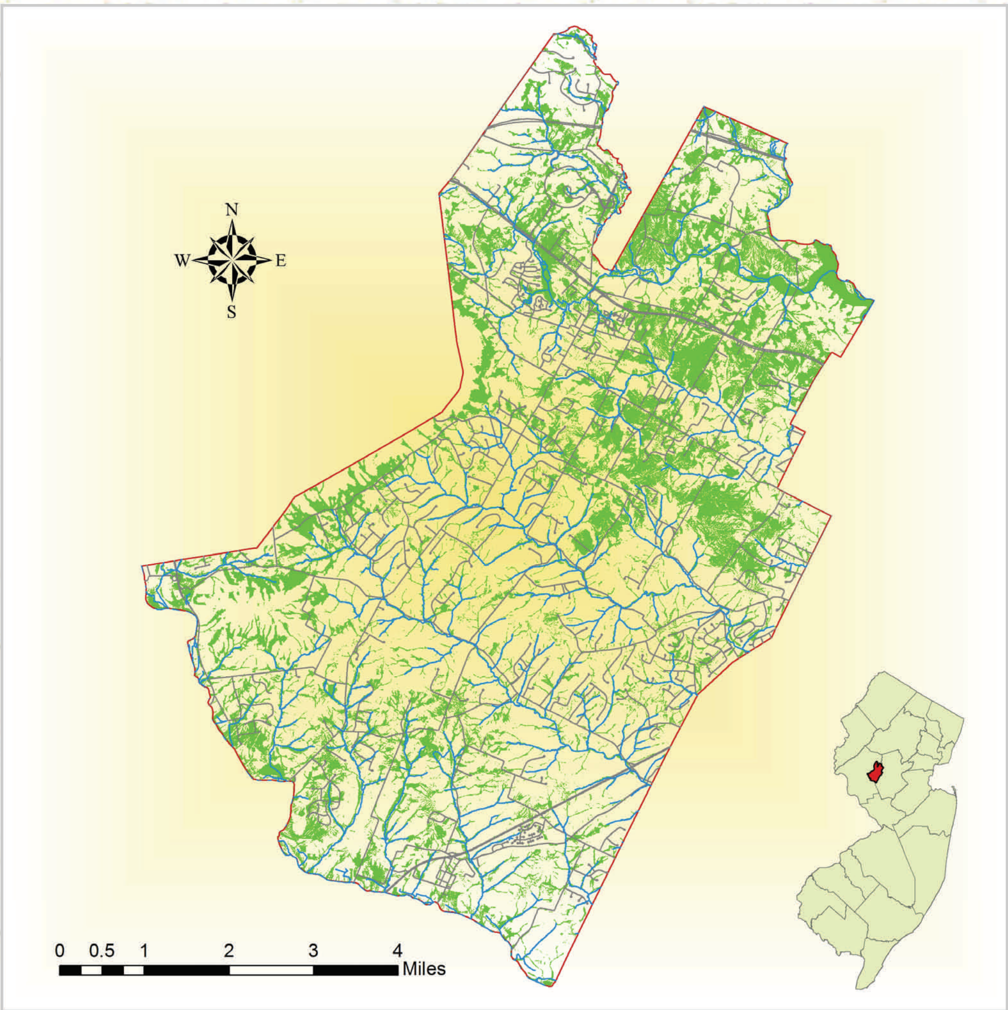
March 2011

Natural Resource Inventory
Hydrologically Sensitive Areas

Readington Township



Donna Drewes, PP/AICP, Co-Director, Institute for Sustainability Planning and Governance, Municipal Land Use Center at The College of New Jersey, Ewing, New Jersey
Zeyuan Qiu, Ph.D., Associate Professor, Department of Chemistry and Environmental Science, New Jersey Institute of Technology, Newark, New Jersey

Introduction

Protection and preservation of hydrologically sensitive areas (HSAs) in landscapes help achieve long-term water quality goals and contributes to the sustainability of water resources efficiently and effectively (Gburek and Sharpley, 1998; Walter et al., 2000 and 2001; Qiu et al., 2002; and Qiu, 2003). Although land use changes have significant impacts on water resources, not every part of a landscape contributes equally to these impacts. Improper land use in one part of a landscape often has more dramatic impacts than it would in another part of the landscape. The modeling, mapping and designation of HSAs into the municipal land use regulation as well as open space and farmland preservation programs will support enhanced water resource protection in Readington Township. Regulatory and management approaches should strive to:

- Manage stormwater runoff to avoid increasing saturated soil conditions.
- Reduce or minimize pollution sources in HSAs
- Minimize or avoid soil disturbance in HSAs

The purpose of this NRI report is to develop the recommendations for the integration of HSAs into Readington Township land use regulations. The modeling and mapping of HSAs was completed for Readington Township. The effectiveness of the Township's existing land use regulations and farmland and open space preservation programs to protect the HSAs were then analyzed. Recommendations are provided to incorporate HSAs into existing or new land use regulations or preservation program objectives.

Information and analysis for this report was completed as part of U.S. Environmental Protection Agency (USEPA) Science To Achieve Results (STAR) grant entitled *Protection of Critical Source Areas for Achieving the Long-term Sustainability of Water Resources*, funded by the USEPA's National Center for Environmental Research through the Collaborative Science and Technology Network for Sustainability (CNS) Program to New Jersey Institute of Technology (Grant Number RD-83336301-0). The report was completed by the Municipal Land Use Center of The College of New Jersey and New Jersey Institute of Technology in collaboration with the North Jersey Resource Conservation and Development Council and the New Jersey Water Supply Authority.

Variable Source Area (VSA) Hydrology: Background and Basis

Variable source area (VSA) hydrology modeling offers interesting insights regarding the complicated hydrological connections between streams and their upland contributing watershed areas. According to the VSA hydrology model (Hewlett, 1982), the runoff that carries pollutants and contributes to the stream flow hydrograph is primarily generated in relatively small, but predictable, HSAs in a watershed where the soils are saturated (Hewlett and Hibbert, 1967; Dunne and Leopold, 1978). The VSA hydrology model applies a saturation-excess hydrological process to explain how runoff is generated primarily from discrete saturated areas in the landscape. VSAs are those saturated areas that actively contribute to generating runoff.

The term VSA implies that the extent of saturated runoff source areas varies with soil moisture levels. VSAs expand and shrink in a consistent pattern during and after each storm event, as soils absorb water and become saturated or dry out or drain away excess moisture after rainfall ends. The climatic variation in annual rainfall also influences the VSA saturation patterns on a seasonal basis.

Runoff processes in humid regions such as the Northeastern United States are best represented by the VSA hydrology model (Steenhuis and Muck, 1988; Merwin et al., 1994; Walter et al., 2003). This is because most water runoff is generated by saturation excess, i.e. via direct precipitation on or exfiltration from saturated areas in the landscape (Ward, 1984).This often occurs near stream channels or along drainage ways that have soils with high soil moisture levels. Soil wetness determines the production of surface runoff, which is the driving mechanism for nutrient and sediment transport in landscapes. For this reason, a better representation of the spatial and temporal variations of soil wetness through the use of VSA modeling will support the integration of HSAs into land use planning frameworks (Chaplot et al. 2003).

