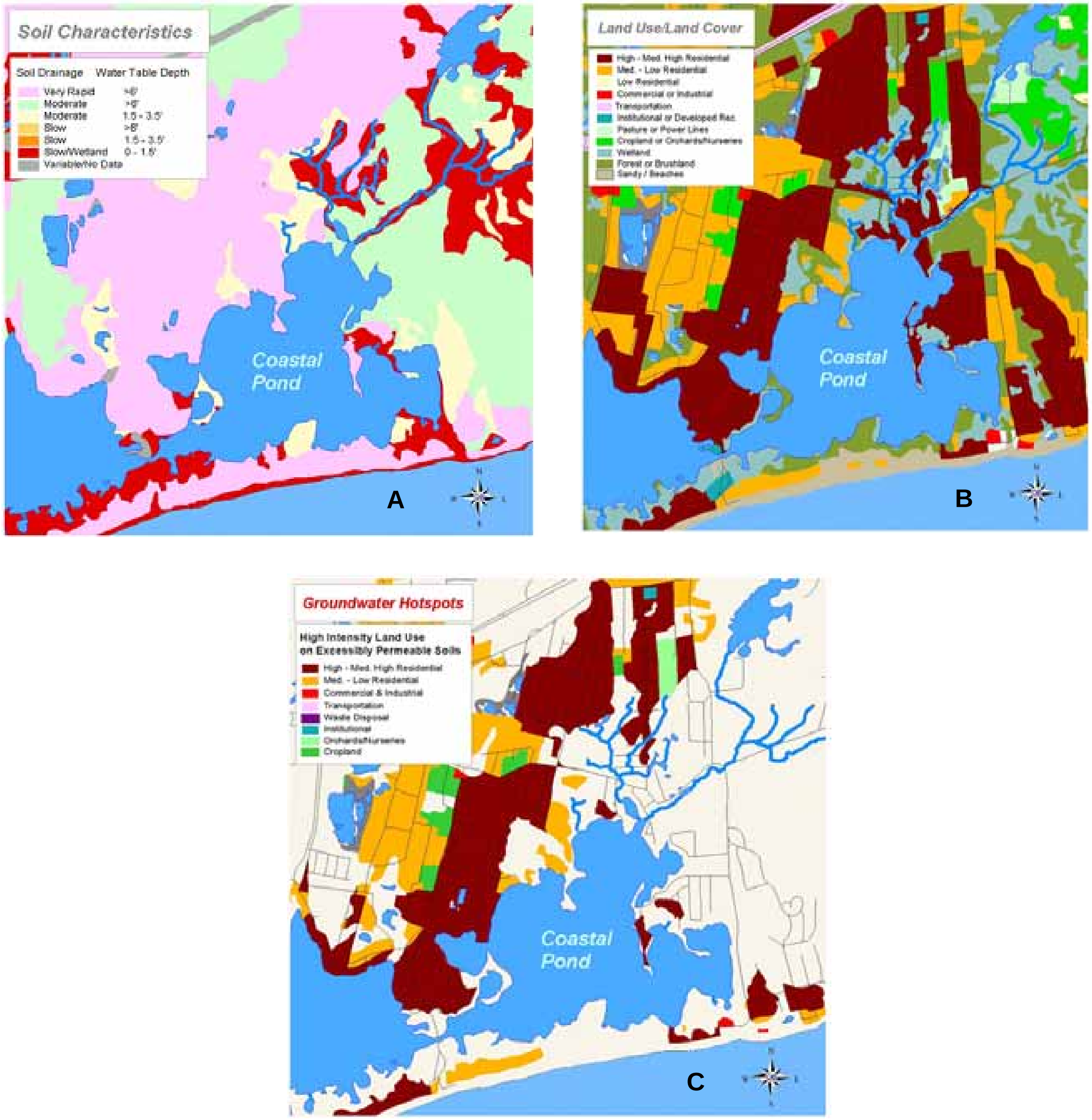


Figure 8-5
Hot Spot Mapping for a Coastal Pond Community

Specialized Mapping to Evaluate Onsite System Suitability

The following data can be used when evaluating the current conditions of onsite systems as well as the suitability of sites for future onsite system installation. If these data are available, mapping them together can help identify problem areas and can help guide future decision-making.

- Hydrologic soil group and water table depth
- Slope
- Proximity to surface waters
- Location of groundwater supplies
- Parcel size
- Number of onsite systems per acre
- Number of large flow/high strength systems
- Age of housing
- Repair records
- Variance records
- Water use records
- Pump-out frequency

Parcel-Based Onsite System Hot Spot Mapping

Overlaying parcel data with soils data enables users to target potential wastewater hot spots at the site level. Figure 8-6 shows an example where parcel data was overlaid with soils data to assess overall soil patterns in the neighborhood and to identify older onsite systems located in soils with a seasonal high water table (SHWT) within six feet of the soil surface. Map A shows parcel data and soils data. Map B identifies only those parcels developed prior to 1970. Map C identifies only those parcels that are currently undeveloped and that could be developed in the future In addition, a tabular analysis can be done to help prioritize areas of concern (see Table 8-1). Tabular analysis is most effective when used in conjunction with maps (such as those shown in Figure 8-6) as visual aids.

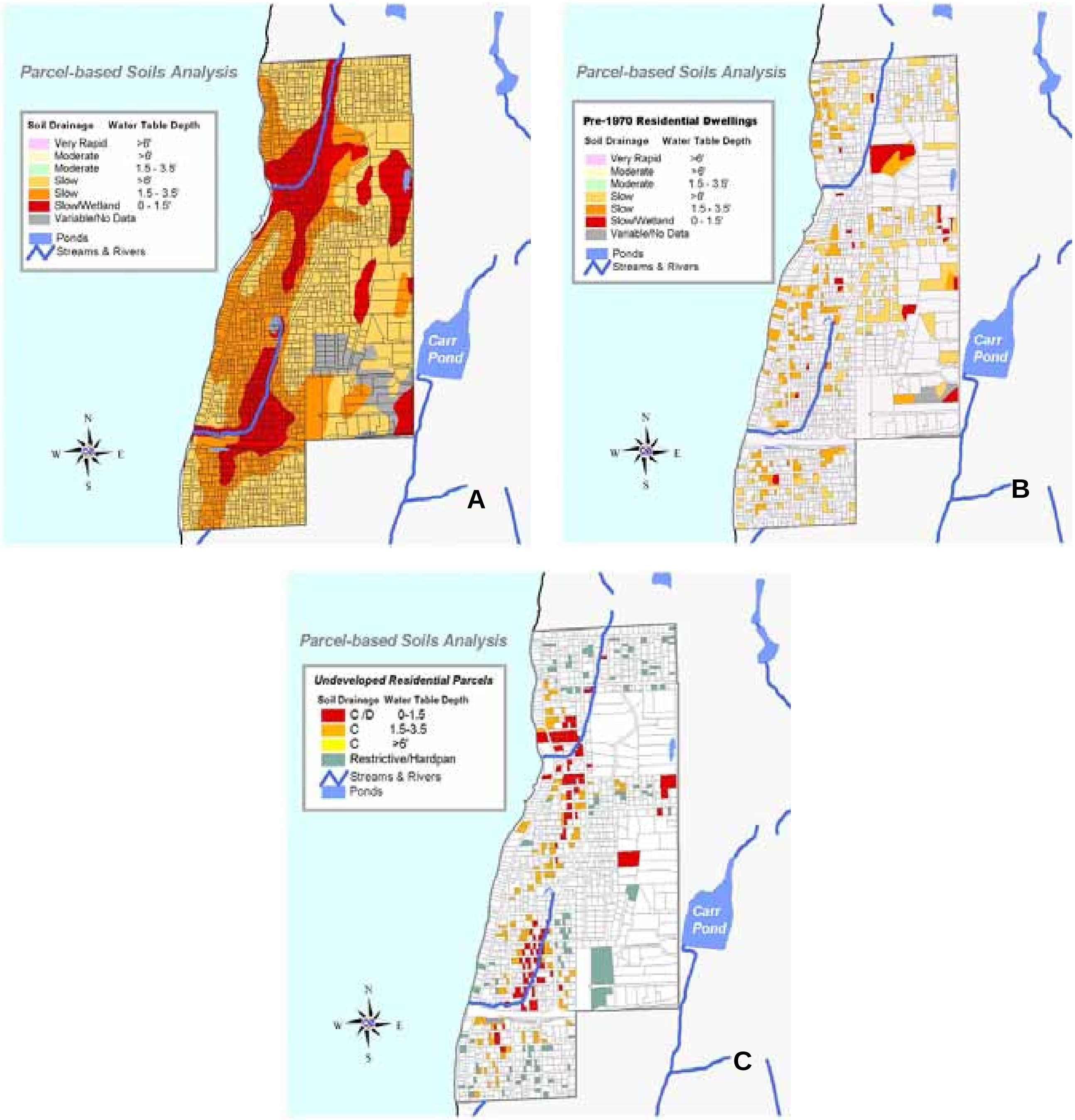


Figure 8-6
Example of Parcel-Based Analysis to Evaluate the Existing Conditions of Onsite Systems and the Suitability of Parcels Not Yet Developed for Onsite System Installation

Table 8-1
Example of a Parcel-Based Tabular Analysis Used to Evaluate Potential Wastewater Pollution Hot Spots and to Support Wastewater Management Planning Efforts

Parcel Size (sq. ft.)	Residential Parcels Built Before 1970
< 5000	3
5000 to 9999	104
10,000 to 19,999	112
20,000 to 39,999	64
> 1 Acre	11
Total Number of Onsite Systems	294
Onsite System Repairs	31
Sited within 200 ft of wetland or surface water	25
Sited on soils with SHWT within 6 ft of soil surface	117

Using Hot Spot Mapping in Local Decision Making

The quality of groundwater and surface water is directly related to the type of land uses occurring within a groundwater recharge area or watershed. Land use activities not only generate pollutants, but also bring about fundamental changes in landscape hydrology that reduce infiltration and increase stormwater runoff (Wickham et al., 2002). Map analysis of land use activities and landscape features helps target the site-specific location of pollution sources and other landscape variables that can increase or minimize pollution risk, such as the presence of riparian shoreline treatment zones.

Hot spot mapping can provide local decision-makers with a more comprehensive and informed view of the carrying capacity of lands as well as the potential cumulative impacts of land use decisions on local water resources. Hot spot mapping of potential pollution sources can also change the nature of discourse about non-point source pollution from abstract concepts to concrete issues where local landmarks and properties are recognizable, and where underlying causes and solutions can be discussed. The hot spot mapping approach can also provide a basis for

- Targeting areas for additional field studies or monitoring
- Selecting management strategies
- Evaluating site suitability for future growth

Examples of hot spot mapping for evaluating onsite wastewater treatment needs are provided in Chapter 10, *Identifying Management Options*.

9 AN OVERVIEW OF THE WASTEWATER NEEDS ASSESSMENT PROCESS

This chapter introduces a number of simple methods for synthesizing assessment results. An assessment can generate a great deal of descriptive information about a study area, so there is a need to interpret and distill results in an effective manner. The methods described in this chapter focus on ranking and displaying results using simple charts and graphs as well as GIS mapping, with the goal of identifying and displaying key findings to support management decisions and public education activities. Because an understanding of the rating system used is fundamental to interpreting results, the approach used to rank indicator results is described first.

Using Multiple Indicators to Evaluate Pollution Risk

The pollution risk assessment methods described in this handbook use selected characteristics of a watershed or groundwater recharge area to evaluate the degree to which water resources in each study area are susceptible to pollution. Although many watershed assessment methods rely heavily on one or two indicators—most commonly percent impervious cover and nutrient loading—the MANAGE approach incorporates a number of watershed characteristics focusing on both land use and natural features. Additional factors used in this approach, such as disturbed or undisturbed riparian areas and percent of wetland cover are widely used measures of potential water quality impacts at the watershed scale. These factors have long been used in evaluating water quality functions of both individual wetlands and collective wetland resources within a drainage area (Center for Watershed Protection, 2002; Ammann and Stone, 1991).

As with any watershed assessment method, the effort required to calculate additional indicators must be weighed against the value of the information generated. Where high quality GIS databases for soils and land use are available, indictor analysis can be conducted for a wide range of variables, only some of which have been presented in this handbook.

Clearly one of the primary advantages of using a variety of watershed indicators is that the range of data generated can shed light on the type of pollutant or stress most likely to influence water quality. This information is especially useful where the link between a watershed characteristic and associated water quality conditions is weak. For example, more recent research on the effect of watershed imperviousness suggests that in relatively undeveloped watersheds with average impervious cover levels less than 10 percent, other factors such as forest cover, contiguous shoreline buffers, soils, agriculture, historical land use, and a “host of other stressors” can greatly influence water quality in sensitive areas. Consequently, watershed managers should evaluate a range of watershed variables to predict actual stream quality (Center for Watershed Protection, 1998). Because drinking water supply watersheds often fall under the 10 percent impervious level, multiple indicators are especially valuable in evaluating these sensitive watersheds.

Using a range of indicators avoids over-reliance on one or two factors, especially where input values and results may be uncertain. Minor map errors and inaccuracies are common to all map databases, but in general, the simplest watershed indicators obtained directly from high-quality maps—such as percent high-intensity land use and percent forest cover—are the most reliable. Some indicators, such as percent impervious cover, the estimated number of onsite wastewater systems within a study area, and all future projections, are created by overlaying map coverages in combination with population and housing data, and use of simplifying assumptions. Any of these operations can amplify map errors and introduce uncertainty associated with input values and assumptions. These uncertainties are inherent in any type of modeling, and as long as assumptions remain consistent among study areas, the comparative value of the results is unaffected. Using a range of indicators, including reliable land use factors, can help reduce reliance on any one factor while providing a range of supporting data.

When a variety of watershed features are available, key indicators can be selected to focus on pollutants of concern to particular receiving waters. For example, primary factors for evaluating impacts to groundwater aquifers include nitrogen loading to groundwater (where nitrogen is both a drinking water contaminant and an indicator of other dissolved pollutants) and percent high-intensity land use. In contrast, key indicators for fresh surface waterbodies include impervious cover, percent forest and wetland cover, estimated phosphorus inputs, and land use activities within riparian areas.

Examination f the watershed indicators shows that many of the factors measure similar features. For example, high-intensity land use, impervious cover, runoff and nutrient loading all tend to increase as development increases. Results are best used to compare general trends and to focus on a few primary pollutants or stressors of concern for particular receiving waters, rather than to try to add up the total risks from a large number of different factors. Where indicators appear to be similar, basic differences can factor into interpreting results and selecting management practices. For example, high-intensity land use encompasses both urban land and tilled agriculture, while impervious cover measures only urban roads, rooftops, and parking lots. As a result, riparian areas having both high-intensity land use and high-impervious cover are likely to be more urbanized and difficult to restore. Those with high-intensity land use and low-impervious cover are likely to be in agricultural use or in backyards of moderate to large house lots, where reclaiming natural buffers may be more feasible. For sensitive cold-water trout streams, any areas where naturally vegetated shoreline buffers have been lost would provide useful information on the possible extent of impacts and potential sites for restoration.

Interpreting Results

Assessment results are best used to compare relative differences in risk among study areas or between different land use scenarios. When comparing results for a number of subwatersheds or recharge areas, it is useful but not always possible to select study areas representing a range of land use conditions. Undeveloped study areas with unfragmented forest and naturally vegetated riparian areas are particularly valuable as reference sites, which represent natural background conditions. Even lightly developed study areas with good water quality, though not pristine, provide a useful benchmark of 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 any 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.

Watershed indicators are useful in evaluating the sensitivity of a watershed or aquifer recharge area to changing land use conditions and to different pollution control practices. Typical analyses include the following:

- Comparing differences between current and future land use, where a future “build-out” map is used to calculate indicators representing future land use
- Evaluating the range of results possible using low-and high-input values for factors that are difficult to estimate precisely, such as impervious cover or nutrient loading
- Comparing the relative change in risk among alternative management scenarios. Alternative land development options and pollution control practices can be modeled for the entire study area, for particular land use types, or for any combination of land use by soil type or location in riparian areas. Typical pollution control strategies that can be modeled include:
  - Reduced fertilizer application
  - Use of nitrogen-reducing onsite wastewater systems
  - Use of stormwater treatment systems designed to remove nitrogen or phosphorus

Setting Risk Thresholds

Chapter 6, *Watershed Indicators: Linking Land use to Water Quality* introduced different approaches for developing risk indicators. The threshold levels used in this handbook are set based on the following factors:

- Ranking based on literature values
- Relative comparison of results using a selected range of study areas
- Percentile ranking of assessment results

In setting pollution risk levels for the various watershed and aquifer recharge area indicators, risk thresholds are generally set low as an early warning for 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 rating is based on the assumption that *any* high-risk land use within this critical buffer zone is a potential threat and should be investigated. This approach is designed to provide early warning of potential threats to high-quality waters, including drinking water supplies that may be untreated, coastal waters that are sensitive to low-level increases in nitrogen, and unique natural habitats that may also be sensitive to minute increases in sediment, temperature, or phosphorus. Identifying risks in the early stages also provides time 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 waterbody is much more costly and technically challenging than pollution prevention.

Indicators have also been selected to focus on situations of highest pollution risk and may not detect circumstances where a variety of factors combine to magnify pollution potential. For example, medium-density residential development (1 to 3.9 dwellings per acre) is not considered as a high-intensity land use. But development at this density could easily affect water quality depending on site-specific features such as soil suitability, proximity to surface waters, level of onsite wastewater system maintenance, and landscape care practices. Likewise, a high level of protection to wetlands is assumed, which may underestimate risks where wetlands are disturbed through State permit approvals, by zoning variance, or unpermitted encroachment. For example, only buffers to surface waters and tributaries are evaluated when considering shoreline pollution risks.

Wetland buffers are not considered because wetlands themselves provide an extra measure of protection, potentially capturing or transforming pollutants before they reach downstream surface waters. Wetland buffers are often less suitable for development due to high water tables, and usually do not attract waterfront development pressure. Given these conservative assumptions, any development in wetland buffer zones would obviously result in greater pollution risk.

When interpreting indicator results, only major differences are emphasized. Recognizing major differences is important where a rating system is used, since rating and ranking systems can easily mask or oversimplify results. For instance, when indicator risk levels are near the edge of some risk categories, a change in only a few points can shift the rating to the next risk level, while greater increases may occur without rating shifts in other categories.

Statistical tests are not used to evaluate differences between alternative management strategies, partly because doing so may suggest results are actual data points rather than estimates of potential risk. Instead, professional judgment should be used in interpreting results along with community discussion on what is considered an acceptable level of risk when making management decisions. Fundamentally, the strength of GIS methods is the capacity to manage and display spatial data graphically. If the input data are incomplete, inaccurate, or of poor resolution, the results are more susceptible to challenge by the public and/or the regulatory community. High accuracy, fine resolution data offer communities the potential for more advanced decision-making rather than simply providing screening level risk assessments.

Data Analysis and Presentation Examples

This section provides examples of data analysis and presentation that are based on a coastal pond watersheds study. The study areas used in this example are located primarily in two coastal Rhode Island communities, including seven coastal pond watersheds and four inland watersheds that drain to an important estuary (Figure 9-1). The Queens River subwatershed presented in this example is the least developed and serves as a reference watershed representing natural conditions. Using data derived from spreadsheet calculations, it is possible to categorize each study area in the assessment according to its risk level for each indicator.

