## 3.3 Runoff and Nutrient Loading Estimates

### Mass balance hydrologic models

*The mass balance concept uses a simplified water and nutrient "budget" to establish a quantitative relationship between pollutant inputs and outputs to a system. The nutrient loading component of MANAGE estimates pollutant outputs as nutrients (nitrogen and phosphorus) entering surface water runoff or infiltrating as recharge to groundwater. This standard mass balance method is similar to those widely used in comparable watershed assessment applications elsewhere. (Adamus, C. and M. Bergman 1993, Brown, K.W. and Associates 1980, Budd, L.F. and D.W. Meals 1994, Frimpter, M.H. et al. 1990, Fulton III, R.S. 1994, Nelson, K.L. et al. 1988, Reckhow, K.H. and S.C. Chapra 1983, Schuler, R.R. 1987, Weiskel, P.K. and B.L. Howes 1991, EPA, 1990).*

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

### Methods

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

The model used an average annual precipitation of 53 inches per year, with 21 inches per year lost to evaporation and plant use (U.S. Geological Survey, 1961). The proportion of remaining “available” precipitation (32 inches) that is converted to runoff is estimated using runoff coefficients based on the estimated impervious cover for each land use type and the underlying soil hydrologic group. This is adapted from standard methods (USDA NRCS, 1986). The remainder is assumed to seep into the ground to recharge either shallow or deep groundwater. Recharge to groundwater from septic systems is calculated separately based on average per capita water use and discharge to onsite systems of 50 gallons per person per year.

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

### Note on using models to evaluate land use impacts

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

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

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

## Selecting simple vs. sophisticated models

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

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

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

## SURFACE RUNOFF

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

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

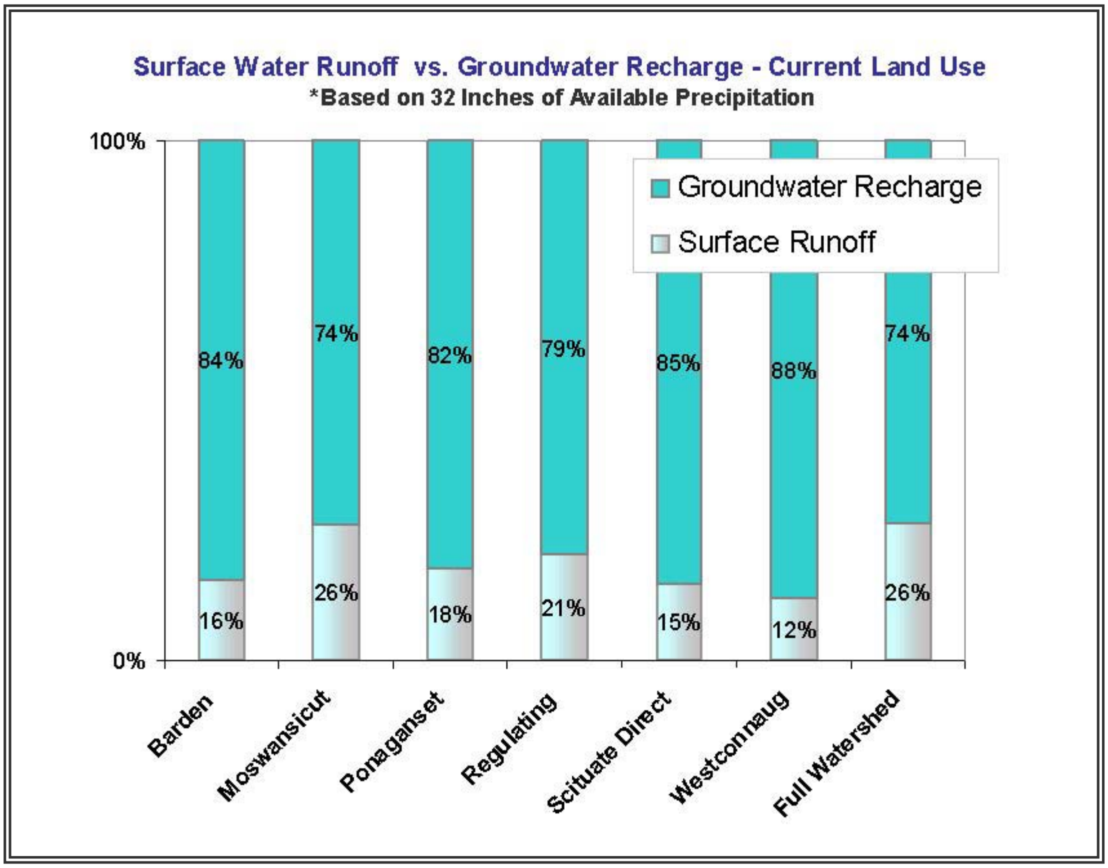
As a watershed health indicator, surface runoff levels signal potential pollution risks by identifying:

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

### Interpreting runoff estimates

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

*Figure 6. Estimates of Groundwater Recharge and Surface Water*



### Results: Surface Runoff

- The primary pathway for water flow in the Scituate watershed is groundwater recharge, with over 80 percent of available precipitation estimated to infiltrate as groundwater recharge, and roughly 20 percent estimated to runoff the surface. The high proportion of infiltration is typical of a healthy watershed.

- The Moswansicut reservoir watershed has the highest estimated rate of runoff at 26 percent. This may be partly due to the higher proportion of wet soils in the watershed, which naturally collect and generate runoff.

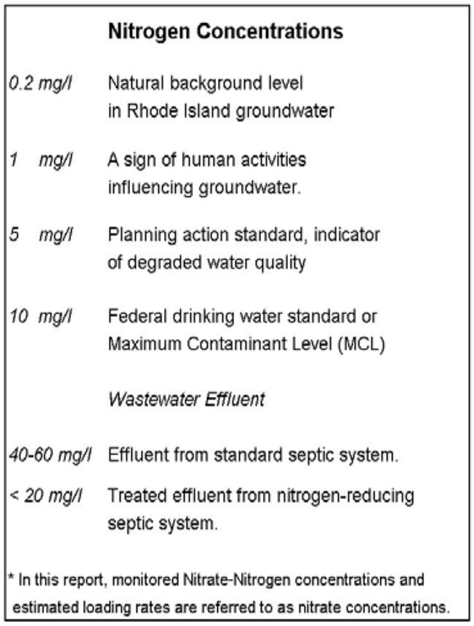
- Commercial and residential land use activities contribute to a higher rate of runoff, given their extensive use of impervious surface area. The Moswansicut reservoir watershed has the greatest proportion of commercial and medium density residential land uses, likely accounting for the increased percentage of runoff.