HSAs and Critical Source Areas (CSAs)

The VSA hydrology has been closely linked to the delineation of HSAs. Since VSAs are the portions of a landscape that actively contribute to generating runoff, those parts of VSAs that most actively contribute to runoff generation are defined as HSAs. The VSA hydrology is also linked to the development of the concept of critical source area (CSAs). Since HSAs are the areas that actively contribute to generation of overland runoff in landscapes that could potentially transport the pollutants from the sources to streams, CSAs can be defined as the intersection of HSAs and pollutant source areas in landscapes where pollution sources and transport coincide (Walter et al., 2000; Heathwaite et al., 2005; Agnew et al., 2006).

The pollutant source areas are generally the areas in landscapes that have been actively used for production and consumption, such as agricultural and silvicultural production, residential development, and industrial and commercial uses. In other words, CSAs are the part of HSAs with high land use intensity. Walter et al. (2000) defined CSAs based on HSAs in an agricultural setting. For an agricultural field in the Catskill Mountain region of New York State in which dairy manure is spread, CSAs were defined as the intersection of the HSAs and the manure spread areas in the field. More generally, CSAs can be identified by overlaying the identified HSAs with an existing land use map.

Figure 1 presents the general relationships among the VSAs, HSAs, and CSAs. It should be noted that land use activities have the impacts not only on sources, but also on pathways of runoff (i.e., VSAs and HSAs). Examples are roads, stormwater infrastructure, tracks and field drainage systems (Tomer et al., 2003; Heathwaite et al., 2005). The impacts of such land use activities on overland flow path are not addressed in this analysis, but offer opportunities for future research.

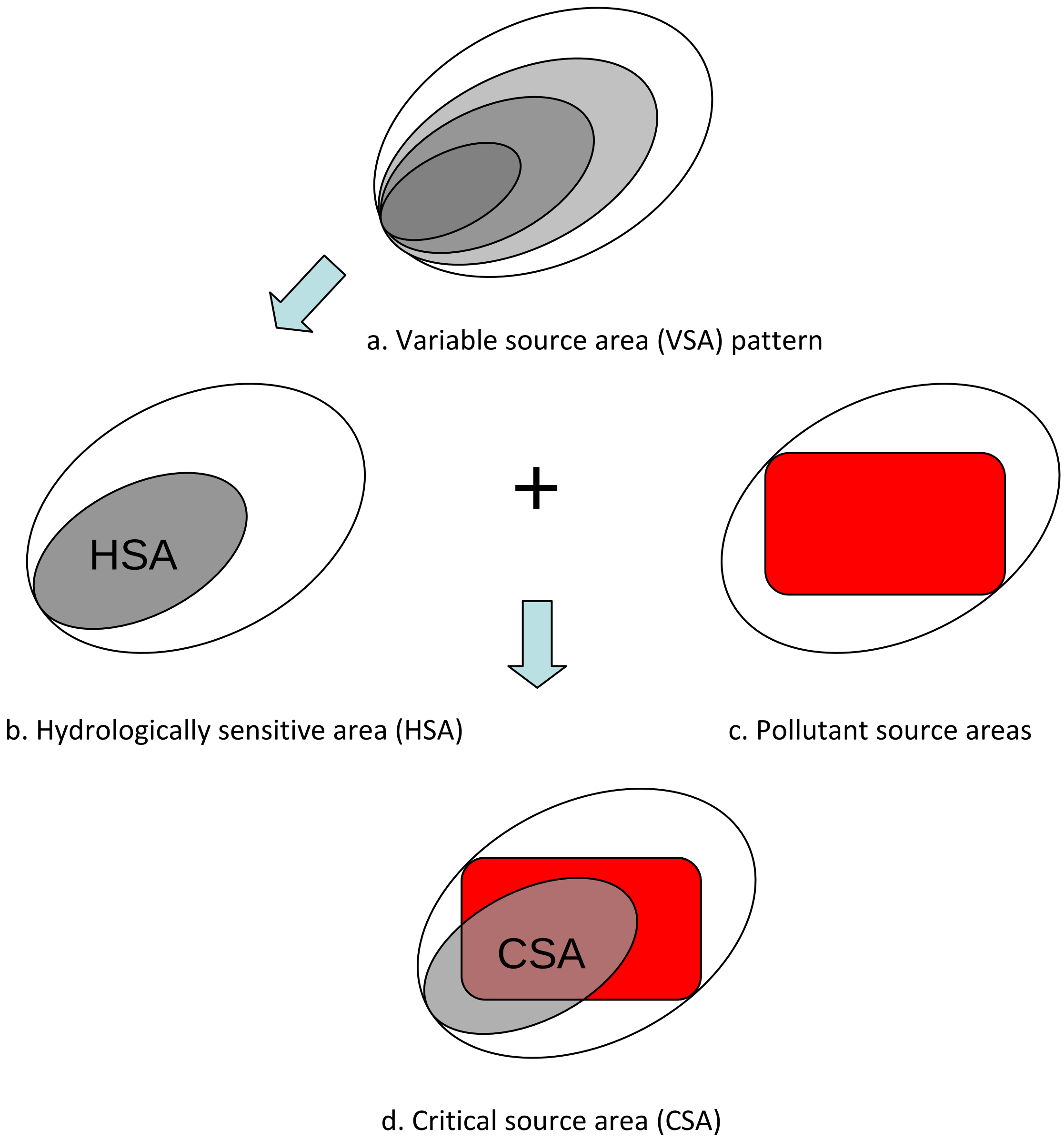


Figure 1: The relationships among VSAs, HSAs and CSAs

VSA Modeling

The Modified Topographic Index (TI) Model

The topographic index (TI) is commonly used to derive VSA patterns in landscape and is first introduced as the basis for the rainfall-runoff model, TOPography based hydrological MODEL (TOPMODEL), which simulates the pattern of surface runoff contributing areas following the VSA hydrology. The most common form of the topographic index (λ) is:

(1) $$\lambda = \ln\left(\alpha / \tan\beta\right),$$

where α is the upslope contributing area per unit contour length to a given point in a watershed in meters and *β* is the local surface slope angle in decimal. The index measures the propensity of a given point in a watershed to become saturated and act as a source area for surface runoff (Beven and Kirkby 1979). The index is often called a wetness index (O'Loughlin, 1986; Moore et al. 1991). In practice, a watershed is divided into small grids and the index is measured at each grid. The index is often derived from a digital elevation model (DEM) using terrain analysis in GIS (Tarboton 1997). The higher the index, the more likely the grid is saturated during a storm event.

Because of its simplicity and the ability to visualize the spatial predictions, the TI has been widely adopted to simulate hydrologic processes with various modifications and extensions that reflect the different modeling assumptions and take into account the additional natural resource conditions (Beven, 1997; Gomez-Plaza et al., 2001; Wilson et al., 2005). The TI and its variants have been incorporated into rainfall-runoff models to predict streamflow (Hornberger et al., 1985; Wood et al., 1990; Gallart et al., 2007; Schneiderman et al., 2007). As noted by Beven (1997), TOPMODEL is not a single model, but rather a set of conceptual tools that can be used to simulate hydrological processes in a relatively simple way, particularly the dynamics of surface or subsurface contributing areas. The original TOPMODEL implicitly assumed a water table below the entire watershed, which did not conceptually apply to watersheds hydrologically controlled by shallow interflow of perched groundwater. Walter et al. (2002) further re-conceptualized the TOPMODEL by using soil moisture deficit instead of water table depth as the state variable to make it applicable to shallow, interflow-driven watersheds. Consequently, the TI that predicts the spatial distribution of runoff contributing areas can be approximated as follows:

(2) $$\lambda = \ln\left(\frac{\alpha}{\tan(\beta) K_s D}\right) = \ln\left(\frac{\alpha}{\tan(\beta)}\right) - \ln\left(K_s D\right),$$

where *D* is the local soil depth in meters to the fragipan, bedrock or other type of restrictive layer, K_s is the mean saturated hydraulic conductivity of the soil profile in meters per day above the restrictive layer, and other variables are defined as before. The redefined TI is similar to the one defined by Ambroise et al. (1996). Equation (2) has two components: the wetness index,

$\ln\left(\frac{\alpha}{\tan(\beta)}\right)$, and the soil water storage index, $\ln(K_s D)$. Unlike equation (1), equation (2) considers the impacts on the index of soil water storage capacity ($K_s D$) above the restrictive layer. In general, the deeper the topsoil (D) and the higher the saturated hydraulic conductivity (K_s), the lower the value of λ, which implies a lower likelihood of generating surface runoff. In reality, there are several topsoil layers with different K_s values above a restrictive layer or bedrock. In this case, K_s is defined as

$$K_s = \frac{d}{\sum_{1}^{n}(d_i / k_i)}, \tag{3}$$

where d is total thickness of the soil above the restrictive layer; d_i is the thickness of layer i, k_i is the saturated hydraulic conductivity of layer i (Freeze and Cherry 1979).

Data and Data Processing

Two spatial datasets were used in deriving the TI using the equation (2) in the study area: a digital elevation model (DEM), and a soil survey database. The 10-m resolution DEM for WMA08 was downloaded from NJDEP website. The NRCS Soil Survey Geographic (SSURGO) soil database for Hunterdon County was downloaded from the NRCS Soil Data Mart website.

The DEM was first processed using the open source ArcGIS extension Terrain Analysis Using Digital Elevation Models (TauDEM) by Tarboton (2005) and the ArcGIS Raster Calculator to obtain a wetness index grid, $\ln(\frac{\alpha}{\tan\beta})$. There was a problem in calculating the wetness index when the local surface slope angle, β, is zero. To ensure the full coverage of the TI, we assumed a minimum surface slope of 0.0001 for all grids with surface slopes less than 0.0001.

The soil depth (D) and the mean saturated hydraulic conductivity (K_s) were extracted for each soil type from the Hunterdon County SSURGO soil database. There were two types of data associated with the county soil database: an ArcGIS shapefile showing the spatial distribution of all soil types in the county and a Microsoft Access database containing the attributes of those soil types. The Access database was first inquired to determine there was any restrictive layer such as fragipan or bedrock under each soil in the *corestrictions* table in the database. Then, the layer thickness and the associated K_s in the different soil layers of each soil were extracted from the *chorizon* table in the database. For a soil type that had a restrictive layer, only the layer thickness and the associated K_s of the soil layers above the restrictive layer were extracted. The soil depth D was calculated as the sum of the soil layer thickness and the mean of the saturated hydraulic conductivity, K_s, in different soil layers was calculated using equation (3). The product (K_s*D) for each soil finally was calculated and linked to the soil spatial distribution GIS layer through the name of the soil mapping unit *MUSYM*. The soil layer was converted into a soil water storage index raster layer based on the value of $\ln(K_s D)$. The converted raster layer had the same resolution as and was in alignment with the wetness index raster layer. In the soil survey database, a small percent of area in the county was classified as water, rough broken land, shale, quarry, and pits, sand and gravel for which there was no attribute value on K_s in the soil database. Since these soil classifications did not have any soil water storage capacity, the grids with these soil classifications were assigned a soil water storage index of -3, which was about 1.2 lower than the highest calculated soil water storage index of -1.8 in the county. Although the index of -3 was arbitrary, it was not expected to have a significant impact on the resulting TI because 90 percent of those grids were water, which generally had high wetness indices.

The Raster Calculator in ArcGIS was used to manipulate the raster layers for the wetness index from the DEM and the soil water storage index from the SSURGO soil data and to calculate the TI based on equation (2). The resulting raster on the TI was then clipped by the municipal boundary layer to generate the TI raster layers for the municipality.

Application to Readington Township

Figure 2 presents the spatial distribution of TI in Readington Township. The indices range from 1.3 to 29.9. The HSAs are the areas with TI greater than the threshold value of 9.0 determined by the Rockaway Creek Watershed Project Advisory Committee. The total delineated HSAs are 7,595 acres for Readington Township, which is 24.9 percent of the total area of the municipality. Figure 3 presents the spatial distribution of the HSAs in Readington Township. HSAs are presented in three layers with TI from 9 to 9.5, 9.5 to 10 and above 10 to show greater details in hydrological sensitivity. The spatial distribution of the HSAs can help to inform the selection of appropriate land use planning controls and management strategies to protect these areas. Although HSAs should be preserved to protect water quality because of their significant role in landscape hydrology, they are actively used in Readington Township. Table 1 presents the distribution of HSAs by land uses in Readington Township. In Readington, 2,376 acres (i.e., the highest percentage of 31.3 percent) of HSAs are in urban. Forest contains 2,313 acres of HSAs or 30.5 percent of the total HSAs in the township, followed by agriculture at 22.5 percent of HSAs. The HSAs in active land uses such as agriculture, urban and barren land are CSAs because water pollutants originating from those areas will be quickly carried away into the streams and pose immediate threats to water quality. Agricultural and stormwater management practices should be first applied to CSAs to achieve the highest effectiveness in mitigating the negative water quality impacts caused by such intensive land uses. Figure 4 presents the spatial distribution of the CSAs in Readington Township.

Table 1: The distribution of HSAs by land uses in Readington Township

	Agriculture	Barren Land	Forest	Urban	Water	Wetlands	Total
Acreage	1,708.8	36.0	2,312.8	2,375.7	183.1	978.7	7,595.1
Percent	22.5	0.5	30.5	31.3	2.4	12.9	100.0