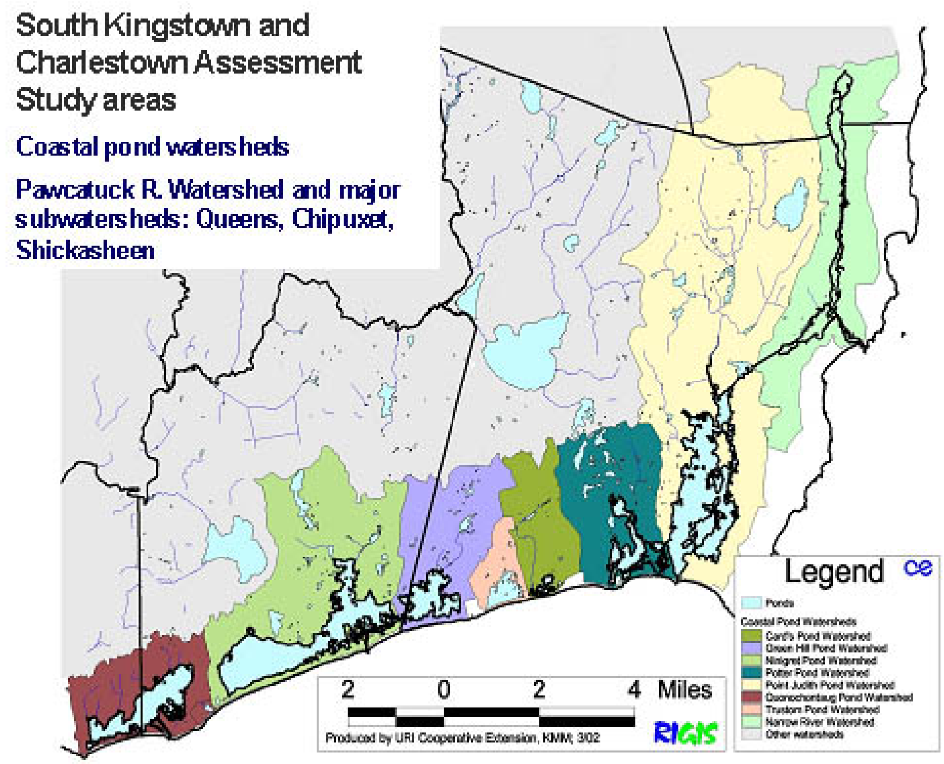


Figure 9-1
Study Area Watersheds for Seven Nitrogen-Sensitive Coastal Ponds and a Large Estuary

Typically, the study areas are subwatersheds within a larger watershed or wellhead protection areas within a larger aquifer recharge area or town. Figure 9-2 shows assessment results for the 12 study areas using four water quality risk indicators, including percent high-intensity land use (Graph A), percent impervious cover (Graph B), percent disturbed riparian land (shoreline area within 200 feet of surface waters without forest or wetland) (Graph C), and estimated nitrate concentration (mg/l) in groundwater recharge (Graph D).

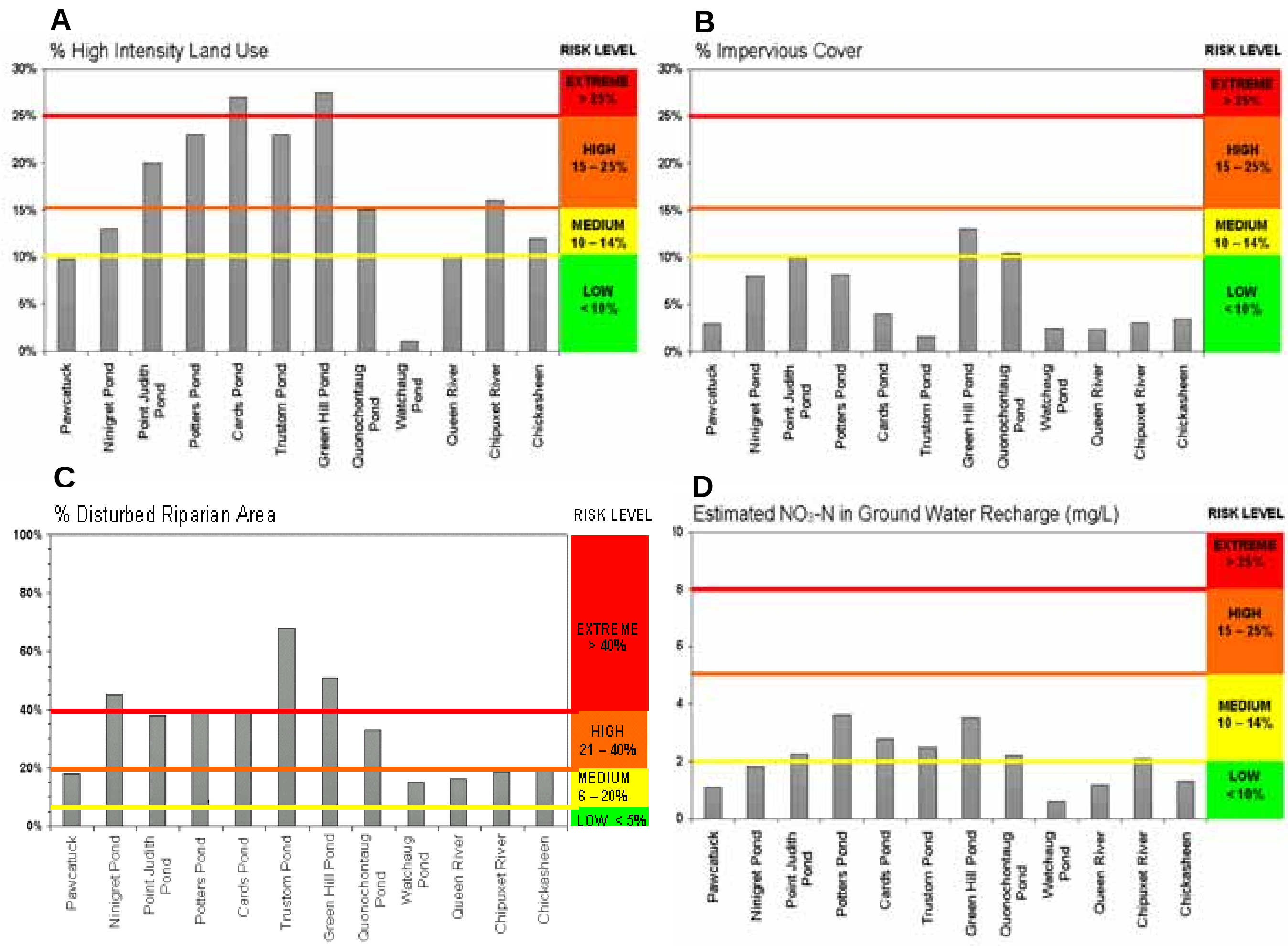


Figure 9-2
Comparison of 12 Coastal Watersheds Using Watershed Indicators Derived from Spreadsheet Calculations

Presenting assessment data as shown in Figure 9-2 enables study areas to be characterized and compared based on threats specific to each area. The graphs show that the Green Hill Pond watershed consistently scores in the highest risk levels for each of the four indicators. Some watersheds, such as Cards Pond and Trustom Pond rank relatively high in high-intensity land use but have low levels of impervious cover, which indicates that the type of high-intensity land use is primarily tilled agriculture. Impervious cover is below 10 percent in most areas, which indicates that the potential to maintain or restore water quality is high. Although estimated nitrate levels are ranked in the moderate category for most of the coastal ponds, these areas are known to be highly sensitive to nitrogen inputs where even slight increases above natural background levels can promote nutrient enrichment.

Because risk levels are scaled differently for each indicator, it can be difficult to present assessment results in terms of cumulative risk. Table 9-1 provides an example of how to effectively organize and present the indicator analyses results.

Table 9-1
Summary of Indicators with Ranked Scores for 12 Study Areas

Watershed	% High-Intensity Land Use	% Impervious Cover	Onsite Systems /Acre	% Disturbed Riparian Area	% High-Intensity Land Use on Highly Permeable Soils	Phosphorus to Surface Water lbs/ac/yr	Nitrate to Groundwater Recharge lbs/ac/yr	Average Rank
Point Judith	2	1	2	2	0	2	1	**1.4**
Potters Pond	2	0	3	2	1	2	2	**1.7**
Cards Pond	3	0	1	2	0	2	2	**1.4**
Trustom Pond	2	0	1	3	0	1	2	**1.2**
Green Hill Pond	3	1	3	3	1	2	2	**2.1**
Ninigret Pond	1	0	2	3	0	1	1	**1.1**
Quonochontaug	2	1	3	2	0	1	1	**1.4**
Pawcatuck (RI)	0	0	1	1	0	0	0	**0.4**
Queen River	1	0	0	1	0	0	1	**0.5**
Chipuxet River	2	0	1	1	0	1	2	**0.9**
Chickasheen R.	1	0	0	2	0	0	0	**0.5**
Watchaug Pond	0	0	0	1	0	0	0	**0.2**
	Low	Moderate	High	Extreme		Low	Moderate	High
Score	0	1	2	3	**Final rank**	<1	1–1.9	2–2.9

Results for each watershed study area in Table 9-1 show that some study areas have multiple indicators in the moderate, high, or extreme categories.

Summary of Indicator Analyses Results

The following information summarizes the data presented in Table 9-1.

- All the Pawcatuck River watershed sites (bottom five study areas) are in the low-risk category overall.
- Green Hill pond has the highest overall ranking—not surprising since the pond has impaired water quality and has been closed to shellfishing.
- All other coastal ponds rank in the moderate risk range, but there are interesting differences. High-intensity land use in the Cards Pond and Trustom Pond watersheds are obviously due to the presence of agricultural land use activity, given low impervious cover levels in these areas.
- Green Hill Pond, Potter Pond, and Quonochontaug Pond are likely to be at highest risk of impact from septic effluent given that these watersheds have moderate to high nitrate loading ranks **and** a high proportion of onsite systems per acre.
- Potter Pond and Green Hill Pond watersheds are at further risk due to a relatively high proportion of high-intensity land use on highly permeable soils, indicating potential for rapid movement of septic effluent to groundwater.

This example analysis focuses on pollution risks from all sources. The next step would be to focus on areas where estimated pollution sources are high and also where onsite wastewater treatment systems represent a major source of risk. These areas can be identified based on the

- Number of septic systems per acre
- Proportion of nutrient inputs generated by onsite treatment systems
- Map analysis considering site-specific suitability for wastewater treatment

Using Maps to Evaluate and Rank Pollution Risks

There are a number of simple methods to present results from indicator analyses using maps. For example, a weight value can be assigned to each risk level in order to show all the indicator results on one graph or map. In the example study, weight values were assigned according to risk level as follows:

- Low risk = 0
- Medium risk = 1
- High risk = 2
- Extreme risk = 3

Taking this approach, the Green Hill Pond watershed, for example, ranks 3 for high-intensity land use, 1 for impervious surface area, 3 for riparian forest/wetlands cover, and 1 for estimated nitrate in groundwater recharge for a total rank of 8. These weight values can be entered directly into an ArcView attribute table (Figure 9-3) or into an Excel spreadsheet and imported into ArcView. A field must be added (in ArcView or Excel) in which the total ranking is calculated as the sum of weight values for each study area.

Attributes of Chsk_threatrank.shp

Shape	Basin_name	HILLival	ImpSurfval	RipBufval	NO3val	Threatrank
Polygon	Cards	3	0	2	1	6
Polygon	Chickasheen	1	0	1	0	2
Polygon	Chipuxet	2	0	1	1	4
Polygon	Green Hill	3	1	3	1	8
Polygon	Ninigret	1	0	3	0	4
Polygon	Pawcatuck	0	0	1	0	1
Polygon	Potters	2	0	2	1	5
Polygon	Pt. Judith	2	1	2	1	6
Polygon	Queen	1	0	1	0	2
Polygon	Quonnichontaug	2	1	2	1	6
Polygon	Trustom	2	0	3	1	6
Polygon	Watchaug	0	0	1	0	1

Figure 9-3
Attribute Table in ArcView Used to Assess and Map Cumulative Risk of 12 Coastal Wetlands

By coding each watershed based on the “Threatrank” field, a simple map can be created showing the watershed with the highest risk levels in red and those with the lowest risk levels in green (Figure 9-4). This map is an effective visual summary of risk levels for different subwatersheds in a region. However, when summarizing data in this way, additional information should be provided documenting which indicators were used and how risk levels were assigned. A combination of graphs and maps can be used to display this information.

Figure 9-4
Visual Comparison of Cumulative Risk for 12 Coastal Watersheds Using ArcView and Combining Four Watershed Indicators: % high intensity land use, % impervious cover, % riparian forest and wetlands, and estimated nitrate concentration in recharge to groundwater. Cumulative risk ranks of 1–2 = Low (green), 3–4 = Medium (yellow), 5–6 = High (orange), and 7–8 = Extreme (red).

Ranking Sensitivity Levels

Although the spreadsheet calculations outlined in the previous section provide techniques for ranking watersheds based on risk indicators, it is equally important to characterize study areas based on water quality standards and monitoring data, habitat and land conservation goals, and other natural resource protection priorities. Information concerning the sensitivity of particular streams, lakes, or other waterbodies in the study area may be included as part of a state GIS dataset. If not, this data can be acquired from state environmental agencies.

In this example, sensitivity rankings were assessed and mapped for the 12 coastal watersheds (Figure 9-5), based on a number of different data layers including

- State water quality standards
- The state's 303 (d) List of Impaired Waters
- A statewide list of Outstanding Resource Waters

State water quality standards that are based on use categories such as drinking water, swimmable waters, fishable waters, and other water uses were used to assign a level of sensitivity to individual watersheds. For example, watersheds draining to the most sensitive waterbodies (drinking water, fishable waters) were assigned a weight value of 3; those draining to less sensitive waters (swimmable) were weighted as 1. The State of Rhode Island also designates certain waterbodies as Outstanding Resource Waters. Watersheds draining to these areas were assigned an additional weight value of 1. Watersheds draining to waterbodies on the state's 303(d) List of Impaired Waters were assigned an additional weight value of 1. For more information on the 303(d) List of Impaired Waters for each state, visit the EPA website at www.epa.gov/owow/tmdl.

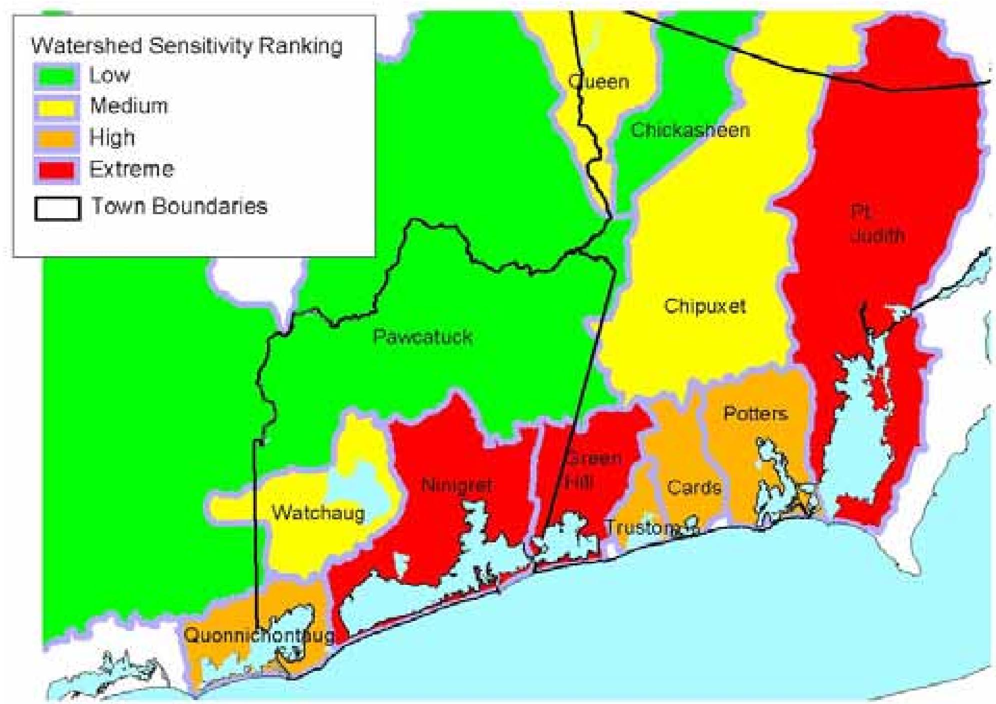


Figure 9-5
Visual Comparison of Cumulative Sensitivity for 12 Coastal Watersheds Using ArcView and Combining Three Indicators: state water quality standards, state 303(d) List of Impaired Waters, and the Rhode Island list of Outstanding Resource Waters. Cumulative sensitivity ranks are coded as 0–1 = Low (green), 2–3 = Medium (yellow), 4 = High (orange), and 5 = Extreme (red).

In Figure 9-5, the Green Hill Pond watershed shows a cumulative sensitivity rank of 5, which was derived from a use status of fishable (rank 3), its listing as an Outstanding Resource Water (rank 1), and its listing as impaired (rank 1).

Combining Risk and Sensitivity

The rankings for cumulative risk and cumulative sensitivity can be combined to display each watershed's total cumulative risk and sensitivity ranking (Figure 9-6). For example, Green Hill Pond watershed has a cumulative risk ranking of 8 and a cumulative sensitivity ranking of 5 for a total cumulative rank of 13. In ArcView, a new field can be added to the attribute table for this combined rank, and ArcView's Field Calculator can be used to sum the Risk and Sensitivity rankings.

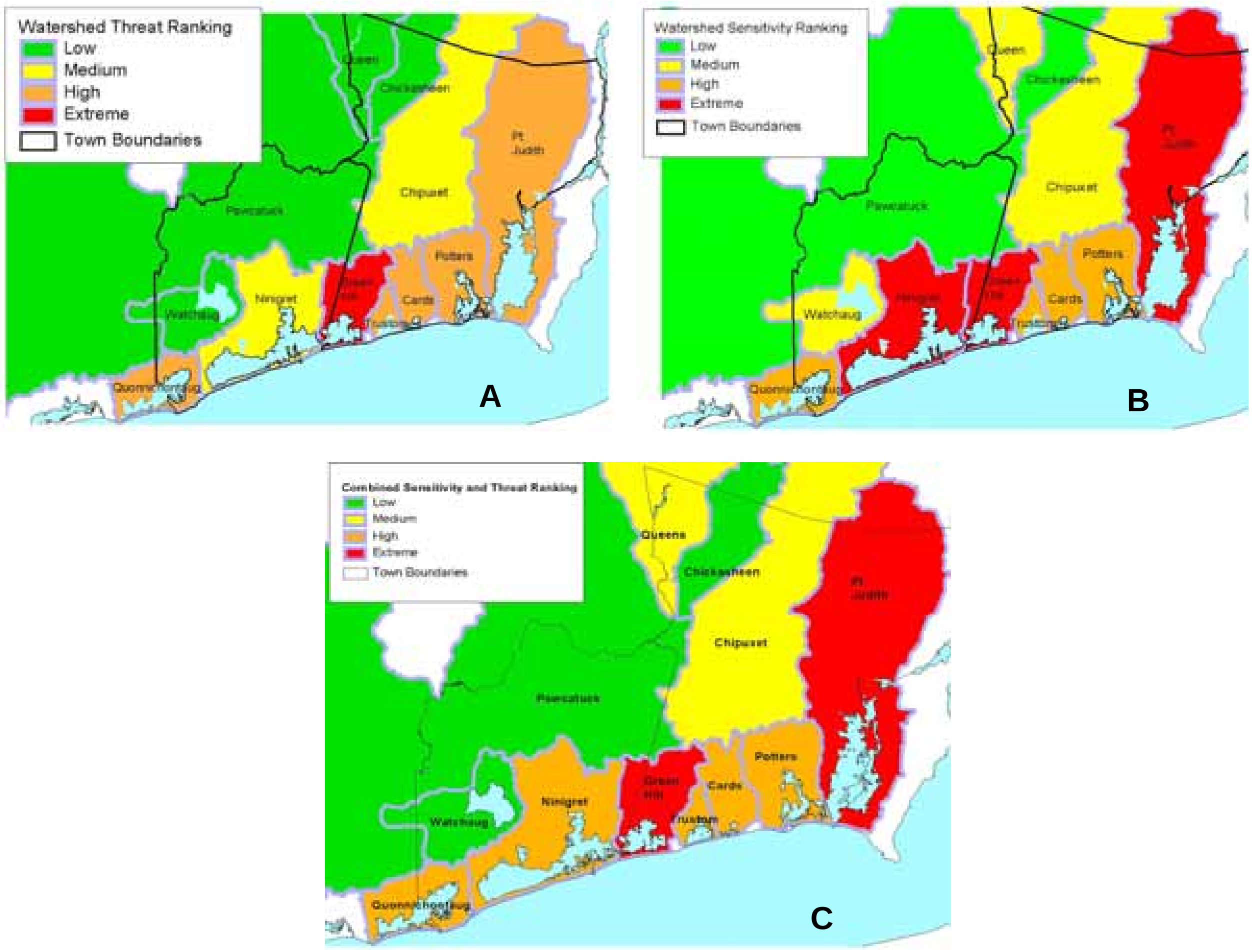


Figure 9-6
Cumulative Risk (Map A) and Cumulative Sensitivity (Map B) Rankings Are Combined to Create a Total Cumulative Ranking for 12 Coastal Watersheds (Map C). Total cumulative ranks are coded 0–3 = Low (green), 4–6 = Medium (yellow), 7–10 = High (orange), and 11–13 = Extreme (red).