# NUTRIENT LOADING

## Nitrogen as a pollution indicator

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

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



| | **Nitrogen Concentrations** |
|---|---|
| *0.2 mg/l* | Natural background level in Rhode Island groundwater |
| *1 mg/l* | A sign of human activities influencing groundwater. |
| *5 mg/l* | Planning action standard, indicator of degraded water quality |
| *10 mg/l* | Federal drinking water standard or Maximum Contaminant Level (MCL) |
| | *Wastewater Effluent* |
| *40-60 mg/l* | Effluent from standard septic system. |
| *< 20 mg/l* | Treated effluent from nitrogen-reducing septic system. |

* In this report, monitored Nitrate-Nitrogen concentrations and estimated loading rates are referred to as nitrate concentrations.

***Note on Nutrient Loading Estimates:***

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

## Input values designed to match the local study area

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

Nutrient source estimates are derived from the number of homes and businesses in the study area and the total acreage of different land use types. For example the number of septic systems, an important input variable for groundwater nitrogen loading, is estimated from the number of homes and businesses in unsewered portions of each study area based on five residential land use categories, four nonresidential mapped land use types, and mapped sewer districts. To refine our estimate, we updated the RIGIS 1995 land use using corrections mapped by trained local volunteers and adjusted the residential units to reflect the town parcel database. U.S. Census data was used to estimate occupancy per dwelling unit. Nutrient loading assumptions were also reviewed by local assessment volunteers and revised as needed.

**Types of Outputs**

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

## Uncertainties in Mass Balance Models

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

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

***ASSUMPTIONS***

***Nitrogen loading to groundwater recharge***

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

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

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

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

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

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

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

## Results: Nitrogen Loading

- Estimated nitrogen loading to groundwater is currently less than 5.4 lbs/acre/yr, considered a low risk to water quality. The only exception is the more intensively developed Moswansicut watershed, with current and future levels in the high risk range above 8 lbs/acre/yr. With future development nitrogen levels are expected to rise slightly, entering moderate levels in a few areas.
- Overall, septic systems and agricultural fertilizers comprise the greatest percentage of nitrogen loading to groundwater.
- In the Moswansicut Reservoir watershed, agricultural fertilizer accounts for 34 percent of nitrogen entering groundwater, while septic systems account for 50 percent of loadings.
- Though the loading for Moswansicut is notably higher than the other watersheds, the proportion of nutrient sources (i.e. septic, agricultural fertilizer, lawn fertilizer, etc) are similar in each area.
- Future nitrogen inputs are expected to increase slightly in most areas, with greater increases in the Ponganset and Barden reservoir areas although total levels are expected to remain relatively low. In general, the contribution of nutrients is expected to shift from agricultural sources to septic systems and residential fertilizers.

*Figure 7a. Estimated Nitrogen Loading to Groundwater*

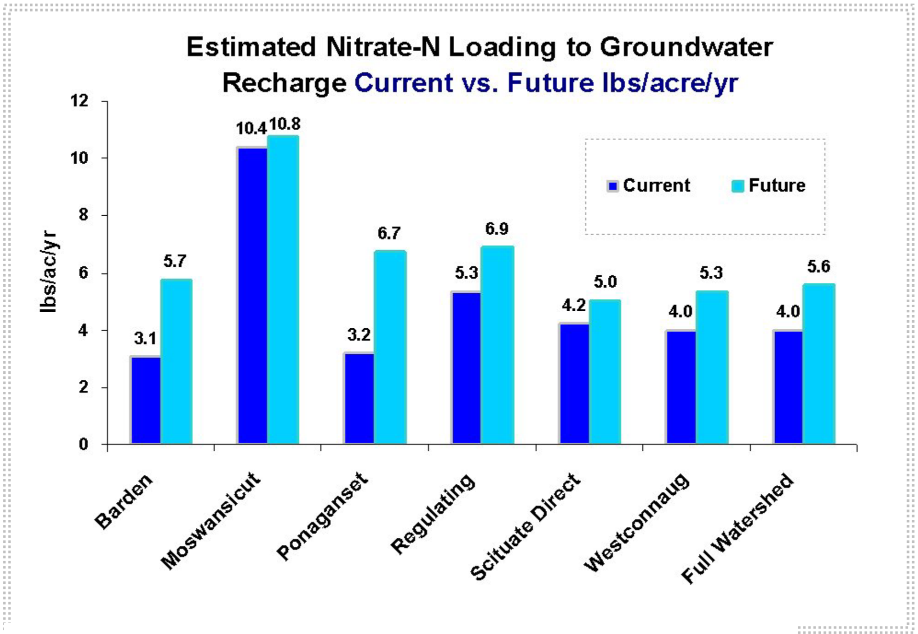
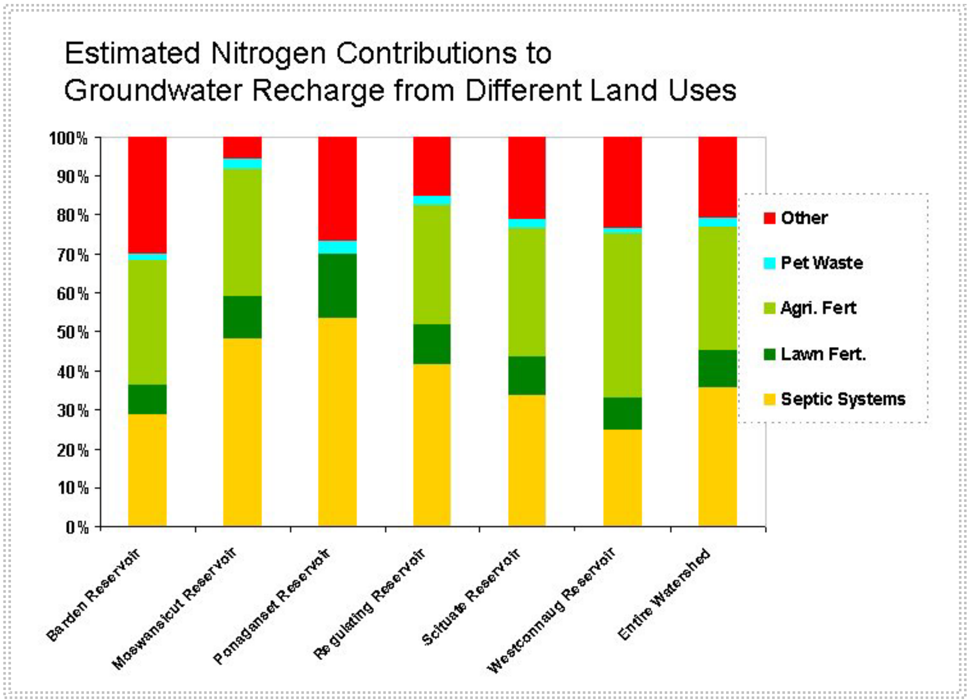