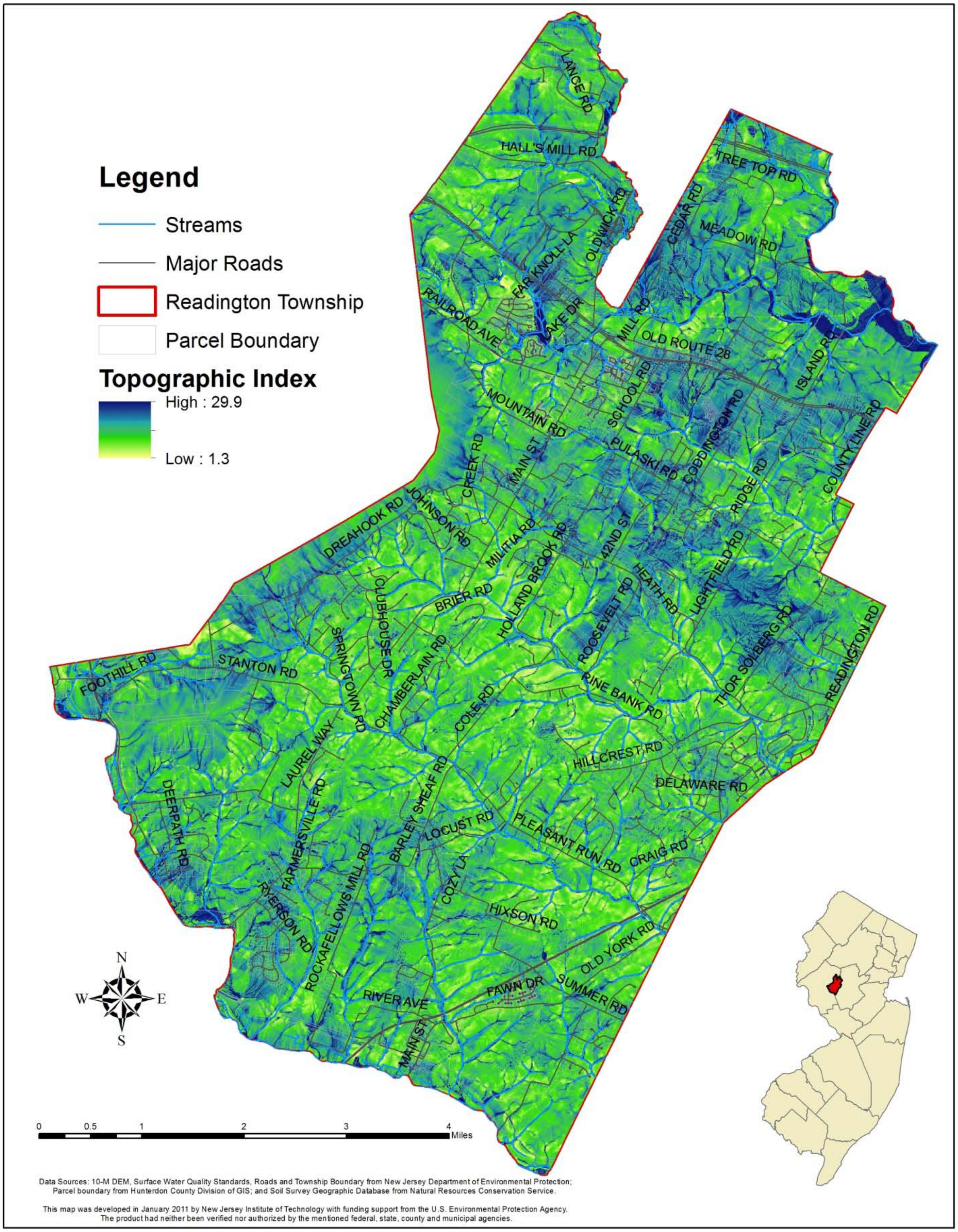


Figure 2: Spatial distribution of TI in Readington Township, New Jersey

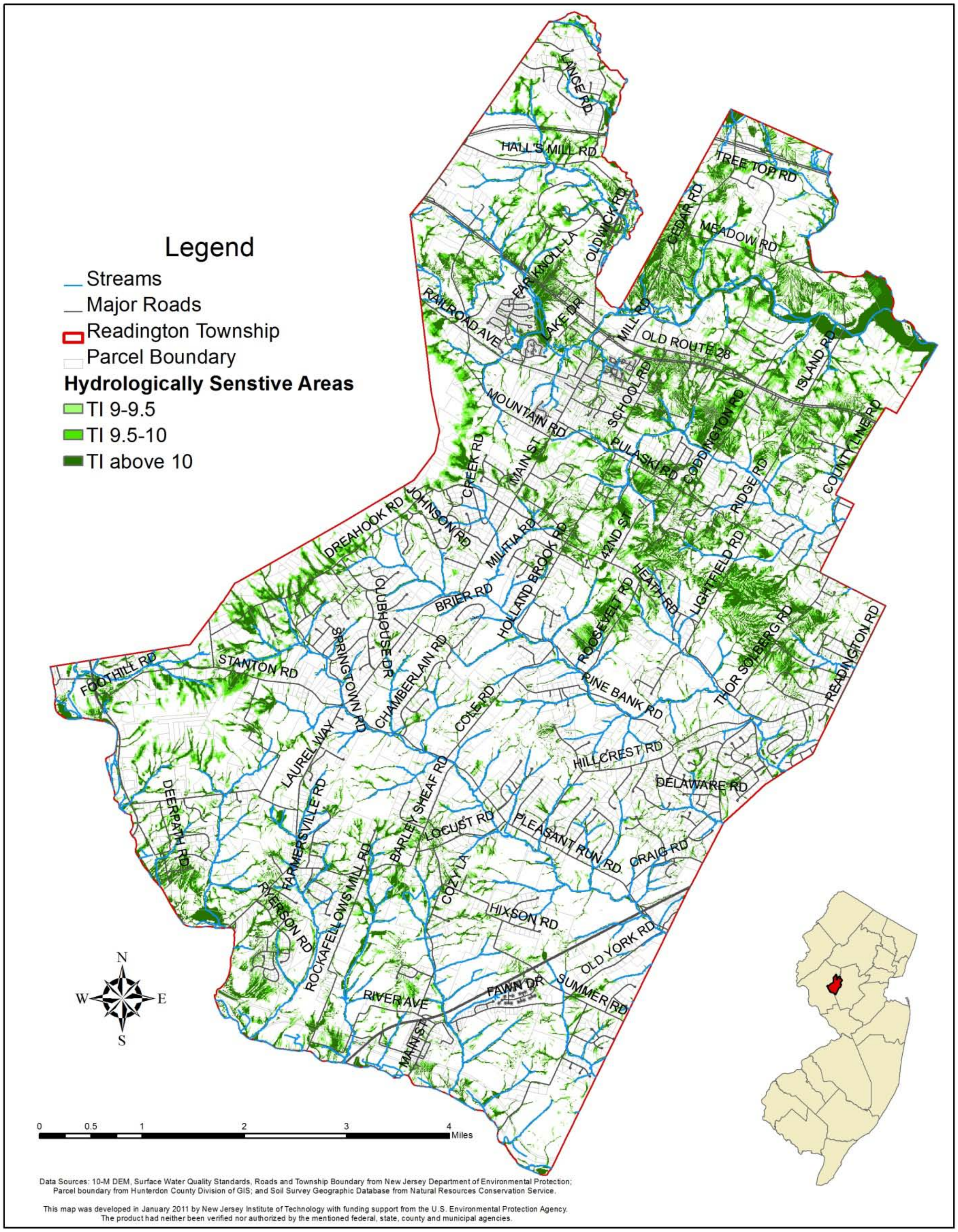


Figure 3: Spatial distribution of HSAs in Readington Township, New Jersey

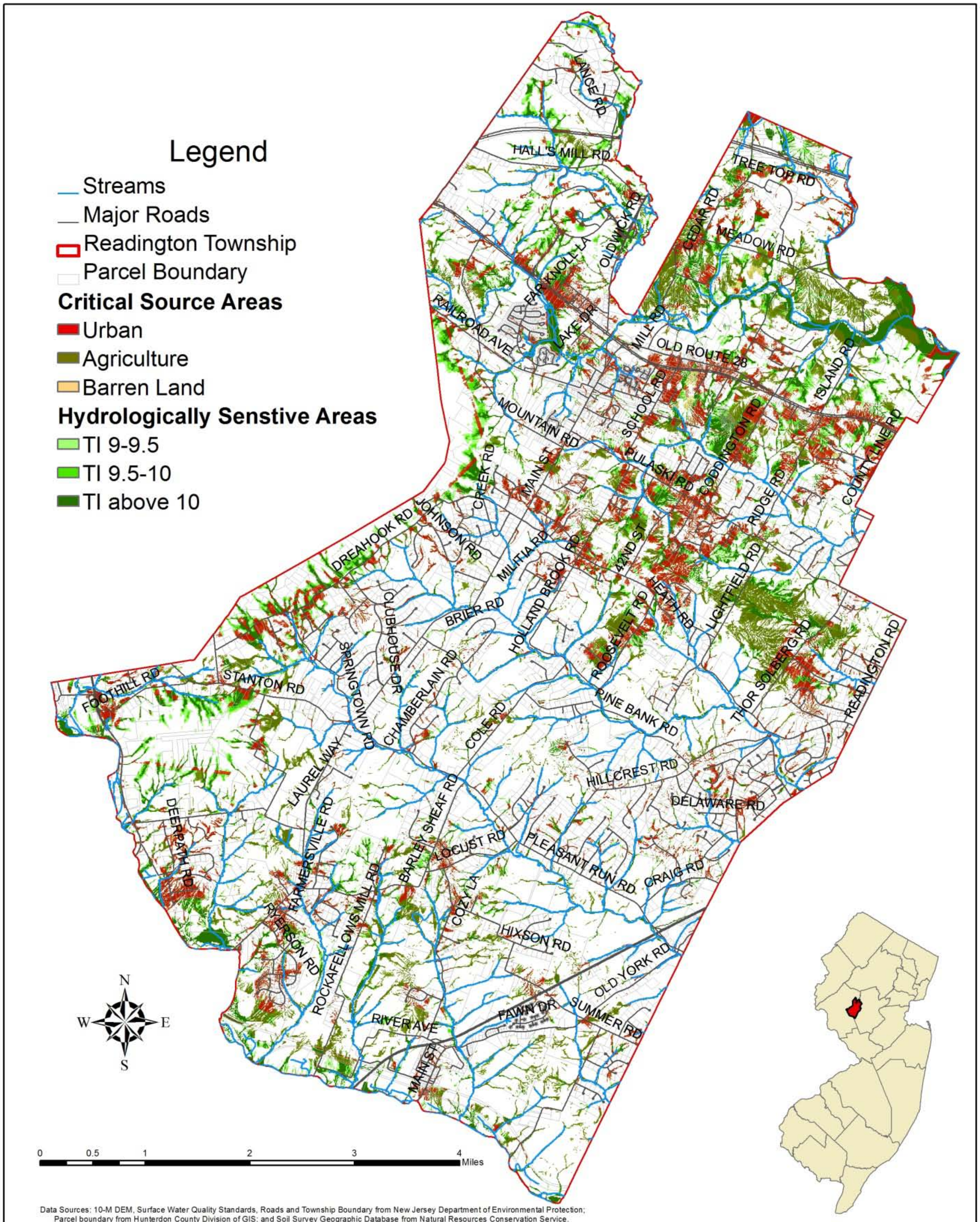


Figure 4: Spatial distribution of CSAs in Readington Township, New Jersey

Existing Municipal Land Use Controls and HSAs Protection

Land Use Planning Controls

Readington Township has a wide range of land use controls to dictate or restrict the land use changes. The following four land use controls are found to have significant impacts on land use changes with strong orientation to protect water resources: (1) stream corridor protection mandated by NJDEP Stormwater Management Rule (NJAC 7:8), NJDEP Flood Hazard Control Act (NJAC 7:13); wetland protection and mitigation, and municipal stream buffer ordinances; (2) steep slope area protection that restricts certain developments on areas with slope greater than 25 percent; (3) open space preservation and (4) farmland preservation implemented by state, county, and municipal governments, private organizations, and individuals. The steep slope area protection, open space, and farmland preservation are relatively straightforward to map and analyze. The stream corridor protection is very complicated and the municipal regulatory controls need to be overlaid with the State regulatory parameters. The stream corridor protection includes stream channels, the riparian areas of the streams, floodplains, and the sloping areas that are adjacent to the riparian areas of the streams and floodplains as discussed in the section on Municipal Review.

Various data sources were used to assess the areas protected under the four land use control measures. The sloping areas are derived from NJDEP 10-meter DEM. The stream corridor protection area in each municipality was derived according to the municipal stream corridor protection ordinance along with the following data:

- NJDEP flood prone area map
- FEMA flood hazard map
- NJDEP 2010 surface water classification standards
- USGS 10-meter DEM maintained by NJDEP

The data sources for preserved open space and farmlands include:

- Hunterdon County Division of GIS,
- New Jersey State Agricultural Development Committee,
- NJDEP Green Acres Program on both state-own and local-owned open space, and
- Readington Township Open Space and Farmland Preservation Properties

Effectiveness of Land Use Planning Controls in Protecting HSAs