While the combined risk and sensitivity map (Figure 9-6, Map C) spatially summarizes the risks and sensitivities for each watershed, it does not specify the reasons why a watershed's combined rank is high or low. For example, Ninigret Pond watershed has a medium rank for risk, but is ranked extreme for sensitivity. Its combined rank was high, but there is nothing in this map to indicate whether this is due to high sensitivity, high threat, or any combination of the two.

One way to convey the nature of the combined rank is by plotting risk versus sensitivity (Figure 9-7). This information should accompany a combined map in order to show why a watershed ranked as it did. Using this method, it is possible to tailor management actions to individual watersheds based on the types of risks or sensitivity levels of waterbodies within the watershed. Furthermore, the degree of risk or sensitivity can be seen in each category. For example, both Green Hill Pond and Pt. Judith Pond watersheds rank in the extreme category in the combined map, yet Figure 9-7 shows that Green Hill Pond is at much greater risk than is Pt. Judith Pond.

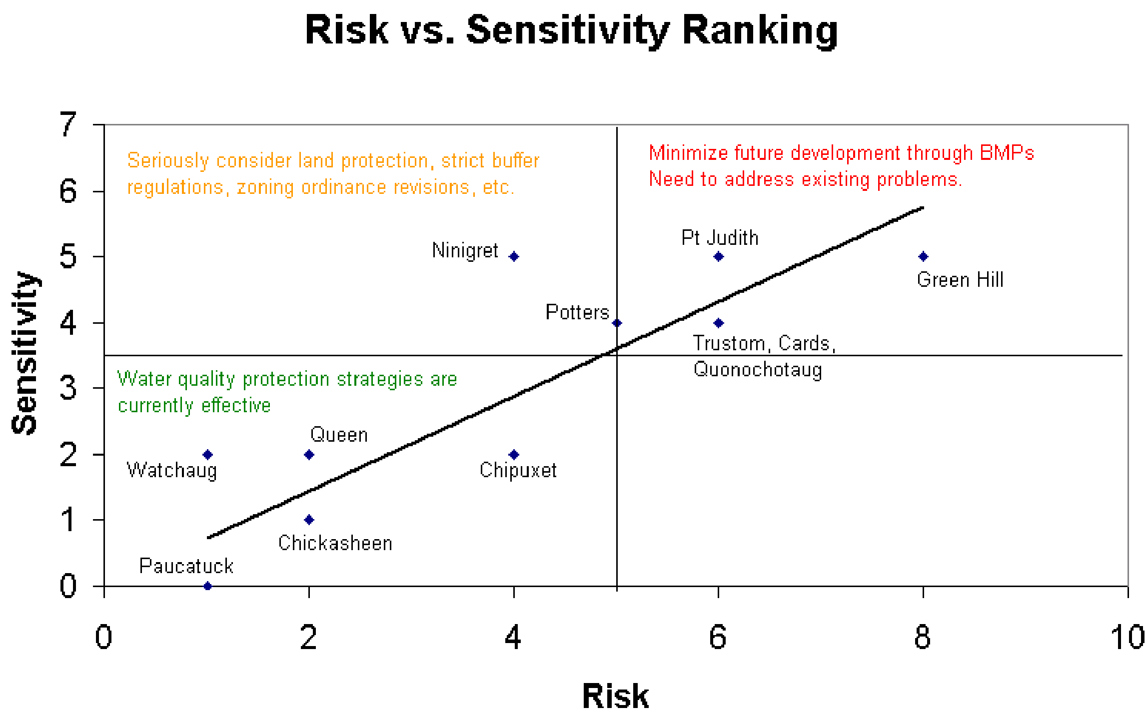


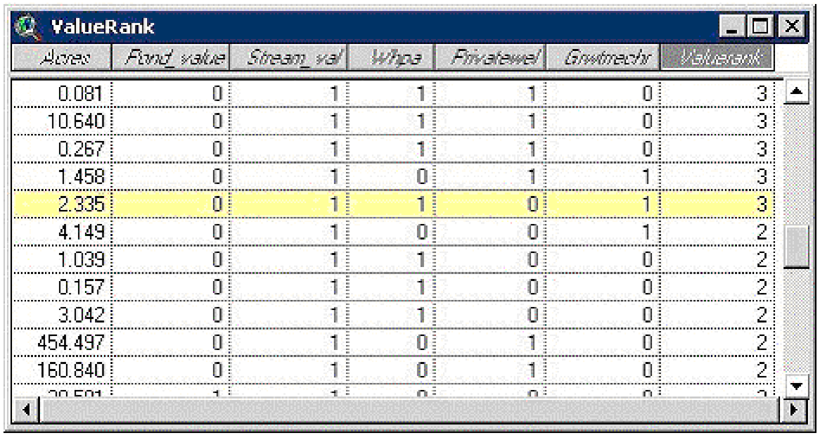
Figure 9-7
Risk Versus Sensitivity Ranking

Including Additional Natural Resource Variables

The maps displayed in this chapter so far show how individual watersheds compare to others in terms of risks and sensitivity. For many areas, however, there is much more data on valuable resources available at the subwatershed level. By ranking and overlaying more data on the combined risk/sensitivity map, it is possible to target specific management actions to certain areas within a study area. Some other data layers that might be available at the state or local level include:

- Wetlands
- Streams
- Wellhead Protection Areas
- Aquifers
- Groundwater Recharge Zones
- Priority Habitat Areas
- Large Roadless Tracts
- Rare Species Habitats

These data may be identified while establishing existing conditions early in the assessment process. If these or any similar data layers are available, each polygon of each data layer can be assigned a weight value of 1. This is done in ArcView by adding a field and using the Field Calculator to assign the value "1" to all records in that field. Layers can then be "unioned," and a new field added to the final overlay in order to sum the values from each layer (Figure 9-8).



ValueRank

Acres	Pond_value	Stream_val	Whpa	Privatewel	Grwtrechr	Valuerank
0.081	0	1	1	1	0	3
10.640	0	1	1	1	0	3
0.267	0	1	1	1	0	3
1.458	0	1	0	1	1	3
2.335	0	1	1	0	1	3
4.149	0	1	0	0	1	2
1.039	0	1	1	0	0	2
0.157	0	1	1	0	0	2
3.042	0	1	1	0	0	2
454.497	0	1	0	1	0	2
160.840	0	1	0	1	0	2

Figure 9-8
Using Other Available Data on Valuable Resources, Such as Wellhead Protection Areas or Rare Species Habitat, a Cumulative Value Rank Can Be Assigned

As an example, the polygon record highlighted in Figure 9-9 has a value rank of 3, from the sum of the stream buffer (1), the wellhead protection area (1), and the groundwater recharge area (1). A new map can now be produced with a coded legend to show the concentration of valuable resources as calculated in this new field. Polygons with the highest concentration of resources can be coded a dark green and colors can be graduated down to the lowest concentration of resources in light green (Figure 9-10). Resources included in the ranking are based on the protection priorities determined during the assessment process and on data availability.

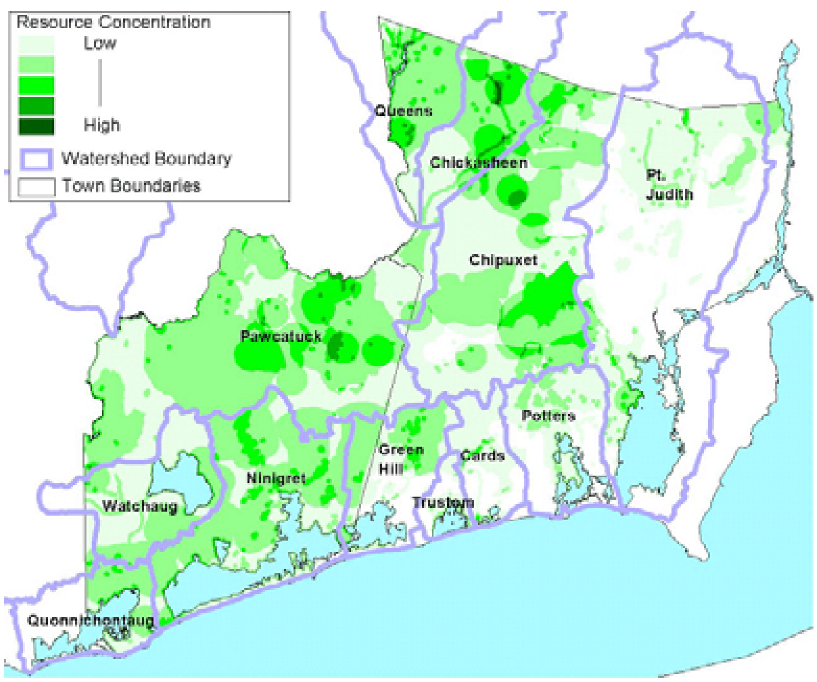


Figure 9-9
Cumulative Valuable Resources Included Ponds, Cold Water Streams (Including a 200-Ft. Wide Riparian Area), Wellhead Protection Areas, Groundwater Recharge Zones, and Private Well Areas

Finally, this map can be unioned with the combined risk/sensitivity map to show distinct areas of each watershed where management actions or restoration activities may be targeted and prioritized (Figure 9-10). A new field is added to the attribute table in which the sum of all prior rankings is calculated. Based on this new field, graduated colors of red can be used to denote the lowest to highest ranking in the final "priority" map.

Like the combined risk/sensitivity map, the final priority map shows the coastal pond watersheds as having the highest rank. The advantage of the final priority map is that it reveals certain areas within several watersheds where protection efforts or better management practices should be put into place. For example, the Pawcatuck Watershed ranked low for both risks and sensitivity, but the final map shows several wellhead protection areas and wetlands in the middle of the watershed that boost the ranking higher in this area. Overall, the coastal ponds, which are more sensitive to bacteria and nitrogen, rank higher in susceptibility to contamination and would justify a higher level of protection. This information may help to direct management decisions in these specific portions of the watershed or simply be used as tools for educating the public.

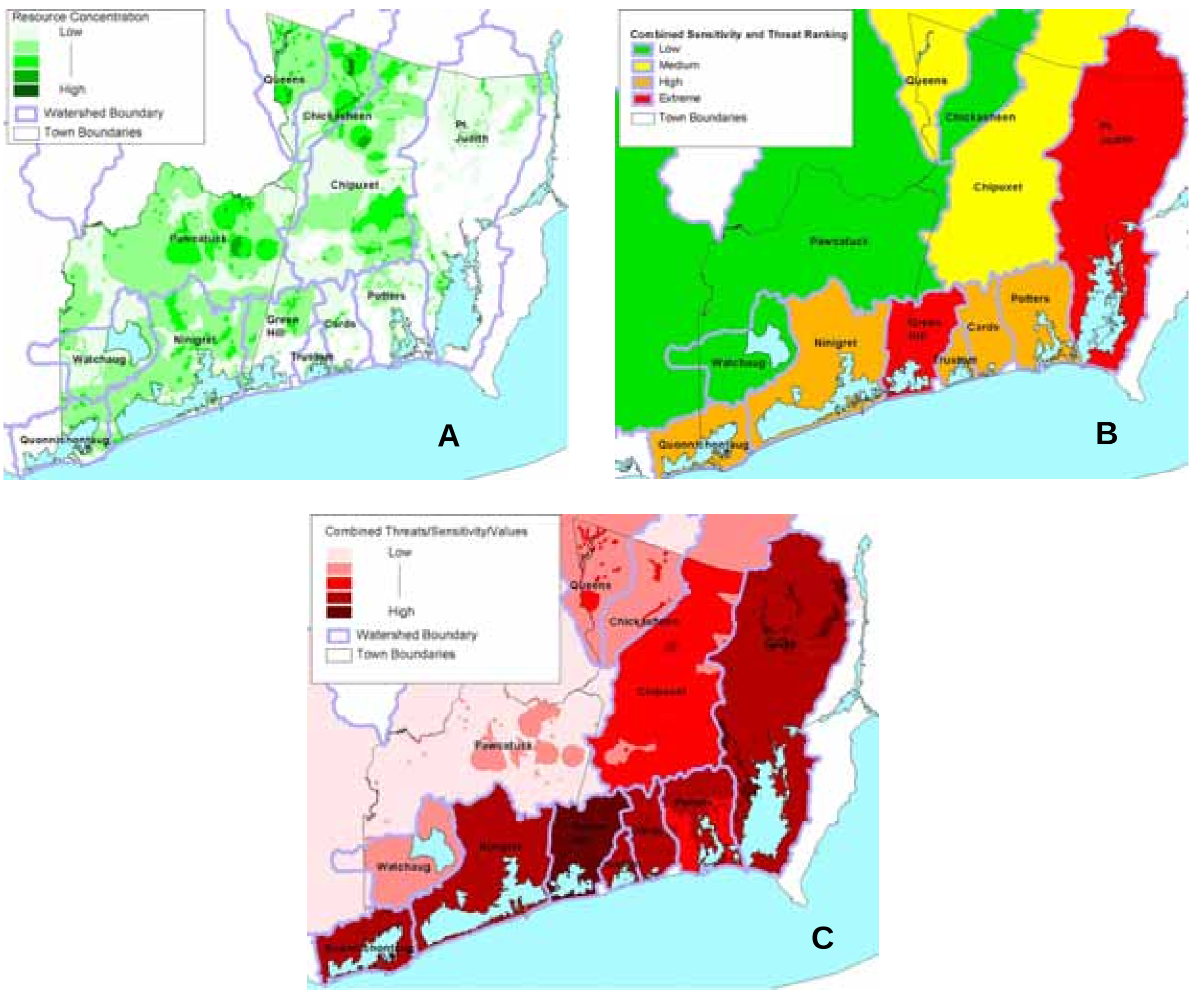


Figure 9-10
Overlaying the Valuable Resource Map (Map A) with the Risk/Sensitivity Map (Map B) Results in a Priority Map (Map C) that Shows Areas of Higher Priority for Management and Protection Efforts

Using Assessment Results in the Selection of Management Options

Chapter 10, *Identifying Management Options*, provides guidance on how to use assessment results in the selection of management options and wastewater treatment levels to better protect public health and vulnerable water resources. The chapter presents case studies of how communities in Rhode Island have used this needs assessment method to select sites for advanced treatment technologies, to target and upgrade small lots with substandard systems, to find shared solutions to failed systems, and to protect public drinking water supplies.

10 IDENTIFYING MANAGEMENT OPTIONS

The GIS-based approach described in this handbook focuses on the evaluation of risks from onsite wastewater treatment systems and recommendations for alternative wastewater treatment options and development standards. Assessment efforts focus on identification of the most serious threats to priority water resources, targeting locations where impacts are potentially greatest. The results generate site-specific information needed to support selection of management alternatives.

This chapter describes the process of interpreting assessment results to select appropriate wastewater treatment options based on local water quality goals. Because onsite wastewater effluent is typically only one of the pollution sources in unsewered areas, the factors considered in integrating management of onsite wastewater treatment systems with other pollution controls such as stormwater management are also addressed. In addition, methods for evaluating the effectiveness of alternative management practices are presented, using watershed indicators and map analysis tools introduced in previous chapters. The following case study examples are used to illustrate GIS applications for directing management actions:

- Use of hot spot mapping and other map analysis techniques to guide selection of alternative treatment technologies.
- Use of nutrient loading to examine the effectiveness of nitrogen-reducing onsite wastewater treatment systems to minimize nitrogen loading to groundwater.
- Use of percent impervious analysis, nutrient loading, and other watershed indicators to evaluate the relative benefits of improved stormwater management and reduced fertilizer inputs in combination with onsite wastewater management.

Evaluating and Selecting Watershed-Based Wastewater Management Options

The approach to evaluating and selecting watershed-based wastewater management options includes:

- Onsite Wastewater Management Focus Options
- Levels of Wastewater Treatment Selection

Onsite Wastewater Management Focus Areas

Onsite wastewater management focus areas include:

- Remediation of failed systems
- Protection of Sensitive Water Resources

Remediation of Failed Systems

Wastewater management planning and assessment is typically motivated by community desires to provide for adequate wastewater treatment to meet current needs, remediate failures, and accommodate future growth. Nationally, about half of the occupied homes with onsite wastewater treatment systems are reported to be more than 30 years old (U.S Census Bureau, 1997). These older systems generally pre-date current minimum standards and are likely to be cesspools or other substandard systems where treatment may not be adequate to protect public health, particularly in densely settled areas where small lot sizes also pre-date current density requirements. Remediating failures in these areas is a primary focus of management efforts described in this section. System failure due to age and siting often occur in village centers with very small lots, business districts with high-strength commercial waste, and waterfront shorelines with environmental constraints.

Under these circumstances, alternative wastewater treatment systems are often the only feasible option for overcoming site constraints. Options generally include individual alternative treatment systems or small scale shared treatment systems where a group of two to four homes or businesses may use individual septic tanks to settle solids, but where septic tank effluent flows by gravity (also called septic tank effluent gravity or STEG) or pressure distribution (also called septic tank effluent pressure distribution or STEP) to a common treatment unit and leaching. The level of treatment provided is dependent on the need to protect private or public wells, soil characteristics, and other site constraints, and sensitivity of local water resources. In many cases, the need for system upgrades and repairs had been long recognized. However, remediation action was not taken until advanced treatment technologies were approved by state regulators, training and regulatory mechanisms were implemented for system designers and practitioners, followed by more widespread use in the community.

Protection of Sensitive Water Resources

According to EPA guidelines for managing onsite wastewater treatment systems (USEPA, 2003), current siting and design standards are generally adequate to protect public health but may not be sufficient to protect sensitive environments. Nationwide, 40 to 50 percent of assessed streams, lakes, and estuaries are not meeting designated water quality standards for fishing and swimming (USEPA, 2000b). Key concerns have been nitrate concentrations in groundwater aquifers, phosphorus inputs to freshwater lakes, and nitrogen loading to poorly flushed coastal waters. In recent years, some state agencies have begun to establish more restrictive onsite wastewater treatment standards, specifically to protect vulnerable groundwater aquifers and sensitive surface waters in high-risk situations. Three types of high-risk circumstances are generally considered:

- Locations where onsite systems are densely concentrated
- Site conditions that enhance the potential for pollutant movement, for example excessively permeable soils, high water table, or inadequate setbacks to surface waters
- Areas with vulnerable water resources such as unconfined sand and gravel aquifers, poorly flushed surface waters, and coastal waters that are highly sensitive to nitrogen

Under these circumstances, the wastewater management options evaluated should focus on use of small-scale advanced treatment systems to overcome site constraints as well as the level of treatment needed to control the total amount of wastewater discharged throughout the watershed or aquifer recharge area. Onsite wastewater systems are, however, only one component in the interrelated and complex chain of impacts associated with land use activities. Suitability for onsite wastewater treatment is often the limiting factor determining whether a parcel of land is suitable for new development or building expansion. As a result, effects of wastewater pollutants are often inseparable from interrelated impacts such as construction-related erosion and sedimentation, and hydrologic changes resulting from increased stormwater runoff volume. As Table 10-1 shows, onsite systems are one of the major sources of water pollution. To address these associated impacts, assessment results may be used to identify supporting management practices to address, for example, average watershed impervious cover, alternative stormwater runoff controls, and shoreline protection for surface waters and wetlands.