*Figure 7b. Estimated Sources of Nitrogen*



## Risk of water quality impact from septic systems

In general, sources of nitrogen are likely to shift from agricultural to residential sources, underscoring need for proper septic system siting and maintenance, as well as use of good lawn care practices.

- The current number of septic systems in the watershed is estimated to be 5,600 systems.
- With future development, the total number is expected to increase to 14,390 septic systems. This represents an increase of 8,790 systems.
- Septic systems are estimated to contribute about 36 percent of the nitrogen inputs to groundwater recharge under current land use. With future development, the contribution from septic systems is expected to increase to 65 percent of all sources.
- About 50 percent of these new systems is estimated to be located on slowly permeable soils with restrictive “hardpan” layers where risk of hydraulic failure and improper treatment is greater.
- About 3,000 (34 percent) of future systems are likely to be located in high water tables where groundwater is within 1.5 – 3.5 feet from the ground surface.

Although total nitrogen loading to wells is low, failing septic systems are more likely to impair water quality, particularly through movement of bacteria and viruses to wells and surface waters. The potential for pathogen movement is difficult to model but septic system malfunction and potential for bacteria movement in groundwater or to surface waters is generally considered greatest in areas of high water table. These future scenarios assume highly marginal land with high water table roughly 1.5 – 2 feet from the ground surface will not be developed. If these areas are developed, actual nitrogen loading is likely to be higher than estimated. Because managing runoff is difficult on these wet sites, stormwater runoff impacts are also likely to be much greater.

*“Quite often it is difficult to make accurate determinations on the depth at which the limiting conditions are occurring as they vary n any given area. Also, no matter how a site is selected for a septic tank effluent drainfield system, there is always a good chance that a drainfield area would be saturated for some time in a given year especially in an area where the seasonal water table is within a few feet from the ground.”*
*A. Jantrania 2001*

## Risk of septic system failure in high water table sites

Increasing development pressure in the watershed has driven land values to the point where building on marginal sites is profitable even after accounting for higher development costs and environmental permitting requirements. In many cases these marginal lands may have been considered unbuildable. Building on these sites raises several concerns:

- Stormwater management is difficult, since high water table sites are areas where runoff is generated, complicating erosion control and providing little opportunity for stormwater storage and infiltration on site.
- Areas of high water table are often associated with wetlands, increasing potential for disturbance of wetland buffers; and

- Septic system function can be compromised unless site evaluations accurately estimate the depth to high water table. On highly marginal sites, there is no room for error. If water tables rise higher than predicted, water tables with compromise effluent treatment as water tables rise into the required 3 to 4 foot separation distance between the bottom of the leachfield and groundwater.

Two recent studies shed light on the potential for septic system malfunction in high water table soils. URI researchers compared long term, monitored water table depths with predicted levels based on current RIDEM site evaluation procedures for onsite wastewater treatment in RI. These researchers found that in high water table soils, especially those with dense compacted "hardpan", water tables rose quickly in response to rainstorms, rose higher than expected based on soil features, and stayed elevated for long periods. All study sites had estimated water table depths ranging from 18 inches to 3.5 feet. Their findings showed that in marginal sites, water tables are likely to rise higher than expected, compromising wastewater treatment and increasing risk that improperly treated effluent will move into groundwater.

- In a typical compacted till soil with restrictive "hardpan" layer, the site evaluation predicted the water table would be 3 ½ feet from the ground surface. Water levels actually rose near the surface following rainstorms and stayed high during winter months. (Stolt et.al. 2001)

- In a study of several Rhode Island soil types, where water tables were estimated to be 18 to 30 inches deep, the actual measured seasonal high water table ranged from 1 to 14 inches below the surface in 5 out of 7 sites. On these five sites the actual depth to groundwater averaged 10 inches from the ground surface rather than 18 to 30 inches (Morgan and Stolt 2002).

- Water tables rose higher than predicted in all seven sites. This means that for at least part of the year, septic systems in high water table soils will not maintain the required separation distance from the bottom of the leachfield to groundwater, increasing risk of malfunction and groundwater contamination during at least part of the year. To estimate the total duration a septic system drainfield is likely to be compromised by high water table these researchers used groundwater monitoring results and long term rainfall records to predict water table fluctuations for different soils under high, low and average rainfall conditions. Modeled results showed that the average long term water table depth would exceed the estimated depth using RIDEM site evaluation procedures. The height and duration of water table rise varied by soil type.

- Water tables in loose till soils are expected to rise 1 foot higher 10 percent of the year while those in outwash soils are expected to stay 1 ½ feet higher 10 percent of the year. Compacted till sites, which are considered "flashier", and were the only sites to rise above predicted levels with summer rainstorms, would be at least 1 ½ feet higher 10 percent of the year. These estimates are for a year with average rainfall; in a particularly wet year the percentages would be significantly larger (Morgan and Stolt 2002).

These results show that on marginal sites, high water tables are likely to compromise system function, reducing separation distance between the bottom of the leach field and groundwater for at least 10 percent of the year. The risk of failure would be greater in wet years. In critical areas such as the Scituate Reservoir watershed, potential impacts to surface waters as well as local wells should be carefully evaluated. These results show that in critical areas, prohibiting new construction on lots with water table less than 2 feet would minimize risk of system malfunction.

## Phosphorus as a pollution indicator

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

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

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

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

- Land use activities have significant, measurable impacts on phosphorus levels in surface water bodies.