Table 2 presents the areas and the HSAs protected by the four land use controls in Readington Township. The protection level varies significantly by land use control. The stream corridor ordinance protects 5,566 acres from future development, among which 1,857 acres are HSAs. The HSAs protected by stream corridor ordinance is 24.4 percent of the HSAs in Readington Township, the highest among the four land use controls. Open space preservation protects 13.8 percent of the HSAs in the township, which is then followed by the farmland preservation at 12.4 percent. The steep slope restriction protects only 0.1 percent of the HSAs in the township. The stream corridor ordinance also is the most effective land use control in protecting HSAs in Readington Township. Among the 5,566 acres of stream corridor being protected, 33.4 of them are HSAs. The open space preservation is the second effective land use control in protecting HSAs. 27.9 percent of the preserved open space is HSAs, which is then followed by the farmland preservation at 20.1 percent. The steep slope restriction is the most ineffective land use control in protecting HSAs. Only 2.1 percent of the areas protected by the steep slope restriction are HSAs.

Table 2: The protection areas and HSAs being protected in Readington Township

Land Use Controls	Protection Area (Acres)	HSAs Being Protected (Acres)	% of HSAs Being Protected	% of HSAs in Protection Area
Area Being Protected by Single Land Use Control				
Steep Slope	529.6	11.2	0.1	2.1
Stream Corridor	5,565.9	1,856.6	24.4	33.4
Preserved Open Space	3,747.0	1,044.4	13.8	27.9
Preserved Farmlands	4,666.7	938.1	12.4	20.1
Area Being Protected by One or More Land Use Controls				
One	10,343.4	2,486.5	32.7	24.0
Two	1,980.6	675.3	8.9	34.1
Three	68.1	4.4	0.1	6.5
Total	12,392.1	3,166.2	41.7	25.6

The areas protected by the land use controls overlap. Table 2 also presents the areas and HSAs protected by one or more land use controls. 2,487 acres of HSAs, which is 32.7 percent of the HSAs in the township, are protected by only one type of land use control. There are 675 acres of HSAs (i.e. 8.9 percent of the HSAs in the township) protected by two land use controls. There are only 4.4 acres of HSAs protected by three land use controls. The total areas protected by all four land use controls are 12,392 areas in Readington Township. The total area of HSAs being protected in Readington Township is 3,166 acres, which is 41.7 percent of HSAs in the township. The HSAs being protected are only 25.6 percent of the total protected area in Readington. Figure 5 presents the spatial distributions of HSAs and the areas protected by the four land use controls in Readington Township.