Table 10-1
Contaminants Most Likely to Impair Water Quality

Resource	Common Pollutants	Common Sources
Groundwater—public and private wells	• Fuel and MTBA • Organic solvents • Nitrates • Pesticides • Pathogens	• Leaking fuel tanks and lines • Industrial and hazardous disposal (spills and improper use) • Landfills • Road salt • Septic systems • Fertilizers and pesticides
Coastal waters—poorly flushed, nitrogen sensitive	• Pathogens • Nitrogen	• Runoff • Septic systems • Natural sources • Combined sewers (in urban areas)

Table 10-1
Contaminants Most Likely to Impair Water Quality (cont.)

Resource	Common Pollutants	Common Sources
Rivers and streams	• Pathogens • Phosphorus • Metals (in urban streams)	• Runoff • Septic systems • Natural sources • Direct discharges (in urban areas)
Lakes and ponds	• Pathogens • Phosphorus • Metals	• Runoff • Septic systems • Agricultural fertilizers • Hydrologic modifications

Level of Wastewater Treatment

A number of methods have been developed to evaluate the capacity of a stream, lake, coastal embayment, or groundwater reservoir to accommodate wastewater effluent and other pollutants generated within a watershed or recharge area. The current national strategy for restoring impaired waters to achieve state water quality goals relies on the use of waterbody assessments to determine the maximum allowable load of a particular pollutant. The Total Maximum Daily Load (TMDL) approach (see Chapter 2, *The Need for Comprehensive Wastewater Planning*) assesses the capacity of a waterbody to accommodate pollutants while still achieving water quality goals. Extensive technical documentation has been developed to guide states in implementing these studies (USEPA, 1999a).

Strategies more specifically designed to address performance standards for wastewater discharges are described in the EPA publication *Onsite Wastewater Treatment Systems Manual*, Chapter 3 (USEPA, 2002b). These approaches range from more restrictive nitrogen standards for groundwater recharge—with action levels set as low as 2 mg/l (Wisconsin Administrative Code, Chapter NR 140), to modeling strategies and risk assessment methods as described in this handbook (Chapter 6, *Watershed Indicators: Linking Land Use to Water Quality*). The approach used to select treatment levels in this section loosely follows the vulnerability assessment method developed by Hoover (1997) and the probability of impact approach (Otis, 1999), both described by EPA (2002b) in its *Onsite Wastewater Treatment Systems Manual*. In essence, risk factors such as identification of sensitive receiving areas, high-density areas, and pollutant flow pathways are either identified in the MANAGE assessment process or considered in selecting management options.

In situations where the goal is to manage onsite wastewater systems as part of a comprehensive watershed or aquifer recharge protection plan, the Center for Watershed Protection's (1998) *The Rapid Watershed Planning Handbook* offers guidance in developing a watershed plan using a screening level approach. The handbook describes the process of selecting management practices using eight types of watershed protection tools, where the degree of control provided by each tool is based on watershed vulnerability. For example, sensitive watersheds are generally classified as those with low impervious cover (less than 10 percent), vegetated shoreline buffers, and healthy water quality. These resource areas should be afforded the highest level of protection using the suite of eight watershed management practices. Because the assessment process described in this handbook generates much of the data needed to develop a comprehensive watershed management plan, the Center for Watershed Protection's approach can be used to integrate stormwater management controls and other protection methods with wastewater management practices.

One of the most basic factors in selecting management practices is the pollutant of concern most likely to affect water resources in the study area. Table 10-2 identifies the typical pollutants of concern in wastewater effluent and outlines the general management approach for controlling inputs as a starting point for selecting wastewater treatment levels.

Table 10-2
Pollutants of Concern from Onsite Wastewater Systems

Pollutant	Concern for Septic System Function and/or Treatment	Domestic Septic Tank Effluent Con-centration (mg/l)	Concen-trations from Advanced Treatment Units (mg/l)	Percent Removal in 3–5 ft. of Soil (% reduction of effluent applied)	Management to Reduce Risk of Failure and Enhance Treatment Performance
Biodegradable organic solids (Biochemical Oxygen Demand or BOD)	Stimulates growth of bacteria and clogging at leachfield/soil interface. High BOD removal required for use of alternative drainfield for smaller leaching size and minimal disturbance. In surface waters, consumes oxygen in decomposition, depletes dissolved oxygen, and impairs aquatic habitat.	140–200	5–30	>90%	Keep solids in drainfield through proper use, operation, and maintenance, and effluent filter. Require high BOD removal as prerequisite for use of reduced-size alternative drainfield

Table 10-2
Pollutants of Concern from Onsite Wastewater Systems (cont.)

Pollutant	Concern for Septic System Function and/or Treatment	Domestic Septic Tank Effluent Con-centration (mg/l)	Concen-trations from Advanced Treatment Units (mg/l)	Percent Removal in 3–5 ft. of Soil (% reduction of effluent applied)	Management to Reduce Risk of Failure and Enhance Treatment Performance
Total suspended solids (TSS)	Clogs drainfield and soil pores. High TSS removal required for use of alternative drainfield for smaller leaching size and minimal site disturbance. In surface waters, smothers aquatic habitat and reduces clarity. Solids in drinking water form toxic chlorination byproducts.	50–100	5–30	>90%	Keep solids in drainfield through proper use, operation, and maintenance, and effluent filter. Require high TSS removal as prerequisite for use of reduced-size alternative drainfield
Nitrogen	Over-fertilizes sensitive coastal waters at very low levels ($\leq$ 0.5 mg/l) contributing to low dissolved oxygen and decline of aquatic habitat. Drinking water contaminant at 10 mg/l (5 mg/l action level). In groundwater, indicator of wastewater or fertilizer (1 mg/l).	Average 40 Range 40–100	Average 20 Range 10–60	10–20% in conventional drainfields; 43% in shallow drainfields.	Limit nitrogen inputs to groundwater and coastal watersheds through density controls and/ or advanced treatment. Maximize natural removal in riparian areas.

Table 10-2
Pollutants of Concern from Onsite Wastewater Systems (cont.)

Pollutant	Concern for Septic System Function and/or Treatment	Domestic Septic Tank Effluent Concentration (mg/l)	Concentrations from Advanced Treatment Units (mg/l)	Percent Removal in 3–5 ft. of Soil (% reduction of effluent applied)	Management to Reduce Risk of Failure and Enhance Treatment Performance
Phosphorus	Over-fertilizes fresh waters; contributes to growth of algae, low dissolved oxygen, and decline of aquatic habitat in minute quantities. In drinking water, associated solids result in formation of toxic chlorination byproducts.	5–15 mg/l = 5,000–15,000 ug/l or ppb	Limited data	0–100% in conventional drainfields; highly variable due to soil phosphorus sorption capacity. 66–100% in shallow drainfields.	Avoid system failure; maintain separation distance to groundwater and surface waters. Provide advanced treatment with shallow dispersal in critical areas.
Pathogens (Bacteria and viruses)	Infectious disease hazard by consumption of drinking water or raw shellfish, recreational water contact, or exposure to untreated effluent.	10^6–10^8	0–10^3	>99.9%	Avoid system failure; maintain separation distance to groundwater, surface waters, and wells. Provide advanced treatment in critical areas.
Organic chemicals (fuel components, volatile organic compounds (VOC), endocrine disruptors	Potential carcinogens to humans in drinking water or vapor inhalation during showering. Also impairs aquatic organisms and habitat.	0 to trace levels (Primarily due to improper use or disposal at higher levels.)	0–trace	>99%	Restrict siting of businesses that use or store hazardous materials in recharge areas. Educate residents and business owners about proper waste disposal.

Adapted from EPA, 2002 and Siegrest, R., E. Tyler, and P. Jenssen 2001.

Because wastewater management decisions are typically made at the local level, the selection process includes factors such as local land use goals and resource protection needs that are determined at the community level through public discussion, development of comprehensive plans, adoption of wastewater management programs, and capital budgeting for wastewater treatment improvements. A summary of the factors considered in selecting wastewater management practices, which incorporates information on pollution risks generated by the assessment, follows.

Factors in Selecting Wastewater Management Practices and Treatment Levels

Locally valuable resources that require the highest level of protection and are typically the focus of an assessment may include groundwater aquifers and wellhead protection areas, surface water supplies, coastal shellfishing areas and swimming beaches, and unique aquatic habitat.

These resources are determined by consideration of factors that include:

- Critical water resource areas that are designated in town plans
- Specific water resource protection goals that have been adopted
- The willingness of the community to accept risk of degradation

Water Resource Protection Priorities

To further identify locally valuable resources, evaluate water resource protection priorities, which can be established based on:

- Water use goals
- Pollutants of concern
- Water supply
- Existing water quality conditions
- Pollution risks
- Future land use goals
- Management practices

Water Use Goals

Water use goals identify sensitive water resources with low tolerance limits for pollutant inputs. These may include shellfishing waters (very low levels of bacteria counts typically allowed), cold water fisheries, and state-designated special resource protection waters associated with anti-degradation policies.

Pollutants of Concern

Pollutants of concern are contaminants most likely to impair water quality for the resources in the study area. Table 10-2 lists pollutants of concern from onsite wastewater systems.

Water Supply

Water supply considerations include:

- Private wells (dug versus drilled)
- Availability of public water supply within unsewered areas
- Water supply capacity

Existing Water Quality Conditions

Existing water quality conditions are based on:

- Water quality status relative to meeting water quality goals. Each state compiles a *State of the State's Waters (305b) Report* that provides considerable site-specific information on water quality conditions.
- Trends in nutrient enrichment of surface waters (stable, fluctuating, or declining)
- Groundwater nitrogen concentration and trends
- Water supply monitoring data and the history of contaminant detections
- Presence of other stresses, such as low flow due to water withdrawal, or flushing restrictions.

Pollution Risks

Pollution risks are based on land use and landscape features of the study area, which can include a group of factors generated by the assessment (see Chapters 7 and 8), such as:

- High-intensity land use
- Impervious cover
- Nutrient loading
- Shoreline land use
- Soil characteristics
- Age and number of onsite systems per acre
- Hot spots identified by map analysis

Future Land Use Goals

Community objectives for the study area drive future land use goals. Examples of future land use goals include:

- Preservation
- Low-density development
- Limited growth
- Intensive growth center

Goals should be consistent with resource protection needs and land development capabilities. The community should also consider wastewater treatment needs in developing areas.

Management Practices

Considerations for management practices include:

- Effective controls already adopted
- Local capacity to adopt and implement additional controls
- The availability or ability to obtain appropriate personnel to oversee maintenance of advanced treatment systems
- Complications by watershed/aquifer recharge areas located in shared jurisdiction areas with other communities

Modeling Effectiveness of Management Options Using Nutrient Loading and Other Watershed Indicators

When evaluating results it is important to recognize that runoff and nutrient loading estimates represent only one type of pollution risk. Although nitrogen and phosphorus are used as indicators of other dissolved and sediment-borne pollutants, these estimates do not adequately represent all pollution risks, including the likelihood of contamination from bacteria. Often, the location of onsite wastewater systems will be the likeliest indicator of threats to water quality.

For example, cesspools and other substandard onsite wastewater systems, on densely clustered lots, and in areas where private wells are used, generally pose the most serious threats to water quality, especially where separation distances to wells are inadequate. Other high risk situations where systems are more likely to fail either due to improper treatment or hydraulic failure include system placement in high water tables, especially where subdrains are used to lower the water table. In addition, systems in wetland and surface water buffers have the potential to convey pollutants directly to surface waterbodies.

Nutrient Loading Examples

Due to the limitations of nutrient loading estimates to portray wastewater impacts, caution is necessary to guard against over-reliance on modeled nutrient loading estimates in evaluating water quality impacts and selecting management practices. When used within the context of a other watershed indicators and map analysis, however, nutrient loading estimates can provide useful data to supplement the evaluation of wastewater impacts and management practices, especially when nutrient loading inputs to groundwater are a key concern.

As an introduction to the nutrient loading estimates it is useful to compare estimates of nutrient inputs under different development densities. Figure 10-1 shows estimated average annual nitrate-nitrogen inputs from single-family homes on different size lots ranging from one-half to two acres. This graph depicts the amount of nitrogen that research results have shown is generated from one onsite system serving three people with a standard size fertilized lawn (Gold et al., 1990). Concentrations represent the average annual amount of nitrogen entering groundwater recharge at the source, based on dilution with recharging precipitation and wastewater, after accounting for the level of evapotranspiration and runoff found in Rhode

Island. This type of mass nutrient loading estimate has led some regulatory agencies to establish minimum one-acre residential densities to maintain groundwater concentrations well below the 10 mg/l EPA nitrate standard for public water supplies.

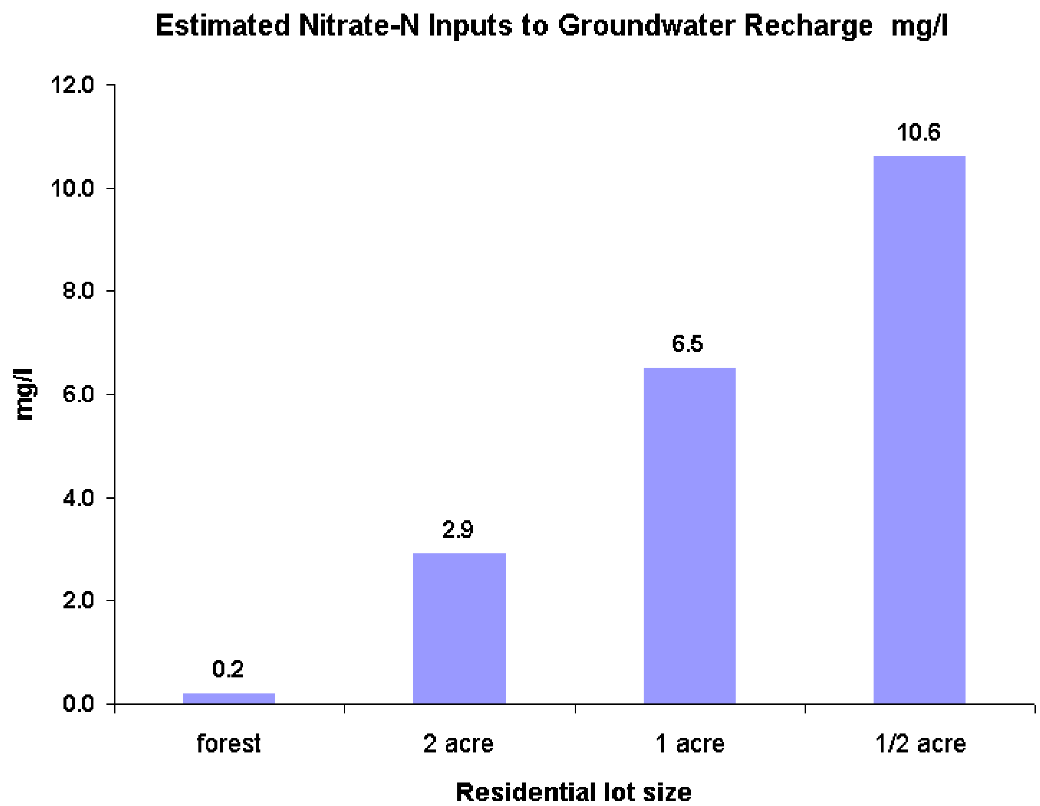


Figure 10-1
Estimated Nitrate-Nitrogen Inputs to Groundwater Recharge mg/l Based on Residential Lot Sizes

To illustrate the influence of stormwater infiltration and fertilizer management on wastewater effluent concentrations, a similar scenario is presented in Figure 10-2 for lot sizes ranging from two acres to one-fourth acre. The blue bar to the left of each set represents assumptions similar to those in Figure 10-1, with one onsite system, lawn area, and standard runoff from each lot. For each lot size, nitrogen inputs are also estimated assuming no lawn fertilizers are used, which results in a slight reduction in concentration, and also with a "low impact" option with no lawn fertilizer and where all rainfall is infiltrated onsite. The low impact option reflects new approaches to controlling stormwater discharges, especially in environmentally sensitive areas. In recognition that standard "first flush" stormwater controls have been ineffective in controlling water quality impacts and do not reduce the total runoff volume generated from developed land, low impact stormwater management design stresses maintenance of pre-development hydrology to preserve high infiltration rates typical of naturally forested land (Prince George's County DEP, 2000).

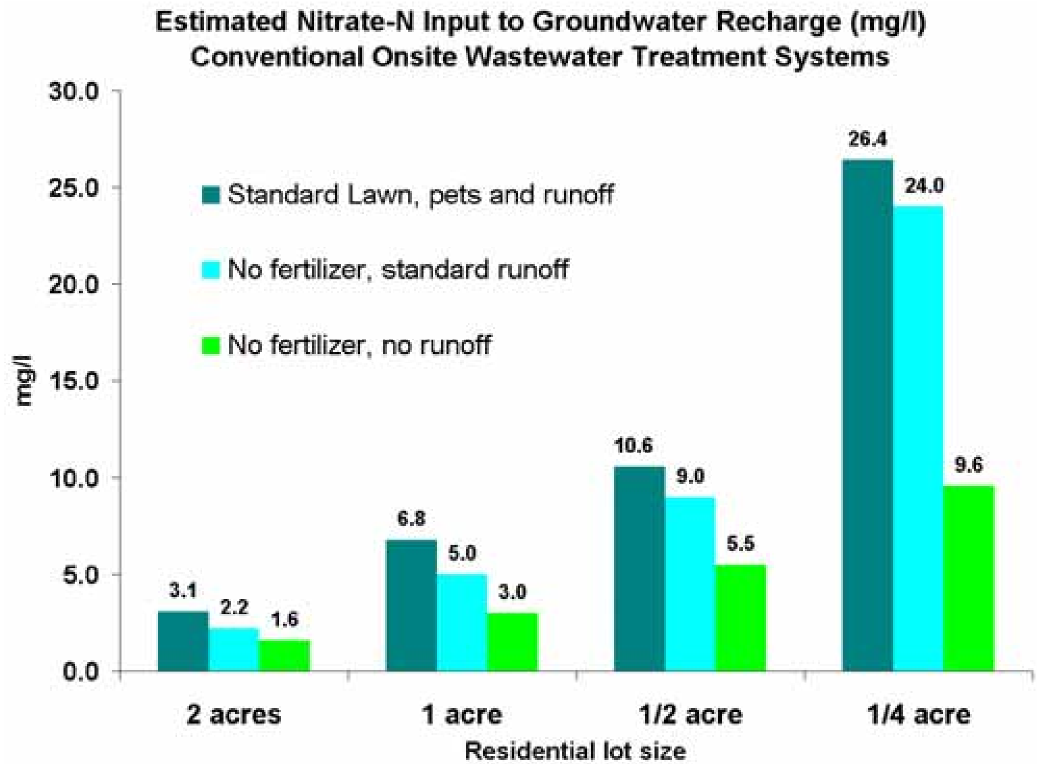


Figure 10-2
Nitrate-Nitrogen Loading Estimates for Different Lot Size Densities Subject to Different Fertilizer and Runoff Management Options

The no fertilizer, no runoff scenario results in significantly lower nitrate-nitrogen concentrations due to increased dilution with rainwater, even without considering potential for additional treatment in soil. For example, average nitrate-nitrogen concentrations from a one-acre lot could be expected to decrease by half, to 3 mg/l with no net increase in runoff and no fertilizer leaching. The no-runoff option may not be realistic in all cases, especially where soils are slowly permeable and temporary storage and infiltration is difficult, but it does represent the range of concentrations possible with different management practices. It is also unclear if homeowners will accept unfertilized lawns. Results also suggest the need to balance wastewater treatment with stormwater controls.