Leaking sewers, agricultural drainage, pet waste, and urban stormwater runoff.

- High phosphorus levels in freshwater bodies are associated with stormwater runoff containing sediment from construction sites and other disturbed land, lawn and garden fertilizers, improperly sited and maintained septic systems, leaking sewers, agricultural drainage and pet waste.

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

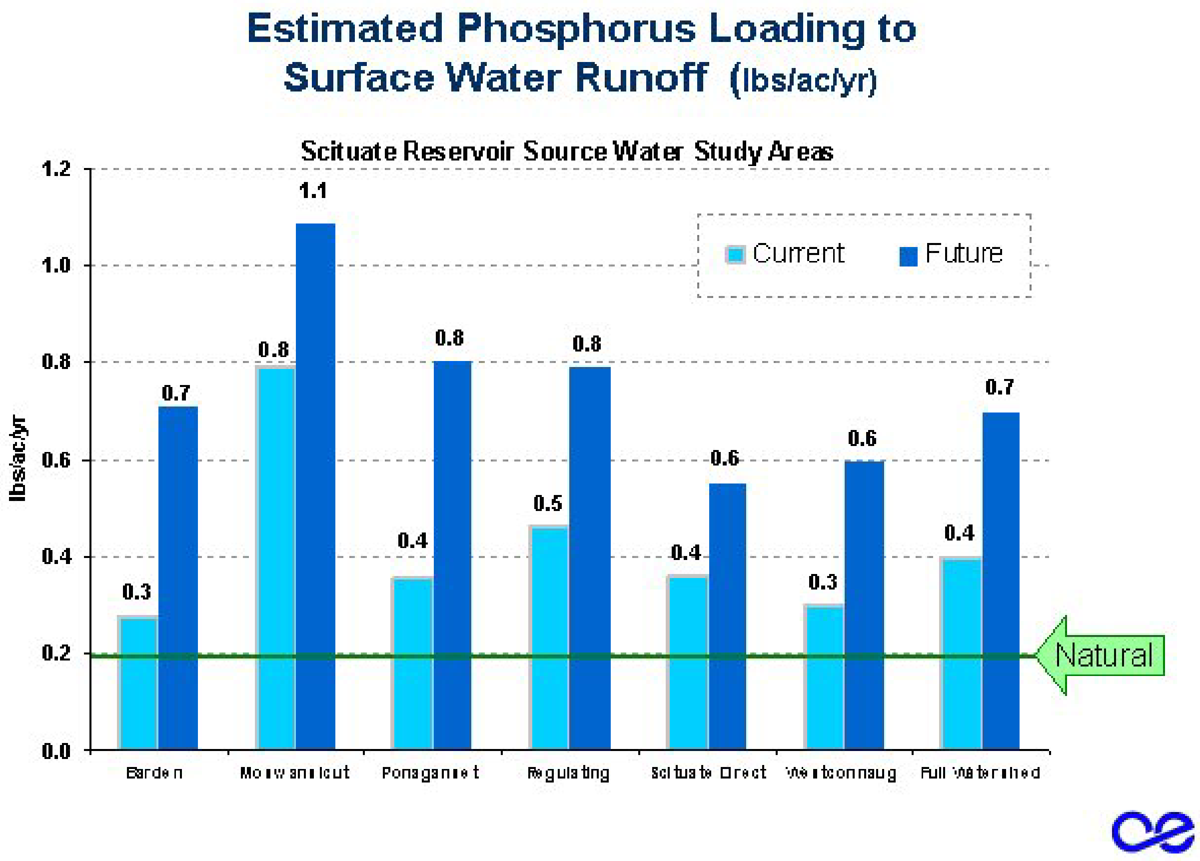
**Trihalomethanes** *(THM) are a group of four chemicals —chloroform, bromodichloromethane, dibromochloromethane, and bromoform — that are formed when chlorine or other disinfectants used to control microbial contaminants in drinking water react with naturally occurring organic and inorganic matter in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

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

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

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

***Figure 8. Estimated Phosphorous Loading to Surface Water Runoff***



## Results: Phosphorus Loading

- Estimated phosphorus inputs, which are partially derived from runoff values, averages 0.4 pounds per acre each year in the watershed. This value is only slightly elevated above the natural background value of 0.2 pounds pre acre pre year.
- With future development, the contribution of phosphorus from various sources can be expected to nearly double in most of the Scituate Reservoir's watersheds. This is a concern given the relative increase and because estimated loading rates will approach the high risk level of 1 lb/acre/year.
- Current and future estimated phosphorus loadings in the Moswansicut reservoir watershed are estimated to be much higher than all of the other watersheds. Any increase in this area is a concern given that streams are already showing signs of impact from land use.

## ANALYSIS OF MANAGEMENT OPTIONS

The hydrologic and nutrient loading component of the MANAGE assessment can be used to evaluate the relative effect of alternative development options. In addition to comparing the difference in runoff or nutrient loading with current and future land use, input values can be adjusted to reflect the expected change in nutrient loading with use of various land management practices. The management options that can be evaluated include:

- using creative development techniques to reduce the amount of impervious cover and preserve undisturbed forest,
- management of home or agricultural fertilizers to reduce nutrient losses to groundwater and surface runoff,
- treatment of stormwater runoff to reduce nutrient inputs to surface runoff, and
- use of nitrogen-reducing septic systems to minimize nitrogen loading to groundwater.