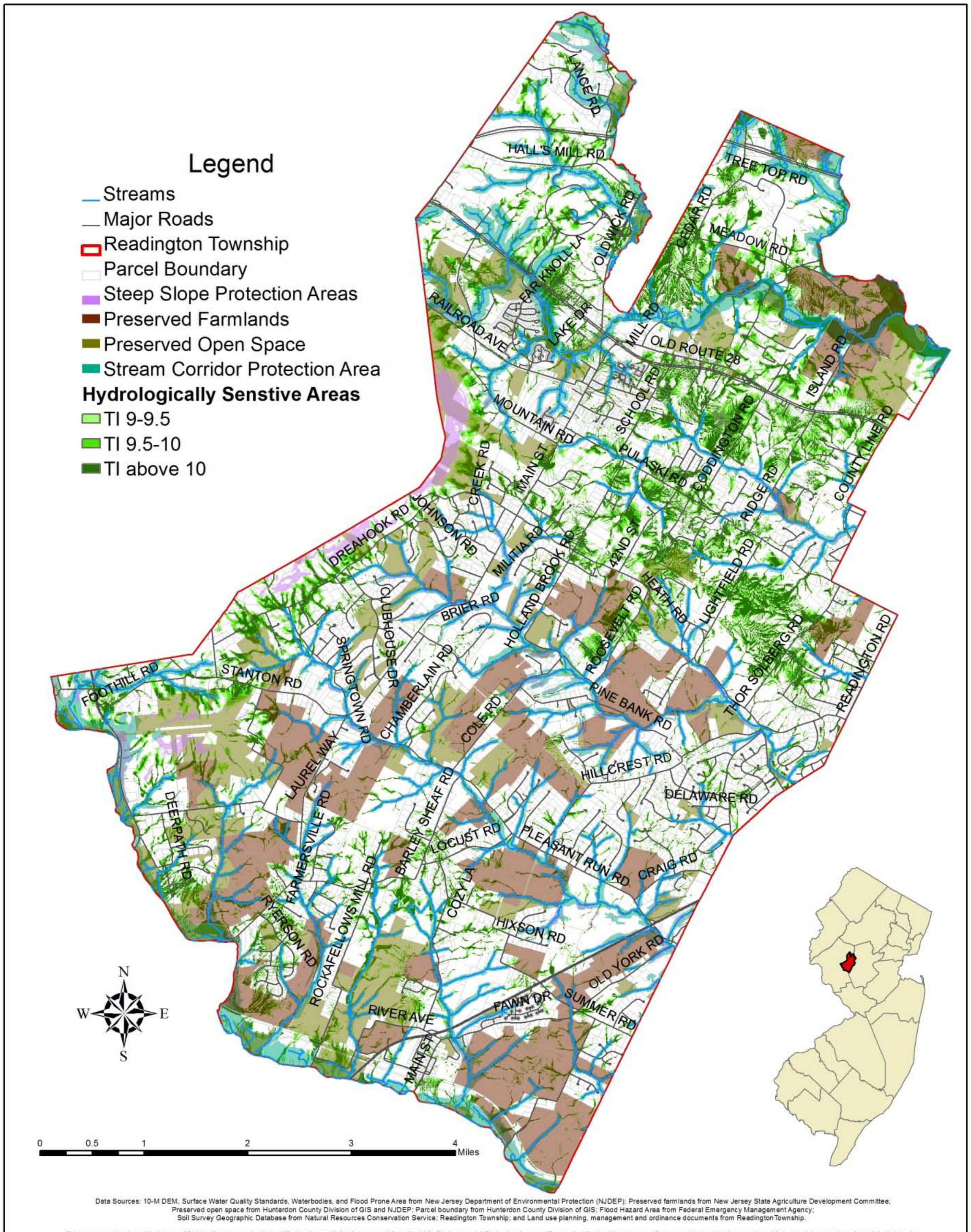


Figure 8: HSAs and land use controls in Readington Township

Recommendations for Integrating HSAs into Municipal Land Use Programs

The long term management and protection of water quality is a high priority in Readington Township. Protections afforded by the New Jersey Department of Environmental Protection (NJDEP) along with regulatory controls implemented through the Township's land use regulations have created an overlapping and complex regulatory framework for water resource protection. Regulatory programs that underpin New Jersey's water quality strategies include:

- NJDEP's Surface Water Quality Standards (NJAC 7:9B) which establish anti-degradation policies for all surface waters of the State. Category One (C-1) designation provides additional protections to surface waters to prevent degradation and discourage development-induced impacts.
- NJDEP's Stormwater Management Rule (NJAC 7:8) requires a 300 foot Special Water Resource Protection Area (buffer) adjacent to and upstream of all C-1 streams.
- NJDEP's Flood Hazard Control Act (NJAC 7:13) requires 50 foot buffers on Non-trout Streams, 150 foot buffers on Trout Maintenance waterways, and streams associated with Threatened and Endangered Species, and a 300 foot buffer along C-1 designated streams.
- NJDEP's Highlands Water Protection and Planning Act requires 300 foot stream buffers on streams in the Highlands Preservation Areas and along all open waters. Additional restrictions are also placed on development activities in steep slope areas >20 percent, 15-20 percent, and for 10-15 percent slopes located within the 300 foot riparian area.

Readington Township has implemented a rigorous set of have land development regulations and municipal programs that support and complement efforts to protect water resources. The Readington Township Land Use Regulations contain the administrative procedures, subdivision and site plan review procedures, plan and plan details, design standards, zoning regulations and other provisions (e.g., conditional uses, variance procedures) that govern development activities. There are a wide range of provisions, restrictions, and requirements currently in place in Readington Township that provide water resource protection as either their primary focus or as a secondary benefit. Each of these regulations, standards or programs could be modified to incorporate Hydraulically Sensitive Areas factors.

- Deed Restriction Requirements (Conservation Easements, Open Space & Agricultural Preservation)
- Development Density Standards
- Environmental Impact Statement Requirements
- Flood Hazard and Surface Water Management
- Landform Protection
- Open Space Requirements

- Residential Cluster & Planned Development Provisions
- Steep Slope (Critical Area) Regulations
- Stormwater Treatment Requirements
- Stream Corridor (Critical Area) Protection
- Surface Water Management
- Top Soil Removal Restrictions (SSR Zone)
- Tree removal

While each of the above referenced ordinances or standards could be modified to include HSA considerations, the greatest impact in achieving higher levels of water resource protection would be made if the community focuses any future efforts into updating the following provisions.

Landform Protection

Efforts to control changes in the natural topography are included in the Landform Protection ordinance that limits changes in elevation to a maximum of two vertical feet and no more than 35 percent of a lot/tract area. **(Chapter 148-60.1 Landform protection)**

Recommended Updates or Design Considerations

- *The removal or disturbance of soil in areas characterized as HSAs has the potential to significantly impact water quality through the accelerated movement of unstable saturated soils.*
- *The use of Low Impact Development techniques that focus on limiting soil disturbance on HSAs will reduce the propensity for soil and pollutant movement. The presence of HSAs should be used to evaluate compliance with the ordinance intent to minimize the disturbance of steep slopes that coincide with HSAs. Development activities should avoid HSAs to the greatest extent practical.*

Critical Areas – Steep Slope

The purpose of this section is to regulate the construction of buildings and roads, the removal of vegetative cover, the disturbance of soil and the intensity of use in areas of excessive slopes. The ordinance regulates activities on slope classes 15 percent to less than 25 percent, 25 percent to 35 percent and greater than 35 percent through the submission of a lot grading plan. **(Chapter 148-50 Critical areas. A. Steep slopes)**

Recommended Updates or Design Considerations

- *The presence of HSAs should be used to evaluate compliance with the ordinance intent to minimize the disturbance of steep slopes that coincide with HSAs. Development activities should avoid HSAs to the greatest extent practical.*
- *The use of Low Impact Development techniques that focus on limiting soil disturbance on HSAs will reduce the propensity for soil and pollutant movement. The presence of HSAs should be used to evaluate compliance with the ordinance intent to minimize the disturbance of steep slopes that coincide with HSAs.*