The nutrient loading estimates presented in Figure 10-3 carry the analysis a step further to introduce the effect of alternative wastewater treatment technologies capable of reducing total nitrogen by 50 percent. The estimated concentration from nitrogen-reducing alternative treatment systems is estimated for each lot size, using standard runoff and lawn fertilizers, no fertilizer, and no runoff in combination with no fertilizer. As expected, the potential reduction in nitrogen is greatest using both advanced treatment systems in combination with no runoff, and also in situations with small lot sizes.

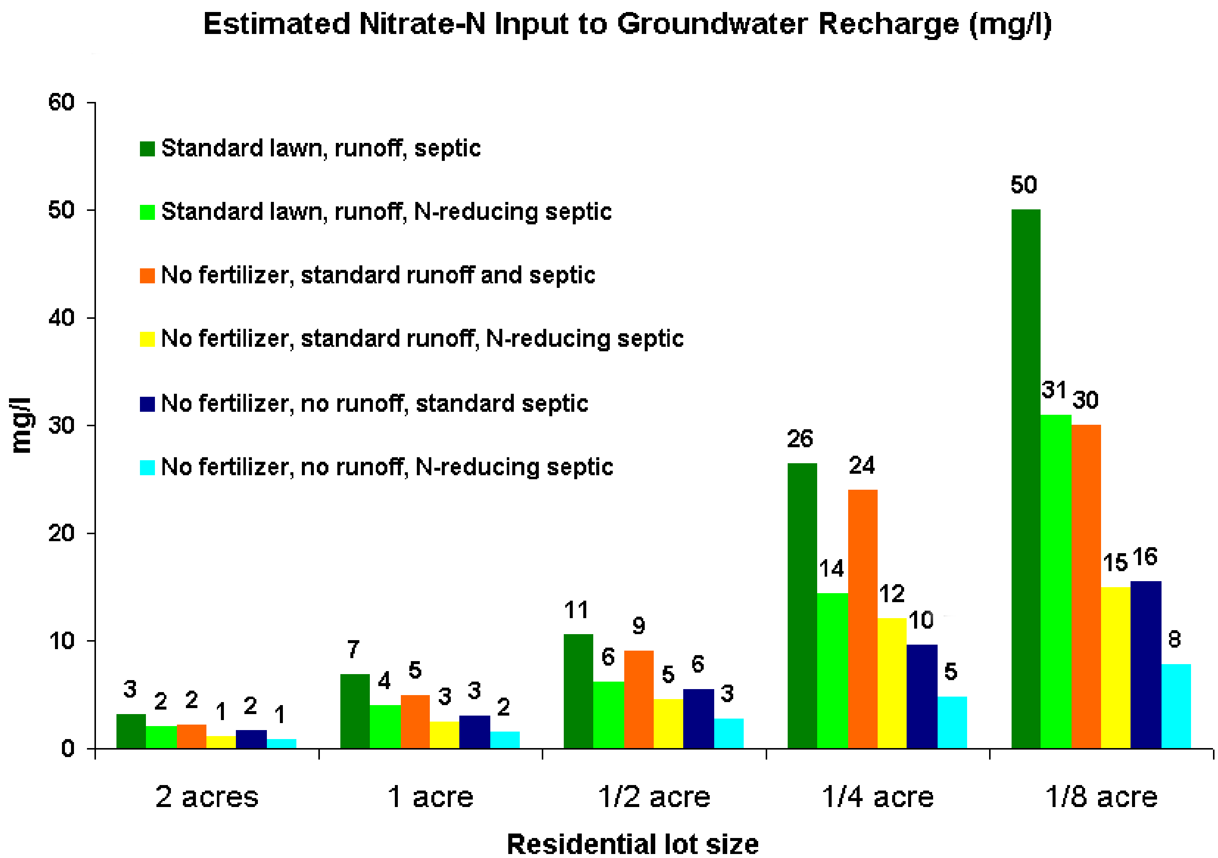


Figure 10-3
Nitrate-Nitrogen Loading Estimates for Different Lot Size Densities Subject to Different Fertilizer, Runoff, and Onsite Wastewater Treatment Options

Wastewater Management Examples

This section provides wastewater management examples, including:

- Selecting alternative treatment technologies
- Treating and upgrading small lots with substandard systems
- Finding a shared solution to failed systems
- Town wastewater management planning focusing on village centers in a public drinking water supply watershed

As described in Chapter 8, *Mapping High-Risk Areas for Pollutant Movement*, GIS can be an extremely powerful tool to target locations where onsite treatment poses a high risk of offsite contamination. The examples that follow illustrate real examples where GIS hot spot mapping has served to guide the selection and location of alternative onsite treatment systems.

Selecting Alternative Treatment Technologies

Analysis—This assessment involved Stony Fort Brook hot spot mapping to locate dense residential development with septic systems on high water table soils.

Assessment Objective—The assessment objective was to evaluate suspected problem areas to determine the extent or failing of substandard systems to protect private wells.

Pollutants of Concern—Pollutants of concern included:

- Bacteria and nitrogen reaching private wells
- Site disturbance in wetland areas increasing sediment load to the Queens River

Methods—The seasonal high water table soils (less than three feet from the ground surface) in the GIS coverage were overlaid with developed land uses including tilled agricultural land. Other land uses on deeper water table soils were dropped out. The resulting map shows only developed land situated on high water table soils.

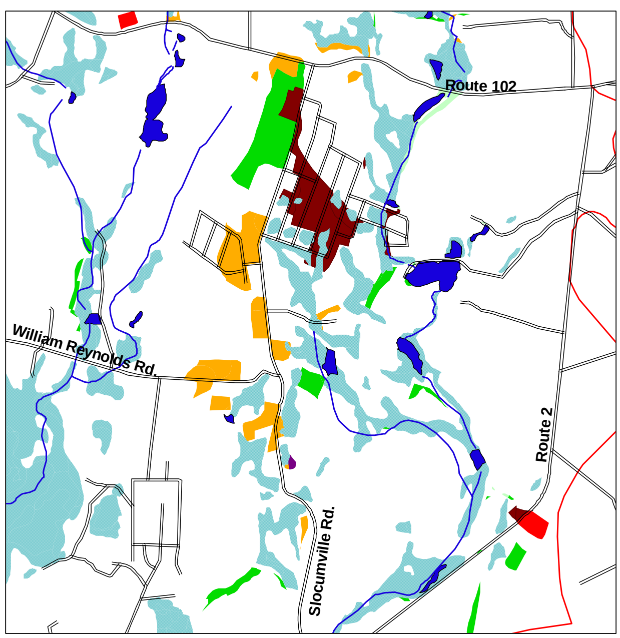


Figure 10-4
A Hot Spot Map That Shows Areas with Onsite Systems on High Water Table (Queen's River, Stony Brook example)

Results—The final map clearly shows a residential area with lot sizes of one-fourth acre (dark brown) and one acre (orange) located in natural drainage areas adjacent to wetlands. In this case, wetlands drain to a tributary of the Queen's River, which is ranked as a regionally significant habitat for rare and endangered aquatic habitat, including various species of dragonflies and freshwater mussels. Other high-risk areas identified include pockets of tilled farmland (green) and commercial uses (red) where the risk that fertilizers, wastewater effluent, and other wastes generated will be more likely to migrate to surface waters.

Treatment Alternatives—Onsite wastewater treatment systems on lots with high water tables or restrictive soils have a high risk for offsite transport of phosphorus and pathogenic pollution resulting from clogging and hydraulic failure. Phosphorus and pathogens are a particular risk when soil absorption fields fail and septic effluent breaks out at the ground level and moves to surface waters through storm drains or in runoff from storm events. A number of alternative technologies are in widespread use that can minimize risks associated with these types of sites. These technologies include a variety of packed bed filters (with sand, peat, foam, or textile media), aerobic treatment units (ATU), or fixed activated sludge systems followed by either a traditional type soil absorption field or pressurized drainfields. These systems are effective at reducing the organic materials and solids in septic effluent that are often responsible for clogging and hydraulic failure.

Alternative treatment systems enhance soil treatment, which is generally quite effective in removing phosphorus and pathogens from onsite system effluent. In more extreme situations, shallow narrow drainfields can be used in place of conventional trench systems, which facilitates contaminant removal within the unsaturated zone. If pathogen contamination is a priority due to proximity to drinking water sources or shell fishing areas, ultraviolet light disinfection units (UV treatment) can be added to the alternative system treatment train. UV treatment can be extremely effective at eliminating pathogens from onsite wastewater.

Implementation—Map analysis of natural resource features and potential pollution risks within the Stony Fort Brook and larger Queens River watershed was used to illustrate the location of sensitive aquatic habitat and to identify potential pollution risks associated with land uses and landscape features. Mapping, estimated nutrient loading, and information on management practices for controlling pollution risks from onsite wastewater treatment systems was provided to municipal officials through a number of training programs and regular meetings of the planning board, town council, and regional planning councils. Although many factors influence local management decisions, the Stony Fort analysis helped support management decisions leading to the following actions:

- Town officials joined with two other small communities, applied for, and received a state grant to develop a wastewater management program. Preliminary plans include:
  - Developing a town-wide septic system inspection and repair program in each community managed by one shared staff person
  - Exploring the feasibility of establishing town GIS systems to support local wastewater management planning and other town data needs, also managed by one staff person shared by all three towns
- The town developed amendments to land development regulations requiring advanced wastewater treatment for major development projects.
- Map analysis and nutrient loading was used in preliminary analysis of a proposed federal job training center in the Stony Fort Brook watershed. The center, currently under development, was approved with use of an advanced onsite wastewater treatment system and other management practices to minimize impacts.

- To promote better site design based on natural resource features and suitability for onsite wastewater treatment, the town adopted requirements for use of conservation development design for new development projects. The application fee structure enables the town to hire their own consultant to review projects rather than relying solely on the applicant's consultants.

Targeting and Upgrading Small Lots with Substandard Systems

Analysis—This assessment involved Wickford Village parcel mapping and hot spot analysis.

Assessment Objectives—The objectives of this assessment were to:

- Evaluate age and condition of wastewater treatment systems
- Identify vacant lots as potential sites for community treatment systems
- Identify critical areas for remediation of treatment failures

Pollutants of Concern—Pollutants of concern included:

- Bacteria from failing onsite systems in shoreline areas reaching harbor waters, which support recreational boating and shellfishing outside of marina areas
- Nitrogen loading to the harbor in densely developed areas

NOTE: This site is served by public water.

Methods—The town converted CAD-based parcel maps to ArcView GIS coverages (Figure 10-5). The town parcel record included assessed value, which indicates developed lots and data of building construction. Repair permits were obtained by the State regulatory agency. Locations were matched using plat/lot numbers and address matching for remaining unmatched parcels.

Results—Wickford Village is a good example of how parcel mapping can identify available open space lots that may be used to solve wastewater problems by utilizing a small community treatment system. The hot spot mapping analysis identified sites where onsite wastewater system upgrades, using either individual or shared system, are a priority. Results can also be used in combination with parcel mapping to identify priority locations for shared systems. In this particular example, the parcels indicated in red in Figure 10-5 are lots built prior to adoption of onsite wastewater treatment system regulations in 1970, and most likely consist of substandard systems (cesspools and outdated steel septic tanks). Parcels indicated in green are vacant open space lots where a small community advanced wastewater treatment system could be sited to serve the wastewater needs of several adjacent homes.

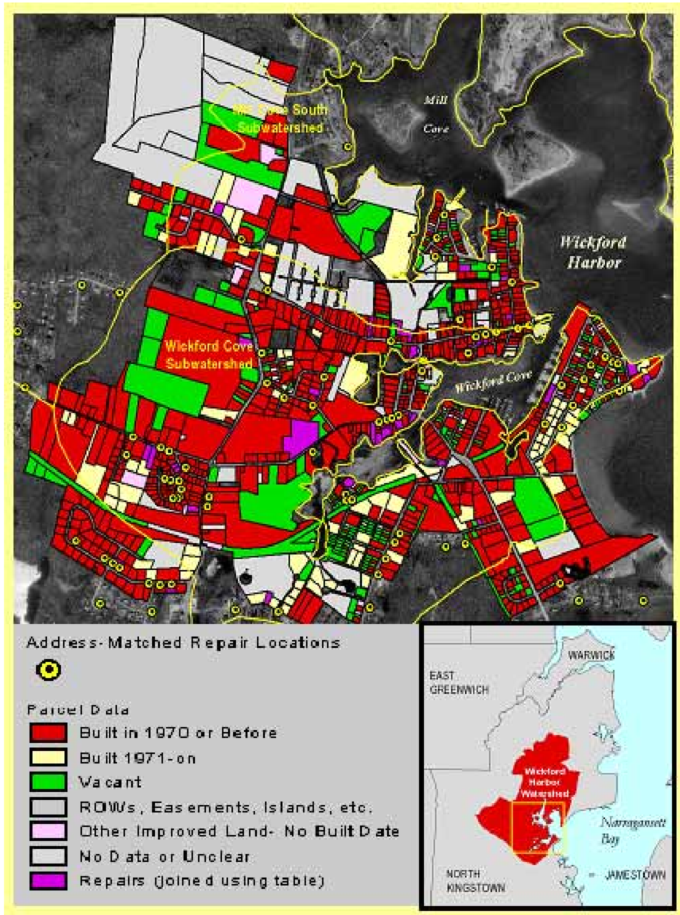


Figure 10-5
Wickford Village Harbor Parcel-Based Hot Spot Mapping

Treatment Options—Hot spot mapping at the parcel scale can highlight areas where small lots, built prior to modern onsite wastewater treatment regulations are located. Alternative wastewater treatment technologies that are compact, modular, and comparatively lightweight are available that can be used to retrofit these lots with a minimal amount of site disturbance. Of note are peat, foam, and textile packed bed filters, aerobic treatment units, and fixed activated sludge systems. These small-footprint modular technologies are capable of reducing pathogens and/or nitrogen contamination, and they can enhance absorption and treatment of wastewater in the soil absorption system. Where pathogens are of particular concern, UV light disinfection units can be added.

A number of factors make the Wickford Village area potentially feasible for shared wastewater treatment systems, either using small groups of shared systems or one or more larger community systems. Lot sizes are small, with homes and businesses within short distances of each other, enabling efficient collection and transport of waste to common leachfields. For example, soils are generally sandy, providing suitable leachfield locations and minimizing construction costs for small-diameter pressurized sewer lines. Availability of vacant lots or undeveloped land on developed parcels provides potentially suitable sites for leachfields. Onsite investigation is needed to determine site suitability based on soils, water table depth, and other constraints.

Town-owned recreation land provides a potentially suitable site for a large community system. The feasibility of using this site, and its capacity to accommodate wastewater, would have to be evaluated through a detailed cost assessment that considers construction and maintenance costs over a 20-year life cycle. Cost and feasibility should be compared with other alternatives, including individual system repairs and small groups of shared systems. To keep the size of the community system to a minimum, a site investigation (or results of mandatory wastewater treatment systems inspections, where inspection results are reported to the town) would be needed to identify systems that could be repaired onsite using a conventional system in case of eventual failure. Priority for connection to the community system would be commercial high-flow and high-strength uses and sites where onsite solutions are not feasible or that are marginally suitable for onsite repairs. Since Wickford Village is within a historic district, marginally suitable sites where a "filled" system could be constructed in a raised leachfield of gravel fill, should be required to install an advanced treatment system to avoid visual impacts, and also to provide nitrogen removal to restore critical aquatic habitat in the harbor.

Implementation—Although town officials expressed interest in investigating the feasibility of a community system on town-owned park land, a local initiative to explore this option would require much more staff effort than the present minimalistic approach, where homeowners are simply required to ensure systems are properly maintained without failure. Because onsite system owners are finding alternatives through free market channels, the town has little incentive to devote staff time and effort and earmark funds for feasibility studies. In addition, development of a community system for existing properties would require that all parties involved reach an agreeable consensus with voluntary tie-in. No mechanisms currently exist to require landowners to abandon individual onsite systems and connect to a shared unit. Yet a certain number of connections to a community system may be needed for cost effectiveness.

Finding a Shared Solution to Failed Systems

Analysis—This assessment involved using a shared small community treatment system.

Assessment Objectives—The objectives of this assessment were to:

- Identify locations of failed systems relative to vacant parcels to identify opportunities for remediation using a shared system using city parcel maps as a base
- Evaluate age and condition of wastewater treatment systems
- Identify vacant lots as potential sites for community treatment systems
- Identify critical areas for remediation of treatment failures.

Pollutants of Concern—Pollutants of concern included:

- Protection of public health through remediation of failed systems
- Nitrogen loading to nearby coastal waters

NOTE: This site is served by public water.

Methods—Using state funds provided under the Narragansett Bay Estuary Project, the City of Warwick advertised availability of funds to partially offset the cost of repairing failing onsite wastewater treatment systems. Using parcel maps as a base, the city mapped applications for funding. The town parcel record included assessed value, which indicated built and undeveloped lots.

Parcel mapping was used in a case study where several failed onsite systems were clustered in a neighborhood consisting of mostly one-fourth acre lots with municipal water service. Parcel scale mapping pinpointed locations of each lot with a failed system and helped identify an open lot centrally located in the cluster of failed systems. The owner of this vacant lot was also experiencing onsite system problems and was receptive to using this extra lot as a treatment zone lot, and partnering with neighbors on a shared system.

Results—Four homes are now using this small, shared community system. The city reassessed the property as a treatment zone lot and the homeowner received a tax break because the lot is no longer buildable. The system for this example consists of a 2,000 gallon per day recirculating sand filter and a shallow narrow drainfield as a final treatment and dispersal zone (Figure 10-6).

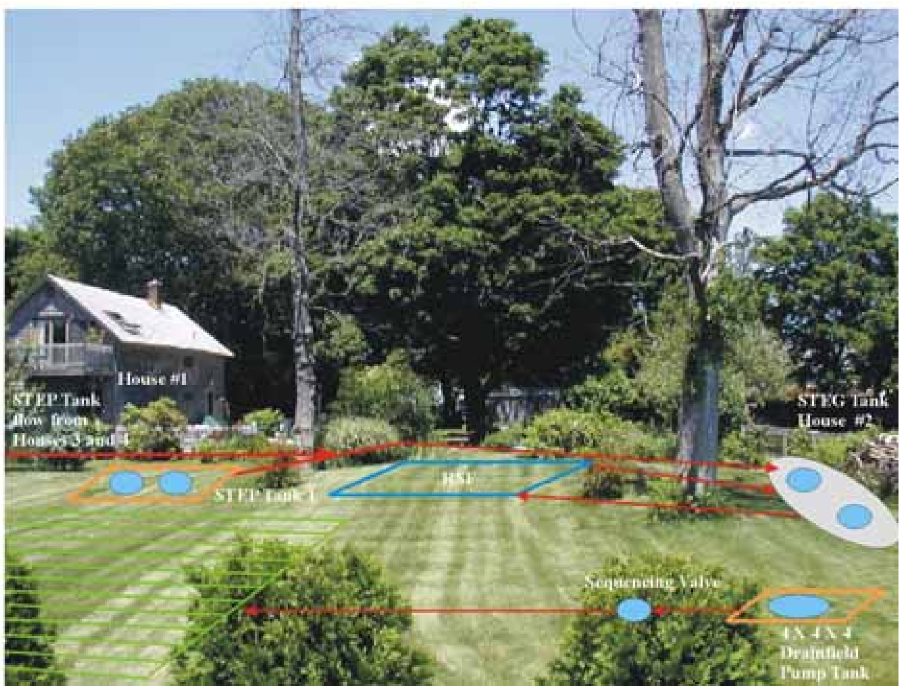


Figure 10-6
Shared Small Community Recirculating Sand Filter

Each of the four homes has its own septic tank, trapping and storing solids for individual homes, with relatively clear wastewater flows to a recirculation tank located on the treatment zone lot, where the rest of the treatment system is located. Wastewater is treated in the time-dosed recirculating sand filter and final effluent is pressure-dosed to a shallow narrow drainfield on the treatment zone lot. This system has the capacity to accommodate another one or two homes depending on their size or flow.

Town Wastewater Management Planning Focusing on Village Centers in a Public Drinking Water Supply Watershed

Analysis—Scituate Reservoir Watershed assessment of pollution sources from land use activities.