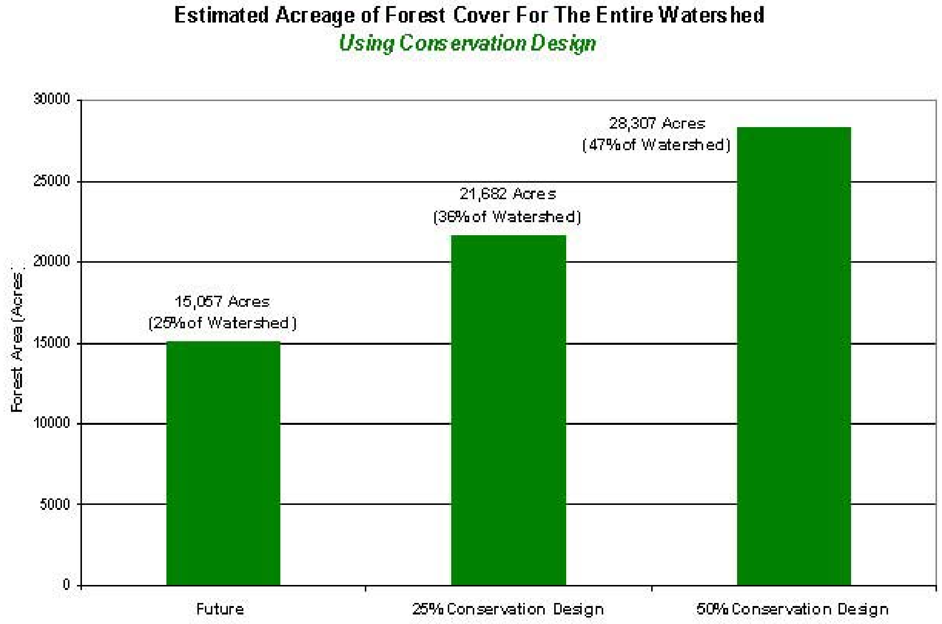
The input values for improved management practices are based on results of local research conducted by URI researchers on nitrogen losses to groundwater and other accepted literature sources. As with any of the indicators, the results are best used to compare relative differences among various scenarios, and should not be compared with monitored data.

In 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 likelihood of contamination from bacteria. For example, cesspools and other substandard septic systems, on densely clustered lots, and in areas where private wells are used are generally considered 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 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 a surface waters. Examining only the change in nitrogen loading with use of advanced wastewater treatment systems will not indicate the change in pollution risk under these various conditions. Because well-functioning septic systems are designed to leach nitrogen into groundwater some management practices, such as instituting wastewater management programs to eliminate failed septic systems will have little or no effect on nitrogen loading to groundwater and can’t be modeled this way.

Management options evaluated in this assessment were selected to address key risks and concerns identified in the assessment process. Because nutrient loading analysis has limited application and can’t be used to evaluate all management options, recommendations are developed based on both modeling results and generally accepted management practices for preventing pollution from land use activities.

## Change in Watershed Forest Cover with Conservation Development

Figure 9.



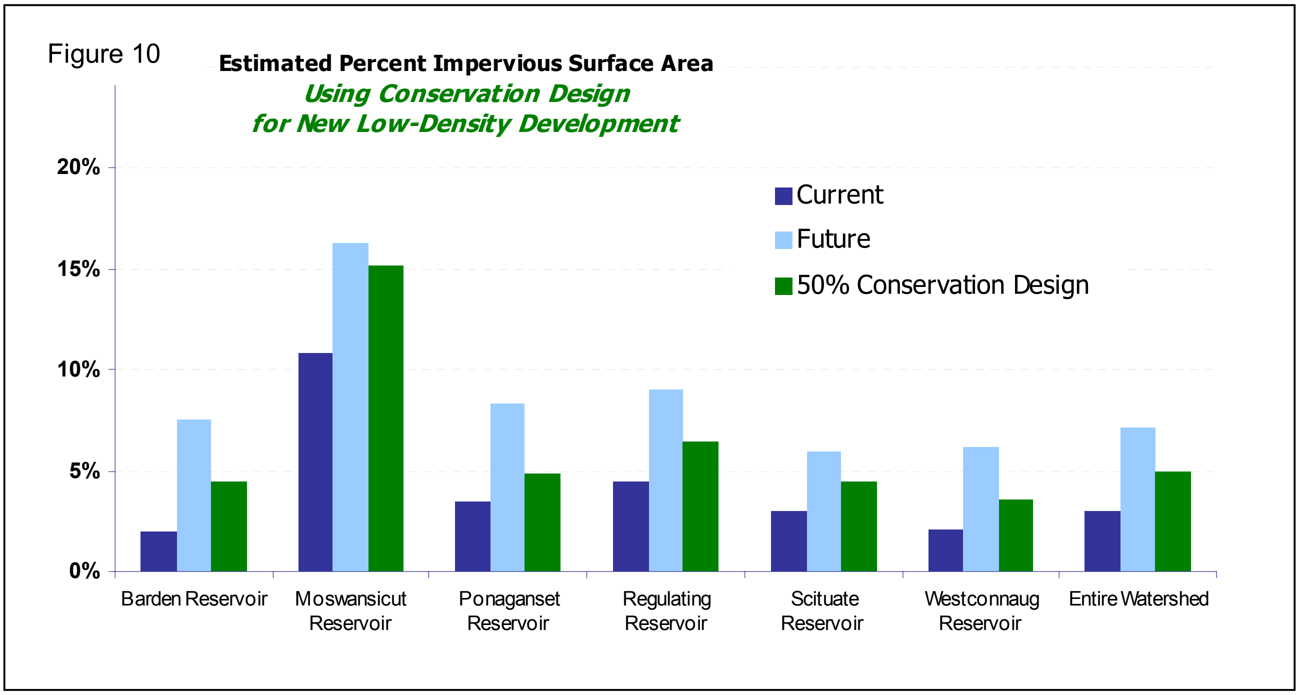
The communities in the Scituate Reservoir Watershed have already adopted large lot zoning, requiring 3 to 5 acres per dwelling in most areas. Low development density helps protect water quality by keeping pollutant inputs from residential sources low. However, the amount of forest that can be fragmented or converted to other uses can be substantial. Forest fragmentation is a concern for several reasons: 1) Wildlife habitat. Many species of birds, amphibians and other wildlife, particularly less common and more sensitive species require large tracts of unbroken forest. On a statewide basis, the forestland in the Scituate Reservoir watershed represents a significant portion of the state's unfragmented forest. 2) Economic use of forests. Breaking up woodlots into smaller tracts makes logging and other use of forest products less economical. 3) Water quality. Under current development regulations, the amount of forest remaining to infiltrate stormwater and filter pollutants can vary widely depending on how homeowners choose to manage their property. As a result, pollutant inputs can also vary greatly and actual impacts are very difficult to predict. If most of the lot is left wooded impacts are minimal; however, large lawns that are heavily fertilized and watered, creation of mini farms with horses in natural drainage ways, and land disturbance within wetland buffers and shoreline areas can greatly magnify pollutant inputs far beyond our estimates. Methods for controlling forest loss include: creation of very large lot zones for forest management and harvesting of wood products with proper erosion controls; use of building envelopes for new construction to limit area of disturbance around dwellings – which can also be used to maintain wooded buffers from roads to maintain scenic character; and use of conservation development to preserve 50 percent or more of new subdivisions as permanently protected open space. This last technique is the most effective for subdivisions since the open space can be specifically reserved in forest while house lots can be sited on the most suitable land for onsite wastewater treatment, outside of wetland buffer zones. Ideally, town or regional open space plans should be developed to identify greenways and other open space priorities to form contiguous networks with existing protected areas. These open space plans can be used to direct selection of open space with new subdivisions, to gradually build the open space network as land is developed.