Critical Areas – Stream Corridor

The purpose of ordinance is to protect property from flooding; to reduce land development impacts on stream water quality and flows; to maintain quality of streams and improve the currently impaired streams in the Township; to protect significant ecological components of stream corridors such as wetlands, floodplains. woodlands, steep slopes, wildlife, plant and riparian habitats within the stream corridors of the Township: to complement existing state, regional, county and municipal stream corridor protection and management regulations and initiatives; to protect existing natural drainage features; to protect other's rights within the same watershed from adverse effects of improper stream corridor development; and to provide recreation and wildlife migration corridors. Stream corridors shall remain in their natural state, with no clearing or cutting of trees and brush (except for removal of dead vegetation and pruning for reasons of public safety), altering of watercourses, regarding or construction. If development is proposed in the stream corridor applicants are required to submit detailed engineering information. A conservation easement is required on all stream corridors. Stream Corridors are defined as the stream channel, area within 100 year flood line plus 100 fee for non-trout waters, 150 feet for trout maintenance waters and 300 feet for Category One Waters. Additionally areas abutting the outer boundary of the composite area of the stream above that have slopes of 15 percent or greater. **(Chapter 148-50 Critical areas. B. Stream corridors)**

<u>Recommended Updates or Design Considerations</u>
Stream buffer requirements currently are described by a fixed linear distance (between 100 to 300 feet perpendicular to a stream), and in some cases have flexibility to some percentage of the nominal buffer. The State of NJ requires 300 foot buffers along Category One waters, with allowance for a reduction to 150 feet in certain circumstances. These buffer distances are approximations for more complex relationships that are hard to map or identify on a site-specific or regional basis. They often reflect more than one concern, such as stream shading, influent stormwater quality, sediment movement, concentration of runoff, riparian ecosystem protection, to name a few.

- *HSAs could be used to identify where a lessening of the stream buffer through flexibility provisions should <u>not</u> be allowed. Other parts of the buffers will have a lower potential for stream damage if disturbed.*

- *HSAs can identify where stream buffers could be expanded as part of an averaging plan*

Flood Hazard and Surface Water Management

These regulations seek to restrict or prohibit uses, protect uses against flood damage, control filling, dredging, grading or alteration of natural floodplains, stream channels and prevent construction of flood barriers. Encroachments therein shall therefore be permitted most sparingly and only in cases in which the public interest will be served, such as bridges, roads, utility installations and the like and the temporary storage of material or equipment in connection with and during the construction thereof, or where the obstruction is minimal, such as surface parking or recreation areas, open fencing and the like, and then, in either case, only in accordance with conditions designed to limit the obstruction to the practicable minimum. **(Chapter 148-79.3 to 148-79.7 Flood Damage Prevention)**

<u>Recommended Updates or Design Considerations</u>
The alteration, filling, grading or changes to drainage patterns and flow paths could significantly impact HSAs found in the floodway and flood hazard areas. Requests for encroachments in the flood hazard area should also consider the extent of the impact on HSAs and the increased risk for water quality impairment.

Surface Water Management

These regulations regulate the discharge of stormwater runoff from land development projects and other construction activities, in order to control and minimize increases in stormwater runoff and volumes and to control and minimize soil erosion, and nonpoint source pollution associated with stormwater runoff. These provisions manage the increased rate and velocity of surface water runoff created by alterations in ground cover and natural runoff patterns. Concerns related to the maintenance of natural stream channels and preventing accelerated bank erosion, degradation of stream biota, and protecting the streams biological function and address flooding impacts are all considered in this ordinance. This ordinance applies to any development regardless of the area of site disturbance or area of new impervious cover, is subject to this ordinance. Technical standards for structural and nonstructural best management practices are provided. This ordinance also includes a provision for mitigation if an applicant can not comply with the ordinance provisions**. (Chapter 148-65.0 to 148-65.4 Stormwater)**

<u>Recommended Updates or Design Considerations</u>
<u>Ground Water Recharge Techniques</u>
Current regulations require that total post-construction recharge for a development project at least equal pre-construction recharge.

- *HSAs, because they have more frequent soil saturation, are locations where recharge techniques are unlikely to work, and in fact could cause significant harm by causing more frequent soil saturation.*
- *The concentration of recharge techniques directly up-gradient of HSAs should probably be discouraged, unless the areas are fully vegetated and stable, because additional recharge at those locations will increase the frequency of soil saturation and sediment/pollutant mobilization.*

<u>Low Impact Development Techniques</u>

NJDEP stormwater regulations require consideration of low impact development (LID) techniques.

- *HSAs should have high priority to remain undisturbed as a LID technique, reducing the potential for disruption of areas that have a high propensity for soil and pollutant movement.*

<u>Stormwater Facility Placement</u>

Stormwater facilities are usually placed in the most downhill location, as all stormwater flows are gravity based.

- *HSAs will often be inappropriate locations for stormwater facilities such as detention basins and release channels that increase the frequency of soil saturation, unless facility design addresses the potential for soil and pollutant migration.*

<u>Restoration Projects Implemented Under Mitigation Provisions</u>

Stormwater management and stream restoration projects need to address both the stream channel and outside forces that can disrupt the project.

- *HSAs should be mapped on stream restoration designs to avoid the development of stream or channel head cuts, reduce existing overland flow velocities into these areas and reduce sediment movement to the stream.*
- HSAs *where disturbed and unstable, can serve as mitigation project sites under the Stormwater Management Rules.*

Soil and Soil Removal Regulations

The purpose of this chapter is to control soil erosion, sedimentation and surface water runoff damage and related environmental damage by management of soil disturbance and alteration of vegetative ground cover and natural drainage patterns in order to promote the safety, public health, convenience and general welfare of the community. It shall be unlawful for any person to engage in any land disturbance activity on any property within the Township without having submitted a soil and surface water runoff management plan, together with erosion and sediment control plans, to the administrative authority and obtaining approval of such plan and a permit or written waiver of necessity from the administrative authority. **(Chapter 197-1 to**

197-17 Soil Erosion and Sediment Control- Readington Township Soil and Surface Water Management)

<u>Recommended Updates or Design Considerations</u>
The removal or disturbance of soil in areas characterized as HSAs has the potential to significantly impact water quality through the accelerated movement of unstable saturated soils.

- *HSAs should have high priority to remain undisturbed when applicants are developing projects that require soil disturbance or removal. The use of Low Impact Development techniques that focus on limiting soil disturbance on HSAs will reduce the propensity for soil and pollutant movement.*

Environmental Impact statement

Applicants that are required to prepare and submit an environmental impact statement (EIS) shall submit a completed EIS checklist and maps. The EIS shall contain a listing of all environmental protective measures which will be used should the proposed project be implemented. These are measures which will avoid or minimize adverse effects on the natural and man-made environment of the site and region during the construction and operation of the facility. The ordinance requires a summary list of the potential adverse environmental impacts which cannot be avoided should the proposed project be implemented. Short-term impacts should be distinguished from irreversible impacts. The EIS shall contain a concise summary of the environmental impact assessment for the proposed project. This summary will evaluate the adverse and positive environmental effect of the project should it be implemented and the public benefits expected to derive from the project, if any. (Chapter 165-72)

<u>Recommended Updates or Design Considerations</u>

- *HSAs should be added to the required data submission list.*
- *Applicants need to address the impact of the project on the HSAs and describe efforts to include environmental protective measures or avoid adverse development activities on HSAs. Land use activities that have a high potential to contribute nonpoint source pollution should be avoided in HSAs to reduce the potential movement of pollutants.*