Assessment Objectives—The objective of this assessment was to implement proactive watershed planning sponsored by the Providence Water Supply Board. A watershed assessment was conducted as part of a training program for local land use officials, using local site-specific examples to identify pollution threats.

Pollutants of Concern—Pollutants of concern included:

- Bacteria and nitrogen reaching private wells
- Site disturbance in wetland areas increasing sediment load and associated phosphorus to reservoir tributaries

Methods—Complete analyses were performed using watershed indicators, nutrient loading, hot spot mapping, and a review of existing monitoring data. State permits for repairs and construction of alternative wastewater treatment systems were mapped to show trends. Build out analysis was used to predict future impacts.

Results—The Scituate Reservoir, owned and maintained by the Providence Water Supply Board, is the source of drinking water for the City of Providence and surrounding urban communities. The reservoir supplies drinking water to 600,000 people (60 percent of Rhode Island's population). The reservoir and its watershed are located primarily in the towns of Foster, Scituate, and Glocester, RI. Within these communities, residents and businesses rely solely on groundwater to supply private wells and small public supplies.

A watershed assessment conducted by the University of Rhode Island, Cooperative Extension for town officials and the Providence Water Supply Board found that, due to large lot zoning, the reservoir watershed was at overall low risk of contamination from onsite wastewater treatment systems, except for one village that serves as a social and business center. In this village area, dense development on small lots resulted in high nitrogen loading estimates. Further analysis using hot spot mapping showed a high concentration of intense land uses on highly permeable soils (Figure 10-7). In addition, parcel mapping showed that more than one-half of the parcels, and all of the smallest lots, were developed before state onsite wastewater treatment standards were adopted. Additional growth potential on "grandfathered" lots and aging onsite systems raised concerns about the quality of groundwater. Although high nitrogen loading estimates do not always correspond to high nitrogen concentrations based on monitored data, several wells in the village had elevated nitrate levels, with concentrations in groundwater at times exceeding safe drinking water standards. There was also concern in the community that advanced onsite treatment technologies were making it much easier to build on highly marginal sites, once thought to be unbuildable.

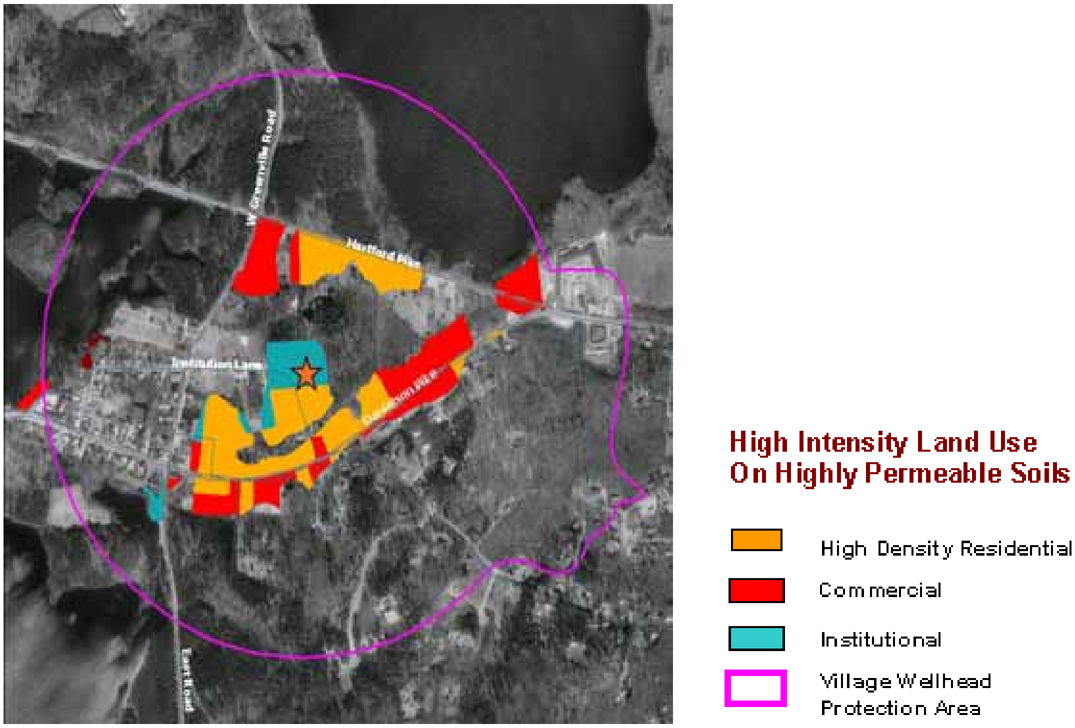


Figure 10-7
Groundwater Hot Spots

Wastewater Management—Based on assessment results, two of the watershed communities applied for and received a state grant to develop a joint wastewater management plan. The plan is currently under development. Based on the finding of low risks throughout the watershed, appropriate management practices would include:

- Implementation of a public education program for onsite system care
- Mandatory onsite system inspections, and maintenance as needed for the village center and other high-risk locations, including large systems throughout the watershed and systems located within wetland buffers
- Private well testing in the village center

Based on the fact that towns are in the process of developing wastewater management plans and do not currently have the capacity to oversee maintenance of advanced treatment systems, it was recommended that the towns establish minimum standards for buildable lots that prohibit new construction of onsite wastewater treatment systems on water tables less than two feet. These standards would eliminate the most highly marginal sites from development and reduce risk of failure if advanced treatment systems are not maintained. In addition, it was strongly recommended that the towns establish minimum standards for impervious cover and adopt a "no net increase in runoff" requirement to decrease runoff in marginal areas.

11 BEYOND THE DESK TOP

Once the assessment is completed and high-risk areas in the community have been identified, further work must be conducted to quantify the need for changes in wastewater infrastructure and management. Before proceeding to this stage, assessment results should be formally presented to the public, with all public input duly noted and incorporated into the assessment process. The next step is to verify assessment results through field studies. Findings can then be used in the development of new wastewater management policies. In order to ensure that new policies are practical and will be supported by the community, further public involvement and education efforts will be required.

This chapter explores a variety of follow-up actions designed to implement recommendations of a screening level assessment including:

- Public outreach strategies using assessment results
- Techniques for verifying results by directed field investigations
- Incorporating assessment results in wastewater plans and ordinances
- Designing an educational strategy to support development of a wastewater management program

Public Outreach Strategies Using Assessment Results

The completion of the assessment is the beginning of the real work in implementing wastewater management recommendations. Typically, only a small group of participants will have been involved in the assessment process, and not all of these participants will be in positions of authority to adopt recommendations. Whether findings are directed toward development of wastewater plans, new maintenance requirements, public education, or monitoring, public input is needed to identify key issues of concern and to generate continued support, particularly while assessment results are still fresh in people’s minds and interest is high.

It is important to realize that assessment recommendations are not truly town priorities unless they are incorporated into town plans, capital improvement budgets, and ordinances. The next step in the planning process is for local officials to:

- Review and discuss assessment results in light of current management practices
- Solicit public input
- Establish local priorities for improving wastewater management
- Determine how these priorities will be incorporated into town plans and ordinances

Outreach strategies must be tailored to the needs and concerns of community members. Community endorsement is essential to the success of management or pollution prevention programs (Olson, et al., 2002). Successful communities have had at least one committed leader capable of persuading other influential members of the community and who was willing to persist even when progress was slow.

Recommended Actions by Advisory Groups

Advisory groups recommend the following actions:

- Frame key messages and recommendations from the assessment results.
- Develop a list of key community leaders who would be influential in adopting wastewater management improvements by lending their support either directly or indirectly. These might include elected officials, appointed board members, town staff, business leaders, or other recognized community leaders. Include those who might be against wastewater management changes, and if possible, have them join the working group. Arrange opportunities to present preliminary results in order to present the case for a local wastewater management program, and to recognize and consider public concerns during formal public presentations.
- Based on feedback from preliminary presentations, finalize key recommendations of the assessment. Develop fact sheets to summarize findings and recommendations. If resources allow, create an attractive, colorful brochure that will attract public attention (Figures 11-1 and 11-2). In the example shown in Figure 11-1, subwatersheds were color-coded based on estimated nutrient loading. The map was used to convey the information at the neighborhood scale.

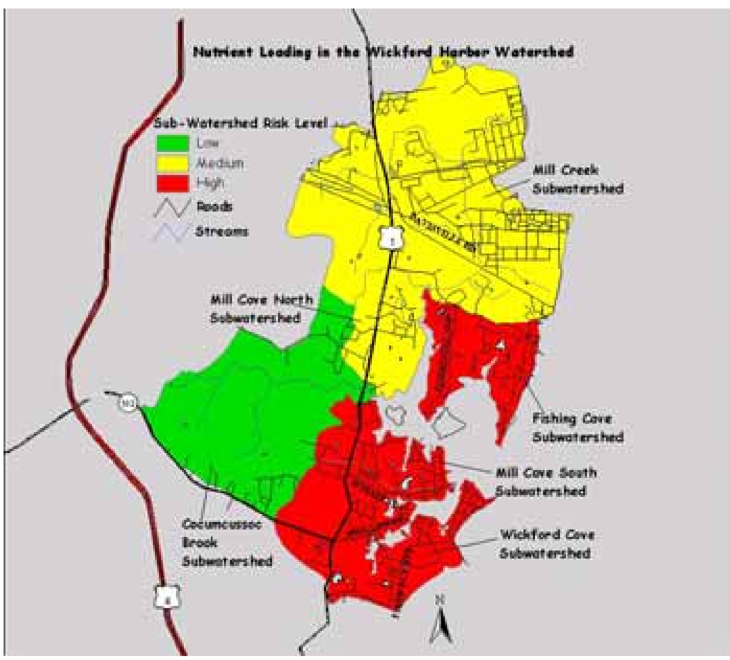


Figure 11-1
Example Portion of a Fact Sheet That Was Developed Based on Assessment Results

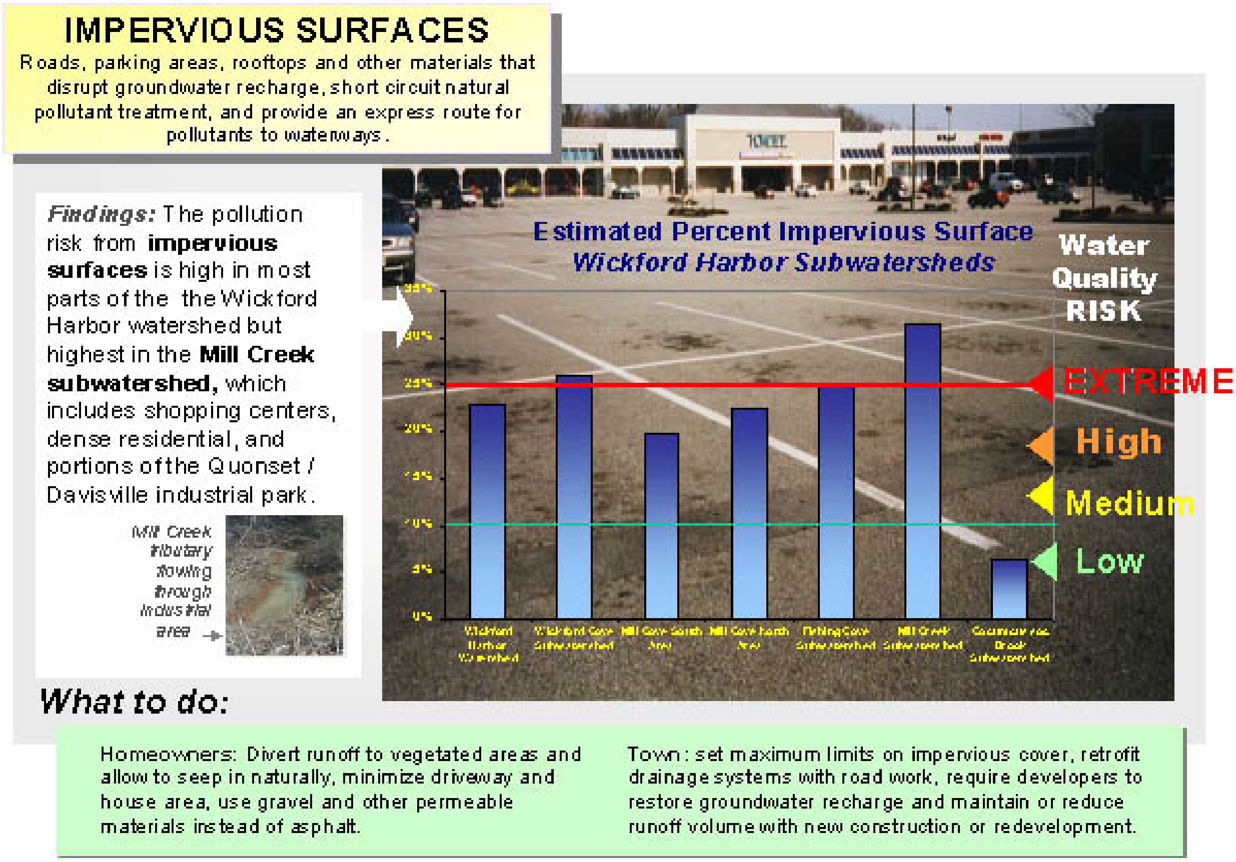


Figure 11-2
Public Educational Material Handouts That Target Watershed Homeowners and Town Officials

- Schedule a presentation of results at the convenience of town officials, either at a regularly scheduled council meeting or special workshop. Publicize the meeting through a press release and follow up with phone calls to reporters to make sure they understand what is being presented. Keep the summary presentation short (no more than 20 minutes), and allow enough time for discussion. If time permits, consider scheduling a companion presentation on a related topic of interest, such as a basic introduction to operation and maintenance of onsite wastewater treatment systems, ideally with sample components and hands-on examples.
- Work with elected officials to formalize or expand membership on the assessment committee. As noted previously, the committee should be a broad-based advisory group representing a variety of interests, with a specific charge and timeline to prioritize recommendations.

Techniques for Verifying Results by Directed Field Investigations

Once assessment results and recommendations have been made public, expect a fair amount of public comment and concern. Ideally, those presenting results will be knowledgeable regarding the types of assumptions and inputs that were used during the assessment process. Public input is a valuable source of information, and can provide new insights. Any comments received during the public review process should be addressed.

Building on Map Assessments

Mapped results can be used to support a number of more advanced wastewater management activities, as follows:

- Target locations for field inspections, and work with regulators to conduct investigations.
- With the aid of parcel maps, identify homeowners in high water table sites and conduct a direct mail survey to collect information about wastewater system function; include educational materials on wastewater treatment system maintenance and alternatives.
- Work with regulatory agencies to obtain accurate information on the location of existing alternative technologies in the community. Because alternative technologies are certain to fail without maintenance, particularly since many are sited in difficult locations, tracking routine maintenance and ensuring maintenance contracts are annually renewed is a top priority.
- Work with local scientist-led watershed groups to monitor water quality near locations mapped as potentially high-risk areas.

  NOTE: Identifying water quality impacts from onsite systems is extremely challenging. Poor sampling designs often show no evidence of contaminants even where systems are known to be failing. In addition, it is critically important that any monitoring done is under EPA-approved Quality Assurance/Quality Control plans. Otherwise, data collected will not meet state and EPA standards and will be a wasted effort. When a credible volunteer-based organization is not available to assist with monitoring, contracting with a consulting professional is likely to be the preferred alternative. EPA offers extensive resources on monitoring that may be useful for groups seeking data or looking to develop a monitoring program (available online at www.epa.gov/owow/monitoring).

Field Studies

GIS analyses often lead to additional investigations using more in-depth map analysis or field studies or a combination of the two methods. Where additional information is needed to build support for adopting management practices, assessment results may be useful in identifying data gaps, selecting the type of data needed, and designing a sampling program.

Mapped “hot spots” are sites of potential pollution risk. Hot spots should be investigated to determine if there is an actual threat, and if so, whether the problem is a low-level nonpoint pollution problem or a serious threat that needs to be remediated. It is important to proceed carefully and work with groups who may already be involved in managing land use in certain areas. For example, USDA's Natural Resource Conservation Service may have developed farm management plans in the area and could share information with town officials about existing conditions.

Local volunteers working with a watershed organization can conduct shoreline surveys. Volunteers can map shoreline features, noting:

- Extent of vegetated buffers
- Stormwater discharge locations
- Lawns extending to the waters edge that might invite waterfowl
- Evidence that wastewater discharges may be affecting water quality

When planning such surveys it is important to have a clear strategy for the use of the results. For example, assessment results can be used to notify shoreline property owners about results, identify actions residents can take, and to periodically repeat the survey to track change over time.

Field studies can include:

- **Rapid stream bioassessment—**Surveys of stream condition and aquatic habitat conducted in cooperation with state agencies, university groups, or volunteer monitoring organizations. Some scientific support is needed to train volunteers and assist in evaluating results.
- **Well-water testing—**In situations where private wells are at risk, organizing a private well-water testing program can raise awareness of potential impacts from onsite wastewater treatment systems and alert residents to contamination problems. In one Rhode Island community, concern over potential well-water contamination from a combination of substandard onsite systems, shallow dug wells, small lots (5,000-10,000 square feet), and sandy soils led a local watershed, the Salt Pond Coalition, to organize a well-water sampling program in the Green Hill Pond coastal area. The same wells were sampled over a period of five years to establish trends, but in the past year, the program has been expanded to all interested citizens. One homeowner with a contaminated well upgraded her cesspool to an advanced treatment system, which eliminated the problem.
- **Mail or phone survey—**A relatively inexpensive means to collect information about the condition of onsite wastewater treatment systems. Before adopting a wastewater management program, a town might want to conduct a public survey to determine system condition and to evaluate public perceptions regarding various wastewater management options.

Incorporating Assessment Results into Wastewater Plans and Ordinances

Because the assessment methods in this handbook focus on potential land use impacts to water resources, assessment results can be used to strengthen onsite wastewater treatment plans as well as system siting and design standards. The specific strategies a community might utilize in implementing a local wastewater management program will vary depending on the level of authority granted to local or county governments to oversee inspection, maintenance, and upgrading of onsite systems. In many cases, local land use authority can be used to incorporate treatment performance standards into zoning ordinances. These provisions may be adopted town-wide with more stringent standards in critical areas. Alternatively, they may be included under watershed overlay districts, groundwater overlay ordinances, or special districts (such as a high water table ordinance that applies to particular areas of the community).

Generally, communities sequentially build management programs. A typical sequence begins with a planning process (such as the needs assessment outlined in this handbook), then the adoption of an ordinance with staged implementation depending on protection priorities, and then eventually the setting of specialized performance standards. Information generated by the assessment process presented in this handbook can be incorporated into each phase of the wastewater management planning process as described in the examples that follow.

Wastewater Management Plans

A wastewater management plan is typically the first step in establishing a wastewater management program. The plan collects existing information about onsite wastewater treatment systems, identifies existing conditions, evaluates suitability for onsite wastewater treatment in developing areas, and may set specific water quality goals for critical water resources. In addition, the plan evaluates septage handling capacity, outlines educational activities, financial aid for homeowners to upgrade systems, and in general, lays out a plan for managing wastewater treatment needs.

Much of the data generated by the assessment is incorporated into the plan, including descriptions of existing conditions, site constraints, and the estimated impact of onsite systems relative to other pollution sources. The plan expands upon the assessment data to evaluate options for wastewater treatment and develop town policies and goals. The wastewater management plan can be adopted as an element of the comprehensive plan, which affords the same legal basis as town ordinances in many parts of the country. In some cases, a state-approved town plan carries other benefits. In Rhode Island, homeowners in towns with a state-approved plan are eligible for low interest loans supported by State Revolving Loan Funds.