Figure 10 shows the potential for permanently protecting forest land under future development scenarios.

- The future development option (#1) is the worst case scenario under current zoning. Approximately 25 percent of the watershed (15,000 acres) could be protected as forest, with the remainder converted primarily to low density residential. The amount of residential land actually remaining in forest depends on how homeowners choose to manage their property. In comparison, the amount of forest in the watershed is currently 65 percent.
- The second option (#2) shows the amount of forest that would be permanently protected if 25 percent of developable forest land is permanently protected through conservation development or other means. Under this option 36 percent of the watershed would remain forested.
- The third option (#3) shows that 47 percent of the watershed would remain in forest cover if conservation development methods were used to protect 50 percent of all developable land in forest. Given the large lot sizes required this option would still provide lot sizes large enough to accommodate both septic systems and wells while preserving forest cover closer to current levels of 65 percent for the watershed.

## Change in Impervious Cover with Conservation Development

Figure 10



Preserving forest cover is widely recognized as a means to ensure watershed health. In fact, some researchers have found that high levels of water quality can only be maintained when forests comprise 65 percent of the watershed and where impervious levels are 10 percent or less (Center for Watershed Protection 2002). Because large lot zoning can contribute to increased impervious area, primarily through construction of new roads and driveways, we also explored the change in impervious cover using conservation development.

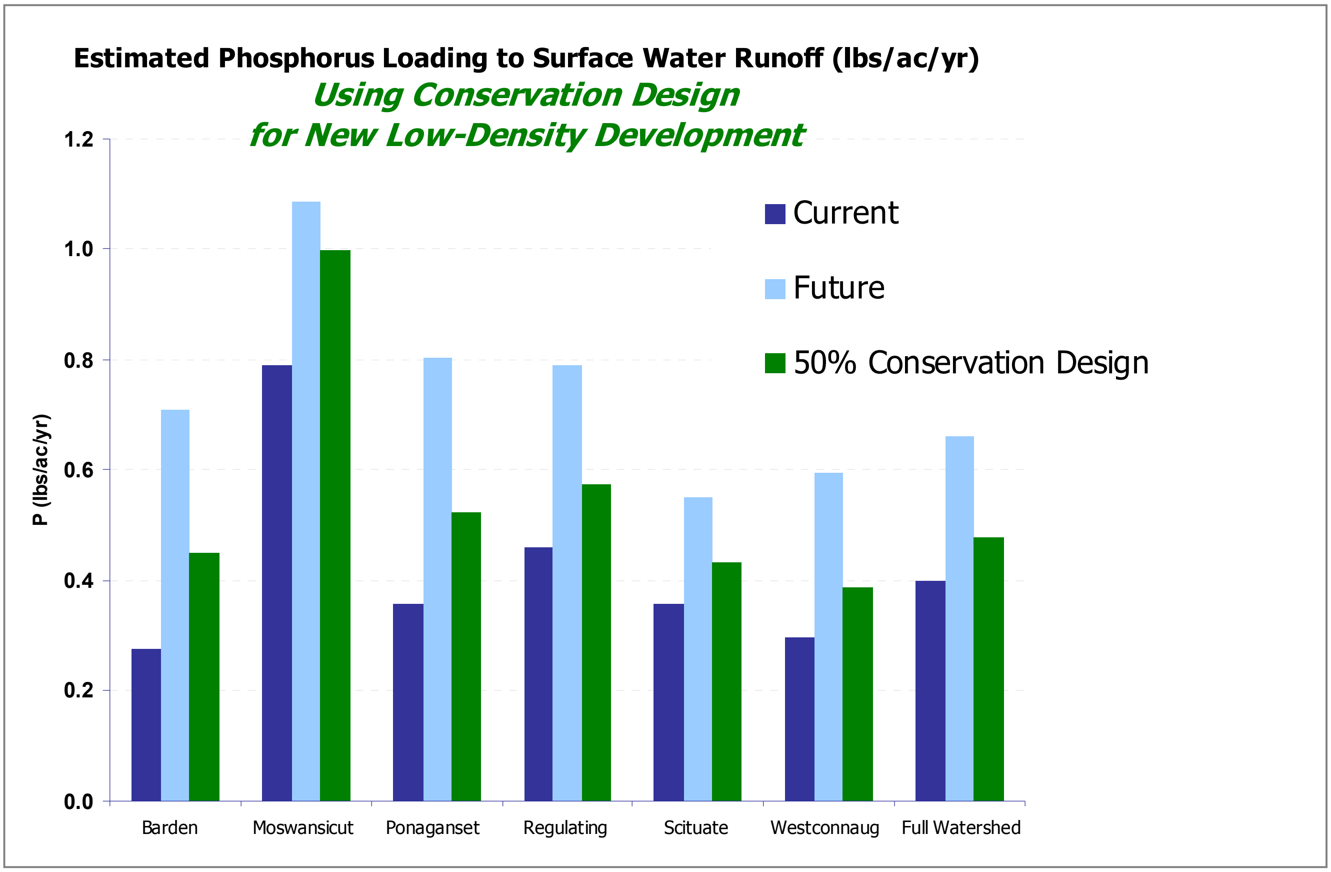
Figure 11 shows current estimated impervious levels and future levels based on current zoning. The third bar in each group shows the percent impervious cover expected if the amount of impervious area associated with new development is reduced by 20 percent using conservation development or other strategies to reduce road length, width or other impervious surfaces.

- The results show that reducing impervious levels by 20 percent for new development would keep average impervous cover closer to present levels, especially in areas where most new development is expected. The Scituate reservoir direct drainage area, which is already well protected, and the Moswansicut area, which is heavily developed, show the least change with this option.