Wastewater Management Ordinances

Local wastewater management ordinances provide for some level of maintenance oversight of onsite wastewater treatment systems. These vary widely in the requirements placed upon system owners. The strongest ordinances mandate system inspection, with inspection results reported to the town. In some cases, the town may hire a town inspector, but typically homeowners are required to contract with a private inspector. To ensure consistency, a standard inspection method must be used, training provided, and certification required for inspectors completing the training program. The wastewater management ordinance should include provisions to require system repair when an inspection identifies deficiencies. A sunset clause for cesspools may be added, requiring that homeowners replace cesspools within a certain number of years from the date of the first inspection. Typically, a part-time staff person can handle the management program. A computerized tracking program is used to maintain results and generate notices as needed. In some communities, data is transferred to a GIS system that is used to track locations of inspections and other actions.

Assessment results are typically used to develop findings of fact for the ordinance, justifying the need for the ordinance based on environmental sensitivity, soils, and site constraints, and the number of aging onsite systems in the community.

The Town of South Kingstown, Rhode Island adopted a wastewater management ordinance that requires all homeowners to inspect their system, pump the tank, and conduct other maintenance as needed, and report results to the town. Failing systems must be repaired or replaced. Cesspools must be replaced within five years of the first inspection, or within one year if the house is sold. With 6,000 systems located within the town, the first inspections were phased in over seven inspection districts based on plat map boundaries (Figure 11-3).

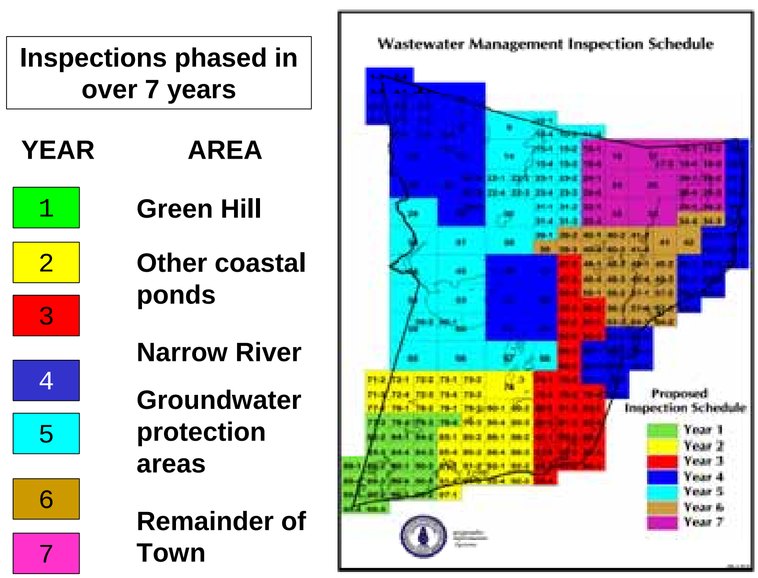


Figure 11-3
South Kingstown, RI Wastewater Inspection Districts Staged Based on Resource Concerns

The districts were established based on resource protection priorities so that the watersheds of sensitive coastal ponds and embayments are inspected first, followed by groundwater recharge areas, and then the remainder of town. The ordinance and accompanying regulations are available to view or download online, along with fact sheets and the town's wastewater management plan at www.uri.edu/ce/wq/Safewater/sk_index.html.

Treatment Performance Standards

Treatment standards specify the level of wastewater treatment that an onsite system must provide. When paired with a mandatory inspection ordinance and cesspool phase-out requirements, the two ordinances can provide a powerful tool for eliminating substandard systems in a fairly short period of time. In critical areas, treatment level can be set to reduce risks from conventional systems. Because technologies continue to evolve and improve over time, the actual list of technologies that meet specified standards should be available through the town, but should not be part of the actual ordinance.

The Town of New Shoreham (Block Island), Rhode Island established treatment standards requiring use of advanced treatment for either nitrogen or pathogen reduction based on location in a critical resource area in combination with site-specific soil conditions. Critical areas included wellhead protection areas, the watershed of the Great Salt Pond coastal embayment, and buffers to surface waters and wetlands. The ordinance defines the level of treatment in terms of Biochemical Oxygen Demand (BOD), Total Suspended Solids (TSS), Nitrogen, and Bacteria reduction.

The Town of Jamestown, Rhode Island, integrates requirements for advanced treatment with maximum percent impervious limits of 15 percent and a requirement for no net discharge of stormwater runoff. This ordinance applies to two densely developed areas of the town where lot sizes are generally smaller than one acre and soils have restrictive permeability and high water table.

Both the Block Island and the Jamestown ordinances establish minimum distances to groundwater for new construction, with a minimum of two feet to groundwater required in Block Island, and 18 inches required in Jamestown. Other requirements that apply town-wide include watertight tanks, tank access risers to grade, and effluent filters. The Block Island and Jamestown ordinances are available online at www.uri.edu/ce/wq/Safewater/bi_index.html (Block Island) and www.jamestownri.net (Jamestown High Groundwater Table Ordinance).

Designing an Educational Strategy to Support Development of a Wastewater Management Program

An education outreach strategy is a key element of a wastewater management program. Education outreach is as essential as a wastewater management plan or ordinance. In some respects, it is the most important element, since it is doubtful that a program would be adopted without ongoing community support.

The concept of developing an educational strategy for a wastewater management program can be overwhelming when viewed as a whole. In practice, educational outreach supporting local wastewater management can be viewed as a series of marketing programs, each designed to support adoption and maintenance of individual program elements.

GIS Maps as an Educational Tool

The computer-generated maps created during the assessment process are also powerful and persuasive tools for capturing local interest. Site-specific, large-scale maps not only capture local attention, but also provide an opportunity to engage local officials and the public in a discussion of pollution threats and control options. For those creating maps, it is important to understand that simple maps that show fewer features are often the most useful, especially when presenting findings to non-technical audiences who may not be accustomed to viewing GIS maps.

Compared to standard street maps and USGS topographical survey maps, GIS land use and soils maps may appear highly abstract. Introducing and describing each map to orient the viewer, especially when dealing with more complex maps, is well worth the extra time involved. Other issues to consider are:

- Overlaying technical maps and charts will only confuse non-technical audiences.
- Where possible, convert chart data to map form for the simplest, most direct display of information.
- Maps created to summarize assessment results, especially those in summary fact sheets, should be simple and readily understandable at a glance.
- Even more useful than technical maps are photographs of the area. Collect photos of the community and intersperse them with charts and graphs to help add interest to presentations.
- Where possible, use standard land use colors adopted by land use planners, and keep use of color palettes consistent. This consistency will enable the audience to easily understand each new map presented.
- When presenting a series of maps order the presentation in a coherent manner, and save more technical maps for last.
- Invite the audience to view the maps close up prior to the presentation, and help them identify their neighborhood.
- Make sure that streets names and local landmarks such as ponds, beaches, or schools are clearly mapped and labeled.
- During the presentation, always point to the areas referred to in the presentation to continually orient your audience.

Reaching the Audience

To effectively communicate to an audience, it is necessary to:

- Define the audience
- Define the message
- Select communication methods

Define the Audience

Key groups that define an audience include:

- Local officials who will ultimately be making the decisions on what program elements to adopt and when
- Homeowners
- Business owners
- Members of local advocacy groups
- Onsite wastewater treatment system designers and installers
- State regulators

Fortunately, there are likely to be a number of local groups that work with some of these audience members. Coordinate closely with others involved in training and education to benefit communication efforts and the audience.

Define the Message

A number of methods are available to determine the messages that will best reach the audience. For example, research target audiences through any of the following means:

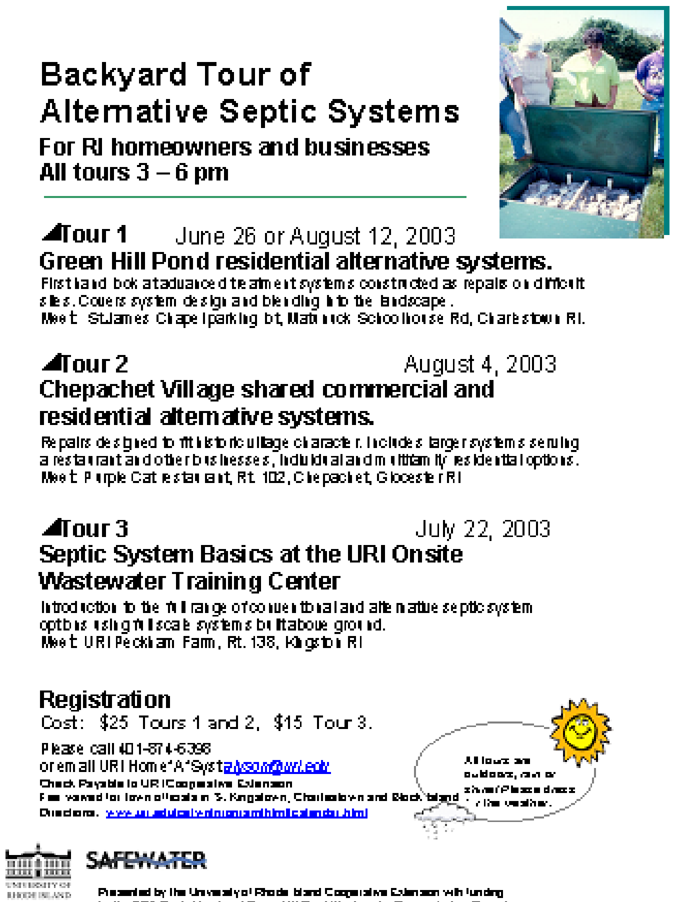
- Focus groups
- Phone interviews
- Trade associations
- Public agencies
- University marketing classes

Working with a local advisory group can provide a diverse sounding board for developing key messages. For professional support, try recruiting volunteers with expertise in public relations, design, or marketing. Hiring a consultant to help craft a message and to give publications a consistent look is often well worth the price. Be careful about being viewed as “too slick”; in many communities, informal approaches are more acceptable.

Select Communication Methods

Types of communication methods include:

- Press releases and press conferences
- Informational meetings with community groups and neighborhood organizations (Figure 11-4)
- Educational workshops
- Demonstration sites



Backyard Tour of Alternative Septic Systems

For RI homeowners and businesses
All tours 3 – 6 pm

Tour 1 June 26 or August 12, 2003
Green Hill Pond residential alternative systems.
First hand look at advanced treatment systems constructed as repairs on difficult sites. Covers system design and blending into the landscape.
Meet: St. James Chapel parking lot, Matunuck Schoolhouse Rd, Charlestown RI.

Tour 2 August 4, 2003
Chepachet Village shared commercial and residential alternative systems.
Repairs designed to fit historic village character. Includes larger systems serving a restaurant and other businesses, individual and multifamily residential options.
Meet: Purple Cat restaurant, Rt. 102, Chepachet, Glocester RI

Tour 3 July 22, 2003
Septic System Basics at the URI Onsite Wastewater Training Center
Introduction to the full range of conventional and alternative septic system options using full scale systems built above ground.
Meet: URI Peckham Farm, Rt. 138, Kingston RI

Registration
Cost: $25 Tours 1 and 2, $15 Tour 3.
Please call 401-874-6398
or email URI Home*A*Syst

SAFEWATER

Figure 11-4
Sample Strategy for Reaching the Audience

There are a number of excellent resources for designing a public information campaign, including:

- The Council of State Government's (1998) *Getting in Step, A Guide to Effective Outreach in Your Watershed* and the companion document, *Getting in Step, A Guide to Engaging and Involving Stakeholders in Your Watershed* (MacPherson and Tonning, 2003). Both documents are available to view or download at EPA's website: www.epa.gov/owow/watershed/outreach/documents.
- *Ready, Set, Present! A Data Presentation Manual for Volunteer Water Quality Monitoring Groups* (Schoen et al., 1999) is another excellent guide to presenting scientific data to non-technical audiences.

Implementing GIS-Based Wastewater Management Planning

This handbook has presented a variety of tools for making use of GIS databases in wastewater management planning. Rather than a structured model, the techniques used present a way of organizing and displaying data that highlights key risks and potential threats. The approach demonstrates the power of GIS as a planning tool to make use of locally relevant data to support wastewater management decisions. Map analysis targeting high-risk problem areas are particularly useful in directing management actions. Techniques for evaluating future growth and projecting potential wastewater treatment needs and associated land use impacts are particularly useful to communities facing the challenge of meeting development needs while also protecting vital water supplies, recreational waters, and other critical water resources.

High-quality, high-resolution GIS databases are already widespread and rapidly expanding. With increasing access to basic land use and soils coverages, more communities will have the ability to apply GIS tools in screening level analyses to bring local data into consideration in meeting wastewater planning needs. The methods outlined in this handbook are intended to provide an approach that can be adapted to GIS databases around the country, recognizing that local landscape features and land use characteristics must be tailored to highlight the type of pollution risks most likely to affect local water resources.

With the focus on watersheds as the basic unit for water resource management and land use planning in recent years, lessons learned using a watershed approach can shed light on applications for wastewater management planning as well. According to Tom Schueler, founder of the Center for Watershed Protection, one reason why watershed plans fail is that the plan focuses on the tools of watershed analysis rather than their outcomes (Center for Watershed Protection, 2000). The intent of the methods presented in this manual is to provide the tools needed to foster tangible outcomes to enable communities to take action to meet wastewater treatment needs and protect local water resources.

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13 LIST OF ACROYNYMS AND ABBREVIATIONS

A_x	Area of land use category falling on hydrologic group A, B, C, or D soils
BMP	Best Management Practice
CERCLA	The Comprehensive Environmental Response, Compensation, and Liability Act.
DRG	Digital Raster Graphic
ET	Evapotranspiration (evaporation + plant transpiration; assigned at the start of analysis)
FEMA	The Federal Emergency Management Agency
GIS	Geographic Information Systems
$GW_{recharge}$	Recharge to groundwater
HD	High Density
HNC	Upper limit export coefficient for nitrogen (N)
HPC	Upper limit export coefficient for phosphorus (P)
HSG	Hydrologic Soils Group
LD	Low Density
LLC	Lower limit of coefficient for a given land use
LNC	Lower limit export coefficient for nitrogen (N)
LPC	Lower limit export coefficient for phosphorus (P)
LU	Land Use
MD	Medium Density
MHD	Medium High Density
MLD	Medium Low Density
N	Nitrogen
NC	Most likely export coefficient for nitrogen (N)
NLCD	National Land Cover Dataset
NOAA	National Oceanographic and Atmospheric Administration

P	Phosphorus
PC	Most likely export coefficient for phosphorus (P)
PPT	Average annual precipitation (depth $\times$ study area)
Res	Residential
RO_i	Runoff volume from land use category *i*
SRC	Surface runoff coefficient for a given land use (LU)
SRC_x	Surface runoff coefficient for LU_i falling on hydrologic group A, B, C, or D soils
SRO	Average annual surface runoff
SSURGO	Soil Survey Geographic digital database
STATSGO	State Soil Geographic database
TMDL	Total Maximum Daily Load
ULC	Upper limit of coefficient for a given land use
USDA	United States Department of Agriculture
UTM	Universal Transverse Mercator
EPA	United States Environmental Protection Agency
USGS	United States Geological Survey

14 GLOSSARY

This section contains definitions of terms used throughout this document.

303(d) List—A list of all surface waters in a state for which beneficial uses of the water—such as drinking, recreation, habitat, and industrial use—are impaired by pollutants. Periodic generation of this list by each state is required by section 303(d) of the federal Clean Water Act.

Accuracy—A measure of how closely a model's outcome mirrors reality.

Activated sludge process—A biological wastewater treatment process in which biologically active sludge is agitated and aerated with incoming wastewater. The activated sludge is subsequently separated from the treated wastewater (mixed liquor) by sedimentation and most of it is returned to the process.

Adsorb—To adhere in an extremely thin layer of molecules (as of gases, solutes, or liquids) to the surfaces of solid bodies or liquids with which they are in contact.

Aerobic treatment unit—A mechanical onsite treatment unit that provides secondary wastewater treatment by mixing air (oxygen) and aerobic and facultative microbes with the wastewater.

Algae—A chiefly aquatic plant or plantlike organism.

Alluvium—Clay, silt, sand, gravel, or similar detrital material deposited by running water.

Anderson Level Classification system—A uniform land use classification system that uses satellite imagery to divide land use into 21 categories.

Anthropogenic—Pertains to the (environmental) influence of human activities.

Aquifer—A water-bearing stratum of permeable rock, sand, or gravel.

Aquifer recharge area—An area where rainfall can infiltrate into an aquifer.

ArcView—Desktop computer GIS and mapping software that provides data visualization, query, analysis, and integration capabilities along with the ability to create and edit geographic data.

Bacteria—Single-celled microorganisms that lack a fully defined nucleus and contain no chlorophyll. Bacteria of the coliform group are considered the primary indicators of fecal contamination and are often used to assess water quality.

Baseflow—Water that enters a stream from sources other than direct runoff of precipitation, primarily from groundwater. Since it constitutes most of the streamflow during low flow periods, it is an important parameter in evaluating groundwater systems and their interaction with surface water.

Bedrock—The solid rock underlying unconsolidated surface materials.

Biodiversity—The variety of life in all its forms, levels, and combinations. Includes ecosystem diversity, species diversity, and genetic diversity.

BUFFER (GIS terminology) —Creates a new polygon theme by adding distances (a buffer) around point, line, or polygon features.

Build-out—A condition in which a town has or will become completely developed in accordance with its current zoning regulations.

Calibration—The process of adjusting model parameters to obtain the best fit of model output with monitored data.

CERCLA—The Comprehensive Environmental Response, Compensation, and Liability Act. This act established prohibitions and requirements concerning closed and abandoned hazardous waste sites.

Clean Water Act—The Clean Water Act contains a number of provisions to restore and maintain the quality of the nation's water resources. One of the provisions is section 303(d), which establishes the TMDL program.

CLIP (GIS terminology)—Creates a new theme by overlaying two sets of features. The polygons of the overlay theme define the clipping region. CLIP uses the clipping region as a "cookie cutter"; only those input theme features that are within the clipping region are stored in the output theme. Input theme features can be points, polylines, or polygons.

Coastal embayment—A coastal area that resembles a bay.

Coefficient—A number that serves as a measure of some property or characteristic (as of a substance, device, or process).

Coverage—A digital vector storage framework for geographic information that is produced by ARC/INFO and used by ARC/INFO, ArcView, ArcGIS and other widely used GIS software.

Decision support model—Provides a relatively quick and inexpensive analysis to aid in planning and directing more detailed analyses or data collection.

Deterministic model—A model that does not include built-in variability: same input will always equal the same output.

Dynamic model—A mathematical formulation describing the physical behavior of a system or a process and its temporal variability.

Easement—A right of way giving individuals other than the owner permission to use a property for a specific purpose.

Effluent—An outflow of water usually containing waste or other pollutants.

Empirical model—Uses equations derived from observed relationships without modeling the processes themselves. These equations are often developed using regression techniques.

ERASE (GIS terminology)—Creates a new theme by overlaying two sets of features. The polygons of the overlay theme define the erasing region. Input theme features that are within the erasing region are removed. The output theme contains only those input theme features that are outside the erasing region.

Estuary—A water passage where the tide meets a river current; especially an arm of the sea at the lower end of a river.

Eutrophication—The process by which a body of water becomes enriched in dissolved nutrients (such as phosphates) that stimulate the growth of aquatic plant life usually resulting in the depletion of dissolved oxygen.

Evaporation—Process of converting to a vapor.

Evapotranspiration—Loss of water from the soil both by evaporation and by transpiration from the plants growing thereon.

F.A.R.—Floor Area Ratio. Commonly used for nonresidential development, floor area ratio measures the relationship of the total building square feet to the total site area. For example, a 10,000 square foot building located on a 40,000 square foot parcel would have a F.A.R. of 0.25 (building area divided by parcel acreage). Because the number of floors is not considered, buildings built on one level may occupy a very large proportion of a lot, while a multi-story structure with the same F.A.R. may have a very small footprint.

Fecal coliform bacteria—A subset of total coliform bacteria that are present in the intestines or feces of warm blooded animals. They are often used as indicators of the sanitary quality of water.

FEMA—The Federal Emergency Management Agency provides many programs, courses, and materials to support emergency preparedness and response for emergency personnel as well as the general public.

Flushing time—The time needed to drain a volume through an outlet with a known current velocity.

Flux—Movement and transport of mass of any water quality constituent over a given period of time. Units of mass flux are mass per unit time.

Geographic Information Systems (GIS)—GIS is a system of hardware and software used for storage, retrieval, mapping, and analysis of geographic data.

Groundwater—The supply of fresh water found beneath the earth's surface usually in aquifers, which supply wells and springs. Because groundwater is a major source of drinking water, there is growing concern over contamination from leaching agricultural or industrial pollutants and leaking underground storage tanks.

Groundwater recharge—The natural process of infiltration and percolation of rainwater from land areas or streams through permeable soils into water-holding rocks that provide underground storage (aquifers).

Hardpan—A very dense soil layer caused by compaction or cementation of soil particles by organic matter, silica, sesquioxides (aluminum and iron), or calcium carbonate, for example.

Heads-up digitizing—Digitizing or drawing lines on the computer screen using scanned aerial photos, satellite imagery, or digital raster graphic (DRG) files as a backdrop.

Hybrid model—Uses a combination of empirical and process-based relationships. Many models fall in this category, with mechanistic relationships being used where they are well understood, such as hydrologic processes, and where input data is available and reliable.

Hydrographic—Of or relating to the characteristic features (such as flow or depth) of bodies of water.

Hydroline—A linear feature on a GIS map representing a waterbody such as a stream or tributary.

Hydrology—The study of the distribution, properties, and effects of water on the earth's surface in the soil and underlying rocks, and in the atmosphere.

Hydropoly—A polygon on a GIS map representing a waterbody such as a lake or pond.

Imperviousness—A catch-all term for pavement, rooftops, cement, and other impermeable surfaces that prevent rainwater from seeping into the ground.

Indicator—A measurable quantity that can be used to evaluate the relationship between pollutant sources and their impact on water quality.

Infiltration—The portion of rainfall or surface runoff that moves downward into the subsurface rock and soil.

Mass balance—An equation that accounts for the flux of mass going into a defined area and the flux of mass leaving the defined area. The flux in must equal the flux out.

Mechanistic model—Uses equations that describe the mechanisms that control the processes. Generally complex and requiring detailed input data.

Monitoring—Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, plants, or animals.

Mylar—A transparent or semitransparent map used for planning purposes.

NPDES—National Pollutant Discharge Elimination System. The national program for issuing, modifying, revoking, reissuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements under Sections 307, 402, 318, and 405 of the Clean Water Act.

Non-point source pollution—Rainfall or snowmelt moving over and through the ground that picks up and carries away natural and human-made pollutants and deposits them into lakes, rivers, wetlands, coastal waters, and even underground sources of drinking water.

Nutrient—Any of the mineral substances that are absorbed by the roots of plants for nourishment.

Onsite wastewater treatment—A system for the removal and treatment of wastewater from the home that treats and distributes the wastewater and protects our water resources.

Orthophotograph—Digital image in which distortion from the camera angle and topography have been removed, thus equalizing the distances represented on the image.

Parameters—Assigned values characterizing the system being modeled. Remains constant throughout the analysis.

Parcel—A tract or plot of land.

Pathogens—Biological entities capable of causing illness in other organisms (for example, protozoa, bacteria, viruses).

Peat filter—Wastewater disposal technology characterized by dosed delivery of treated wastewater to a bed of compacted peat.

Precision—A measure of how many digits a model outcome reports for numerical values.

Precipitation—The falling to earth of any form of water.

Point source pollution—Pollutants from a single, identifiable source such as a factory or refinery.

Pollutant—Dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical waste, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, dirt, and industrial, municipal, and agricultural waste discharged into the water. (CWA Section 502(6)).

Riparian—Relating to or living or located on the bank of a natural watercourse (as a river) or sometimes of a lake or a tidewater.

Runoff—Drainage or flood discharge that leaves an area as surface flow or as pipeline flow.

Sand filter—A packed bed filter of sand or other granular materials used to provide advanced secondary treatment of settled wastewater or septic tank effluent.

Screening-level risk assessment—An assessment performed to determine potential risk.

Sediment—Organic or inorganic material often suspended in liquid that eventually settles to the bottom.

Sensitivity—A measure of how readily a system responds to a stressor.

Shapefile—A spatial data set in GIS that stores geometry and attribute information for the spatial features in a dataset.

Soil hydrologic group—A group of soils having similar runoff potential under similar storm and cover conditions. Soil properties include depth to a seasonally high water table, intake rate and permeability after prolonged wetting, and depth to a slowly permeable layer.

Sole source aquifer—An aquifer that is the sole or principal drinking water source for the area and which, if contaminated, would create a significant hazard to public health.

Sorb—To take up and hold by either adsorption or absorption.

Steady state model—Mathematical model of fate and transport that uses constant values of input variables to predict constant values of receiving water quality concentrations.

Stochastic model—Probability distribution calculated for a set of input probability distributions.

Stormwater—The portion of precipitation that does not naturally percolate into the ground or evaporate, but flows via overland flow, interflow, channels, or pipes into a defined surface water channel or a constructed infiltration facility.

SSURGO—Soil Survey Geographic. The most detailed level of soil mapping done by the Natural Resources Conservation Service (NRCS). SSURGO digitizing duplicates original soil survey maps.

STATSGO—State Soil Geographic. An active database archive of state soil data for 49 states (except Alaska).

Till—Unstratified glacial drift consisting of clay, sand, gravel, and boulders intermingled.

TMDL—Total Maximum Daily Load. The sum of the individual wasteload allocations for point sources, load allocations for non-point sources and natural background, and a margin of safety. TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a state's water quality standard. States are required by the Environmental Protection Agency to carry out TMDL calculations on all of their impaired waterbodies.

Topography—Land contours and elevations.

Transpiration—Passage of watery vapor from a living body through a membrane or pores.

Ultraviolet light disinfection—Use of radiation from the ultraviolet region of the electromagnetic spectrum for purposes of inactivating bacteria and viruses.

UNION (GIS terminology)—Creates a new theme by overlaying two polygon themes. The output theme contains the combined polygons of both themes. Only polygon themes can be combined using UNION. The feature table for the output theme contains all user-selected fields from the input and overlay theme feature tables.

UTM (Universal Transverse Mercator)—A map projection in the form of a grid. The world is divided into 60 north-south zones, each covering a strip 6 degrees wide in longitude. The conterminous 48 states are covered by 10 zones, from Zone 10 on the west coast through Zone 19 in New England.

Validation (of a model)—Process of determining how well the mathematical representation of the physical processes of the model code describes the actual system behavior.

Variables—Assigned values characterizing the scenarios within the system being modeled. Changes with each scenario.

Verification (of a model)—Testing the accuracy and predictive capabilities of the calibrated model on a data set independent of the data set used for calibration.

Wastewater treatment—Chemical, biological, and mechanical procedures applied to an industrial or municipal discharge or to any other sources of contaminated water in order to remove, reduce, or neutralize contaminants.

Water quality—The biological, chemical, and physical conditions of a waterbody. It is a measure of a waterbody's ability to support beneficial uses.

Watershed—A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

Wetland—An area that is constantly or seasonally saturated by surface water or groundwater with vegetation adapted for life under those soil conditions, as in swamps, bogs, fens, marshes, and estuaries.

A DATA ORGANIZATION EXAMPLE

Watershed or Subwatershed

Name for this Analysis: Bailey Brook

Scenario Name: Current Land Use

INPUT TABLE 1:

Surface Watershed Land Use/Hydrologic Soil Group Distribution:

	Total	Hydrologic Soil Group					% of Total
LAND USE	Area (acres)	A	B	C	D	Unknown	Land Use
[1] HD Res.(>8 /ac)	165.6	0.0	0.0	163.6	0.0	2.0	5.8%
[2] MHD Res.(4-7.9/ac)	740.0	0.0	0.0	728.7	3.2	8.0	25.7%
[3] MD Res.(1-3.9/ac)	149.4	0.0	0.0	143.6	0.1	5.7	5.2%
[4] MLD Res.(0.5-0.9/ac)	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
[5] LD Res.(<0.5/ac)	5.0	0.0	0.0	4.7	0.0	0.3	0.2%
[6] Commercial	335.9	0.0	0.0	212.8	0.4	122.6	11.7%
[7] Industrial	162.2	0.0	0.0	35.0	0.0	127.1	5.6%
[8] Roads	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
[9] Airports	82.9	0.0	0.0	41.3	0.3	41.3	2.9%
[10] Railroads	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
[11] Junkyards	7.7	0.0	0.0	7.7	0.0	0.0	0.3%
[12] Recreation	65.7	0.0	0.0	29.3	0.0	36.4	2.3%
[13] Institution	94.4	0.0	0.0	55.0	0.1	39.3	3.3%
[14] Pasture	56.5	0.0	0.0	50.2	4.7	1.5	2.0%
[15] Cropland	135.2	0.0	0.0	131.3	1.5	2.5	4.7%
[16] Orchards	195.0	0.0	0.0	193.1	0.1	1.7	6.8%
[17] Brush	132.2	0.0	0.0	96.2	1.0	35.0	4.6%
[18] Forest	7.8	0.0	0.0	7.7	0.0	0.1	0.3%
[19] Barren	0.2	0.0	0.0	0.0	0.0	0.2	0.0%
[20] Wetland	441.3	0.0	0.0	202.0	23.5	215.8	15.4%
[21] Water	33.7	0.0	0.0	1.9	0.0	31.8	1.2%
[22] Transitional	63.5	0.0	0.0	54.6	0.0	8.8	2.2%
Total (acres)	**2,874.0**	0.0	0.0	2,158.9	34.9	680.2	100%
		0.0%	0.0%	75.1%	1.2%	23.7%	

INPUT TABLE 2:							
Surface Watershed Name:		Bailey Brook					
Scenario Name:		Current Land Use					
Land Use Distribution in the Unsewered Portion of the Surface Watershed:							
	Unsewered	Non-Restrictive*(by hydrologic soil group)					% of Total
LAND USE	Total (acres)	A and B	C	D	Restrictive*	Unknown	Unsewered
[1] HD Res.(>8 /ac)	33.6	0.0	0.0	0.0	33.6	0.0	5.5%
[2] MHD Res.(4-7.9/ac)	75.0	0.0	0.0	0.0	73.9	1.0	12.3%
[3] MD Res.(1-3.9/ac)	8.5	0.0	0.0	0.0	8.0	0.5	1.4%
[4] MLD Res.(0.5-0.9/ac)	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
[5] LD Res.(<0.5/ac)	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
[6] Commercial	1.1	0.0	0.0	0.0	0.8	0.3	0.2%
[7] Industrial	8.7	0.0	0.0	0.0	4.3	4.5	1.4%
[8] Roads	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
[9] Airports	76.7	0.0	0.0	0.0	35.8	40.9	12.6%
[10] Railroads	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
[11] Junkyards	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
[12] Recreation	9.2	0.0	0.0	0.0	1.3	7.9	1.5%
[13] Institution	8.2	0.0	0.0	0.0	3.1	5.2	1.4%
[14] Pasture	11.7	0.0	0.0	0.0	10.9	0.8	1.9%
[15] Cropland	25.7	0.0	0.0	0.0	24.5	1.2	4.2%
[16] Orchards	79.4	0.0	0.0	0.0	79.0	0.4	13.0%
[17] Brush	10.9	0.0	0.0	0.0	10.8	0.1	1.8%
[18] Forest	2.0	0.0	0.0	0.0	2.0	0.0	0.3%
[19] Barren	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
[20] Wetland	222.8	0.0	0.0	0.0	81.8	141.0	36.6%
[21] Water	7.9	0.0	0.0	0.0	0.5	7.4	1.3%
[22] Transitional	27.1	0.0	0.0	0.0	19.2	7.9	4.5%
Total (acres)	**608.5**	0.0	0.0	0.0	389.6	218.9	100%
		0.0%	0.0%	0.0%	64.0%	36.0%	

INPUT TABLE 3:

Surface Watershed Name: Bailey Brook

Scenario Name: Current Land Use

Land Use Distribution in the Riparian Areas (RA 1) of the Surface Watershed:

			Unsewered Areas				
	Total Riparian	Sewered	Non-Restrictive*(by hydrologic soil group)				
LAND USE	Area (acres)	Areas	A and B	C	D	Restrictive*	Unknown
[1] HD Res.(>8 /ac)	19.4	17.0	0.0	0.0	0.0	2.4	0.0
[2] MHD Res.(4-7.9/ac)	67.4	52.4	0.0	0.0	0.0	15.0	0.0
[3] MD Res.(1-3.9/ac)	9.3	8.5	0.0	0.0	0.0	0.8	0.0
[4] MLD Res.(0.5-0.9/ac)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
[5] LD Res.(<0.5/ac)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
[6] Commercial	29.0	29.0	0.0	0.0	0.0	0.0	0.0
[7] Industrial	32.4	30.9	0.0	0.0	0.0	1.4	0.1
[8] Roads	0.0	0.0	0.0	0.0	0.0	0.0	0.0
[9] Airports	8.4	0.0	0.0	0.0	0.0	4.8	3.6
[10] Railroads	0.0	0.0	0.0	0.0	0.0	0.0	0.0
[11] Junkyards	0.0	0.0	0.0	0.0	0.0	0.0	0.0
[12] Recreation	4.6	4.6	0.0	0.0	0.0	0.0	0.0
[13] Institution	19.1	17.2	0.0	0.0	0.0	1.9	0.0
[14] Pasture	8.9	8.9	0.0	0.0	0.0	0.0	0.0
[15] Cropland	6.8	6.3	0.0	0.0	0.0	0.6	0.0
[16] Orchards	2.9	2.9	0.0	0.0	0.0	0.0	0.0
[17] Brush	52.5	47.2	0.0	0.0	0.0	5.3	0.0
[18] Forest	2.5	2.1	0.0	0.0	0.0	0.3	0.0
[19] Barren	0.2	0.2	0.0	0.0	0.0	0.0	0.0
[20] Wetland	110.8	83.6	0.0	0.0	0.0	24.8	2.4
[21] Water	1.0	0.6	0.0	0.0	0.0	0.3	0.0
[22] Transitional	14.9	9.9	0.0	0.0	0.0	2.8	2.1
Total (acres)	**390.1**	321.4	0.0	0.0	0.0	60.4	8.4
		82.4%	0.0%	0.0%	0.0%	15.5%	2.1%

B SURFACE RUNOFF COEFFICIENTS

Using the formula presented by Adamus and Bergman (1993), the runoff coefficient for each SOIL/LAND USE combination is estimated by:

$$C = LLC + (ULC - LLC) \times X$$

C = Runoff coefficient
LLC = Lower limit runoff coefficient for a particular land use
ULC = Upper limit runoff coefficient for a particular land use
X = 0 for soil type A; 1/3 for soil type B; 2/3 for soil type C; 1 for soil type D.

Upper and Lower Limit Runoff Coefficients for Each Land Use

LAND USE	LLC	ULC
HDR[a]	0.64	0.77
MHDR[a]	0.39	0.64
MDR[a]	0.23	0.39
MLDR[a]	0.16	0.23
LDR[a]	0.10	0.16
COMMERCIAL	0.50	0.90
INDUSTRIAL	0.50	0.90
ROADS	0.70	0.82
AIRPORTS	0.70	0.82
RAILROADS	0.70	0.82
JUNKYARDS	0.70	0.82
RECREATION	0.10	0.30
INSTITUTION	0.39	0.64
PASTURE	0.05	0.25
CROPLAND	0.15	0.50
ORCHARDS	0.05	0.25
BRUSH	0.0	0.10
FOREST	0.0	0.10
BARREN	0.05	0.80
WETLAND	0.0	0.10
WATER	1.0	1.0

[a] Calculation of ULC and LLC for Residential (HDR, MHDR, MDR, MLDR, LDR) is based on Schueler's (1987) Simple Method:

$$C = 0.05 + 0.9\ I$$

I = Fraction of site imperviousness (for example, 30% impervious would have I = 0.3)

C NUTRIENT EXPORT COEFFICIENTS TO SURFACE WATER

Total Phosphorus Export Coefficients to Surface Water (A)

The phosphorus loading factors listed below include contributions from diverse sources such as atmospheric deposition, fertilizers, and small animal waste. The loading factors on surface water reflect direct atmospheric deposition only.

Using a similar formula to that used to calculate the runoff coefficient, a most likely phosphorus export coefficient for a particular land use is calculated for each SOIL/LAND USE combination as:

$$\mathbf{PC = LPC + (HPC - LPC) \times X}$$

PC = Most likely phosphorus export coefficient
LPC = Low phosphorus export coefficient for a particular land use
HPC = High phosphorus export coefficient for a particular land use
X = 0 for soil type A; 1/3 for soil type B; 2/3 for soil type C; 1 for soil type D

Total Phosphorus Export Loading Coefficients (lb/acre/yr)

LAND USE CATEGORY	LPC	HPC
HDR	3.6	4.4
MHDR	2.3	3.6
MDR	1.3	2.3
MLDR	0.9	1.3
LDR	0.6	0.9
COMMERCIAL	1.0	2.5
INDUSTRIAL	1.0	3.5
ROADS	1.0	3.5
AIRPORTS	1.0	3.5
RAILROADS	1.0	3.5
JUNKYARDS	1.0	3.5
RECREATION	0.5	1.5
INSTITUTION	2.2	3.5
PASTURE	0.3	1.0
CROPLAND	0.5	4.5
ORCHARDS	0.4	2.0
BRUSH	0.05	0.2
FOREST	0.05	0.2
BARREN	0.05	0.2
WETLAND	0.0	0.0
WATER	0.3	0.3

Total Nitrogen Export Coefficients to Surface Water (B)

The nitrogen loading factors listed below include contributions from diverse sources such as atmospheric deposition, fertilizers, and small animal waste. The loading factors on surface water reflect direct atmospheric deposition only. Using a similar formula to that used to calculate the runoff coefficient, a most likely nitrogen export coefficient for a particular land use is calculated for each SOIL/LAND USE combination as:

$$\mathbf{NC = LNC + (HNC - LNC) \times X}$$

NC = Most likely nitrogen export coefficient
LNC = Low nitrogen export coefficient for a particular land use
HNC = High nitrogen export coefficient for a particular land use
X = 0 for soil type A; 1/3 for soil type B; 2/3 for soil type C; 1 for soil type D

Total Nitrogen Export Loading Coefficients (lb/acre/yr)

LAND USE CATEGORY	LNC	HNC
HDR	11.9	14.3
MHDR	7.3	11.9
MDR	4.3	7.3
MLDR	3.0	4.3
LDR	1.8	3.0
COMMERCIAL	2.0	20.0
INDUSTRIAL	2.0	15.0
ROADS	2.0	20.0
AIRPORTS	2.0	20.0
RAILROADS	2.0	20.0
JUNKYARDS	2.0	20.0
RECREATION	1.5	4.0
INSTITUTION	7.1	11.6
PASTURE	2.0	5.5
CROPLAND	4.0	50.0
ORCHARDS	4.0	35.0
BRUSH	0.9	2.9
FOREST	0.9	2.9
BARREN	0.9	2.9
WETLAND	0.0	0.0
WATER	8.0	8.0

D HIGH-INTENSITY LAND USES

Based on Rhode Island GIS Land Use Data

Urban or Built Up Land	
High-Density Residential	>8 dwelling units/acre
Medium-High-Density Residential	4–7.9 dwelling units/acre
Medium-Density Residential	1–3.9 dwelling units/acre
Commercial and Services	Primary sale of products and services
Industrial	Manufacturing, design and assembly, finishing, industrial parks, and other industrial
Roads	Divided highways with 200 ft. or more of right of way width, interchanges, related terminals, and parking
Airports	Runways, terminals, parking, storage
Water and Sewage	Treatment facilities, land, and associated buildings
Waste Disposal Areas	Active landfills and junkyards
Other	Water-based transportation facilities, commercial docks
Mixed Urban	Light industrial and commercial uses that cannot be separated
Institutional	Education, health, correctional, religious, military, and other institutional
Cropland	Intensively farmed and tillable land
Orchards, Groves, Nurseries	

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