- Based on these results, a goal of 8 percent impervious, as a watershed average for each study area is a realistic goal, except for the Moswansicut watershed, where keeping impervious cover at present levels would require more stringent controls for both new development and redevelopment projects.
- These impervious cover estimates are watershed averages. To achieve a watershed goal of 8 percent for the watershed, impervious cover would be kept to 8 percent or less for residential land. Commercial and industrial uses, which may be 70 percent or more pavement and rooftop, could be kept to 25 – 40 percent impervious, depending on site constraints. In all cases, regulating the total amount of runoff to maintain pre-development levels would limit potential impacts of stormwater runoff, beyond reductions possible from impervious limits alone.

## Estimated Change in Phosphorus Loading to Surface Water Runoff with Conservation Development

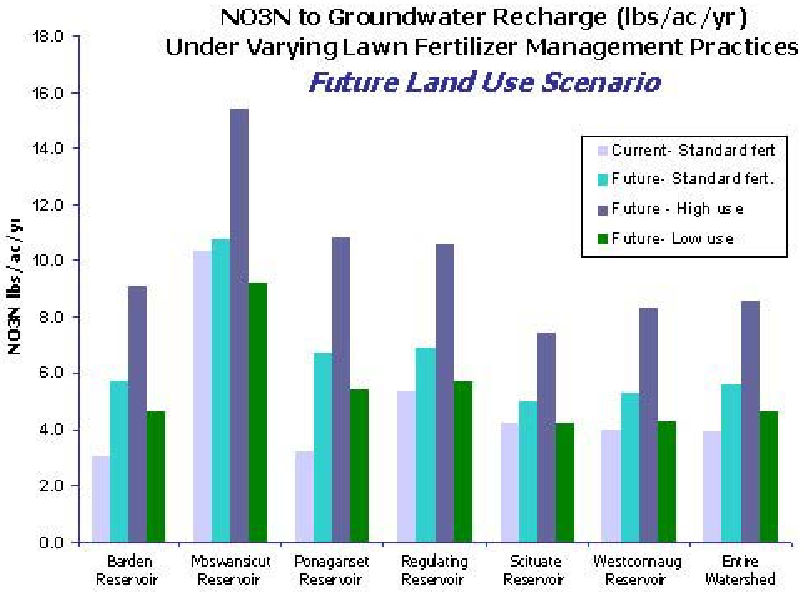
Figure 11



Reducing land disturbance through use of conservation design practices is expected to reduce the total amount of phosphorus generated, even though the total number of housing units developed remains the same. Figure 12 shows phosphorus source estimates for the Scituate Reservoir subwatersheds under current land use, with future full build-out, and future development using conservation development. In all cases, phophorus inputs are much closer to present levels. These estimates assume protected open space created by clustering new development on smaller lots is reserved as forested land.

### Change in Nitrogen Loading to Groundwater with Lawn Fertilizer Management Practices

Figure 12



Standard = 4 lbs/1000 sf, 6% leaching.
High = 4 lbs/1000 sf, 20% leaching.
Low = 2 lbs/1000 sf, 3% leaching.
In all scenarios, 75% of land owners fertilize

The nutrient loading projections assume use of standard land management practices. For residential development, this assumes that 75 percent of homeowners will apply lawn fertilizers to 25 percent of the lot, using 4 lbs/1000 sq.ft/ year, with 6 percent leaching to groundwater. Actual inputs can be much higher or lower depending on management practice used. This is a concern because future nutrient inputs are expected to shift from agricultural to residential sources.

Figure 13 explores the potential range in fertilizer inputs with varying lawn fertilizer practices.

- For each watershed area, the current and future scenario using standard lawn fertilizer assumptions are shown as the first and second bar, respectively, in each group.
- The potential increase in nitrogen loading with high impact lawns is shown in the third bar in each group. These include lawns that are overwatered, where too much is fertilizer applied at one time, or where other poor management results in much higher nitrogen leaching to groundwater (20 percent). Nitrogen and phosphorus running off in stormwater would also be expected to increase.

This scenario assumes all current and future lawns would be high impact lawns, representing a worse case scenario. Although this not likely to occur throughout a watershed area, it is a realistic scenario for new subdivisions with large, intensively managed lawns.

- The fourth bar in each watershed group illustrates the low impact lawn scenario where fertilizer application rates are reduced from 4 to only 2 lbs/ 1000 sq.ft. With proper fertilizer application rates, timing and use of slow release fertilizers, nitrogen leaching is assumed to be reduced to 3 percent. Under this option, the reduction in nitrogen inputs to groundwater is substantially reduced. Because this assumes all current and future lawns are managed in this way, future loading is close to or less than the current levels.

These estimates indicate the range of impacts that can occur with different lawn management practices. Nutrient inputs from properly managed lawns are minimal, but impacts are far greater with overuse or misapplication of fertilizers, and with overwatering. Adopting low-impact lawn care practices can keep nutrient inputs to groundwater and surface waters close to present levels. Limiting lot size and lawn area through limits of disturbance and use of conservation development techniques can reduce the potential for excessive nutrient losses from home landscapes. Protecting wetland buffers and shoreline areas from lawn expansion is especially important since fertilizers applied to shoreline areas are more likely to move directly to surface waters.

## 3.4 Mapping Pollution Risks

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

### Limitations of "Hotspot" Mapping

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

### POLLUTION SOURCE HOTSPOTS

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

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

***Results: Pollution Source Hotspots***

The pollution source "hotspot analysis" completed for the Scituate Reservoir Source Water Assessment Program focused on identifying high-risk areas for pollutant movement to both surface and groundwater. The study used RIGIS land use data (updated) and soils data to map high intensity land use overlying slowly draining soils. Hard copy maps of this analysis will be made available to town planning departments. All of the study areas in the Scituate watershed ranked in the low risk category for this indicator, with less than 5 percent of total land area characterized by high intensity land use on high water table soils. It must be noted, however, that identifying these hotspot areas is only a first step in addressing contamination risks to groundwater resources. All high intensity land use activities located in groundwater protection areas should be considered potential sources of contamination. It is import-ant to identify the specific type, location and extent of high risk land uses in relationship to each reservoir or tributary.

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

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

- Urban stormwater drainage systems short circuit natural water flow and pollutant removal processes. Direct tie-in of sanitary wastes to storm drains, known as illicit discharges, can be an associated contamination source, especially in older settlements.

- Subsurface drains installed in farmland and building lots to lower water tables can serve as a conduit for untreated runoff, carrying fertilizers and untreated effluent to downstream discharge points, especially in high water table areas where the practice may be widespread. These areas should be identified and impacts evaluated at least through observation.

- Water withdrawal resulting in low stream flow during summer periods is a growing concern in areas where various uses compete for limited water supplies or where direct runoff to streams results in loss of groundwater recharge. Similarly, loss of recharge through out-of-basin water supply lines or sewer service can be an additional source of stress.

## MAPPED POTENTIAL SOURCES OF CONTAMINATION

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

### *Volunteer-identified potential sources of contamination*

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

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

### *RIGIS-mapped sources of contamination*

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

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

### *Incorporating mapped data into the basic SWAP ranking*

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

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

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

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

## 3.5 Summary Results

### Fact Sheet

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

### Basic Source Water Assessment Ranking

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

The results of this ranking show that the Scituate Reservoir watershed has a **Low** susceptibility to contamination. According to RI HEALTH a low rating does not mean that the source is free of contamination risk. Without sufficient protection, any water supply can become contaminated. It is important to note this is an average ranking for the supply as a whole. Individual areas may be more susceptible to contamination due to site-specific conditions and land use activities. In addition, this ranking is based on current land use only, without considering future threats with continued development.

### Summary of Land Use Risks

The risk factors described in this chapter, such as  percent impervious cover and estimated nutrient inputs, provide additional information on potential threats from land use features beyond the basic Source Water Assessment ranking. Table 1 summarizes results of several key indicators collectively to highlight areas that may be at risk from multiple factors. This "at a glance" overview highlights relative differences in potential pollution risks among study areas. Where a build out analysis was conducted, it also indicates the expected trend between current and future land use.

The first part of Table 1 shows results obtained directly from map analysis or modeled estimates. The cell for each input value is color coded to show the pollution risk rank for current and future values. Results show that the Moswansicut area, as expected, is identified as being at higher risk of contamination based on watershed characteristics. Because of the potential for gradual alteration of wetland buffers located on private developable land we did not assume unprotected shoreline buffers would be fully protected. However, keeping these areas forested and undisturbed would reduce future pollution risks.

The second half of the table further synthesizes results by "adding" together scores for the different indicators. This is accomplished by converting low to extreme ratings to a simple numerical ranking from 0 to 3. These values are then added up for each study area to create on average value for current and future land use. Final values are then grouped into categories from low to extreme risk, and a final rating from low to extreme assigned based on total scores from less than 1 to 3, as shown below.

When taking all risk factors into account collectively, results show that most subwatersheds are at low risk currently but have the potential to become more susceptible to contamination as development proceeds.  Use of good management practices, strictly enforced, can help minimize future threats to maintain current high quality of this important resource.

This overview is intended to help summarize data to compare study areas and evaluate differences between current and future conditions. Since any method used to summarize and rank results can easily mask important data, even "low risk" areas may be subject to contamination. Site-specific mapping and field data should be used to guide selection of management practices.

Table 1

**Current and Future Land Use Risks - Scituate Reservoir Watershed**

| | | Moswansicut | Regulating | Ponaganset | Barden | Westconnaug | Scituate Direct | Entire Scituate Watershed |
|---|---|---|---|---|---|---|---|---|
| **Septics /acre** | Current | 0.33 | 0.15 | 0.11 | 0.06 | 0.07 | 0.10 | 0.09 |
| | Future | 0.51 | 0.31 | 0.30 | 0.25 | 0.22 | 0.20 | 0.24 |
| **Intensive Land Use** | Current | 9% | 4% | 0% | 3% | 3% | 3% | 3% |
| | Future | 5% | 2% | 0% | 2% | 1% | 1% | 2% |
| **Impervious** | Current | 11% | 4% | 3% | 2% | 2% | 3% | 3% |
| | Future | 16% | 9% | 8% | 8% | 6% | 6% | 7% |
| **Riparian Impervious** | Current | 5% | 3% | 3% | 1% | 1% | 1% | 2% |
| | Future | 8% | 6% | 7% | 5% | 4% | 3% | 5% |
| **Riparian forest & wetland** | Current | 79% | 84% | 83% | 91% | 91% | 93% | 90% |
| | Future | 62% | 48% | 35% | 53% | 61% | 77% | 59% |
| **Nitrate to recharge lbs/ac/yr** | Current | 10.4 | 5.3 | 3.2 | 3.1 | 4.0 | 4.2 | 4.0 |
| | Future | 10.8 | 6.9 | 6.7 | 5.7 | 5.3 | 5.0 | 5.6 |
| **Phos to SW (lbs/ac/yr)** | Current | 0.79 | 0.46 | 0.36 | 0.28 | 0.30 | 0.36 | 0.36 |
| | Future | 1.09 | 0.79 | 0.80 | 0.71 | 0.60 | 0.55 | 0.66 |

**Final Ranking**

| | | Moswansicut | Regulating | Ponaganset | Barden | Westconnaug | Scituate Direct | Entire Scituate Watershed |
|---|---|---|---|---|---|---|---|---|
| **Septics /acre** | Current | 2 | 1 | 1 | 0 | 0 | 0 | 0 |
| | Future | 2 | 2 | 2 | 2 | 1 | 1 | 2 |
| **Intensive Land Use** | Current | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Future | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Impervious** | Current | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Future | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Riparian Impervious*** | Current | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Future | 1 | 1 | 1 | 1 | 0 | 0 | 1 |
| **Riparian forest & wetland*** | Current | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| | Future | 2 | 3 | 3 | 3 | 2 | 2 | 3 |
| **Nitrate to recharge lbs/ac/yr** | Current | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Future | 2 | 1 | 1 | 1 | 0 | 0 | 1 |
| **Phos to SW (lbs/ac/yr)** | Current | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Future | 3 | 2 | 2 | 2 | 1 | 1 | 1 |
| **Final Ranking** | Current | 1.4 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 |
| | Future | 1.7 | 1.3 | 1.3 | 1.3 | 0.5 | 0.5 | 1.1 |

Under current zoning, low density residential development will predominate the watershed in the future. Because riparian buffers are potentially impacted by this type of development, we did not constrain riparian areas when calculating the buildout analysis.

**Pollution Risk Rating**

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