Tree Removal

The Planning Board shall discourage clear cutting of any lot and the removal of more than two living trees from a lot in the SSR Zone. The applicant shall provide a tree removal plan indicating the location, size and number of trees to be removed. A soil erosion and sedimentation control plan adequately reducing soil erosion and sedimentation to the satisfaction of the Township Engineer or other agency with jurisdiction. A planting plan shall demonstrate adequate vegetation cover to prevent erosion or excessive stormwater runoff. The Planning Board shall discourage clear cutting of any lot. **(148-46 Tree removal in the SSR Zone)**

> <u>*Recommended Updates or Design Considerations*</u>
> *Decisions on the importance of individual trees and woodland areas for preservation should be evaluated in conjunction with the presence of HSAs in the vicinity of the tree areas. The removal of trees in areas with HSAs has a great potential to impact water quality due to enhance soil movement in these sensitive area.*

Farmland and Open Space Preservation

The Township's Open Space, Recreation and Farmland Preservation Trust Fund continues to be used in combination with other funding sources to increase the community's open space inventory, including farmland easements, active recreation areas, and environmentally sensitive areas. The Township continues to work with farmland owners throughout the Township to promote its preservation efforts. In addition to targeting properties that meet selection criteria under State and County programs, the Township seeks to preserve lands that will enhance and expand existing preserved open space areas and related natural resources

> <u>*Recommended Updates or Design Considerations*</u>
> *Priorities for land preservation should consider the presence of HSAs as another factor to evaluate during the land revaluation and ranking process. Sensitive areas where stream buffers, wetlands, HSAs and other features should be placed under a conservation easement prior during the preservation process.*

Direct Regulation of HSAs

These areas are significant in and of themselves, and are not always located proximate to mapped streams.

- *HSAs should be identified as important areas for the protection of water quality, in the Conservation Elements of municipal master plans*
- *HSAs can be protected through exclusion from development or site disturbance, similar to protection of stream buffers, wetlands and steep slopes.*
- *HSAs can be protected through clustering, lot size averaging or conservation subdivision design.*

References

Agnew LJ, Walter MT, Lembo A, Gérard-Marchant P, Steenhuis TS (2006) Identifying hydrologically sensitive areas: Bridging science and application. Journal of Environmental Management 78:64-76.

Ambroise B, Beven KJ, Freer J (1996) Toward a generalization of the TOPMODEL concepts: Topographic indices of hydrological similarity. Water Resources Research 32(7):2135-2145.

Beven KJ, Kirkby MJ (1979) A Physically Based, Variable Contributing Area Model of Basin Hydrology. Hydrological Science Bulletin 24(1/3):43-69.

Beven, KJ (1997) TOPMODEL: A critique. Hydrological Processes 11(9):1069-1085.

Dunne, T. Leopold LB (1978) *Water in Environmental Planning*. W.H. Freeman and Company, New York, NY. pp. 818.

Freeze RA, JA Cherry (1979) Groundwater. Englewood Cliffs, New Jersey: Prentice-Hall Inc., 604p.

Gallart F, Latron J, Llorens P, Rabadá D (1997) Hydrological functioning of Mediterranean mountain basins in Vallcebre, Catalonia: Some challenges for hydrological modeling. Hydrological Processes 11(9):1263–1272.

Gburek, WD, Sharpley AN (1998) Hydrologic controls on phosphorus loss from upland agricultural watersheds. *J. Environ. Qual*. 27: 267-77

Gómez-Plaza A, Martinez-Mena M, Albaladejo J, Castillo VM (2001). Factors regulating spatial distribution of soil water content in small semi-arid catchments. Journal of Hydrology 253(1-4):1261-1277.

Heathwaite L, Quinn PF, Hewett C (2005) Modelling and managing critical source areas of diffuse pollution from agricultural land using flow connectivity simulation. Journal of Hydrology 304(1-4):446-461.

Hewlett JD (1982) Principles of Forest Hydrology. Athens, Georgia: University of Georgia Press.

Hewlett JD and Hibbert AR (1967) Factors affecting the response of small watersheds to precipitation in humid areas. IN Forest Hydrology (eds. W.E. Sopper and H.W. Lull). Pergamon Press, Oxford. Pp. 275 – 290.

Hornberger GM., Beven KJ, Cosby BJ, Sappington DE (1985) Shenandoah watershed study: Calibration of a topography-based, variable contributing area hydrological model to a small forested catchment. Water Resources Research 21(12):1841–1850.

Hunterdon County Planning Board (2005) *People and Housing Profile*. Hunterdon County Planning Board, Flemington, New Jersey [online] http://www.co.hunterdon.nj.us/pdf/hcpb/demographics.pdf

Merwin, IA, Stiles WC, Vanes HM (1994) Orchard groundcover management impacts on soil physical-properties. *J. Am. Soc. Hort. Sci*. 119 (2): 216-222.

Moore ID, Grayson RB, Ladson AR (1991) Digital terrain modelling: A review of hydrological, geomorphological, and biological applications. Hydrological Processes 5(1):3-30.

New Jersey Department of Environmental Protection (NJDEP) (2010) *Surface Water Quality Standards, N.J.A.C. 7:9B.* Last Amended January 4, 2010 (42 N.J.R. 68(a)) http://www.nj.gov/dep/rules/rules/njac7_9b.pdf.

O'Loughlin EM (1986) Prediction of surface saturation zones in natural catchments by topographic analysis. Water Resources Research., 22(5):794-804.

Qiu Z (2003) A VSA-based strategy for placing conservation buffers in agricultural watersheds. Environmental Management 32(3):299-311.

Qiu, Z, Prato T, Godsey L, Benson V (2002) Integrated assessment of uses of woody draws in agricultural landscapes. *The Journal of American Water Resources Association* 38(5):1255-1269.

Readington Township (1990) Master Plan and Re-examination Report, Readington Township Planning Board and Clarke & Caton 400 Sullivan Way, Ewing, NJ 08628.

Readington Township (1998) *Amendment to the Master Plan*. Clarke Caton Hintz 400 Sullivan Way, Ewing, NJ 08628

Readington Township (2001) *Open Space Preservation: A Report to the Readington Township Planning Board.* Readington Township Committee. Township of Readington 509 Route 523 Whitehouse Station, NJ 08889

Readington Township (2001) *The Land Development Ordinance of the Township of Readington.* Ordinance No. 15-2001, *as amended.* Township of Readington 509 Route 523 Whitehouse Station, NJ 08889

Readington Township (2002) Amendment to the Master Plan. Clarke Caton Hintz 400 Sullivan Way, Ewing, NJ 08628

Readington Township (2005) *Stormwater Management Plan for Readington Township*. Princeton Hydro, LLC 1108 Old York Road, Ringoes, NJ 08551

Readington Township (2007) *The Readington Township Environmental Resource Inventory*. Princeton Hydro LLC 1108 Old York Road, Ringoes, NJ 08551

Schneiderman EM, Steenhuis TS, Thongs DJ, Easton ZM, Zion MS, Neal AL, Mendoza GF, Walter MT (2007) Incorporating variable source area hydrology into Curve Number based watershed loading functions. Hydrological Processes 21:3410-3430.

Steenhuis, TS, Muck RE (1988) Preferred movement of nonadsorbed chemicals on wet, shallow, sloping, soils. *J. Environ. Qual*. 17 (3): 376-384.

Tarboton DG (1997) A new method for the determination of flow directions and upslope areas in grid digital elevation models. Water Resources Research 33(2):309-319.

Tarboton DG (2005) Terrain analysis using digital elevation models (TauDEM). Accessible at http://hydrology.neng.usu.edu/taudem/.

Tomer, MD, James DE, and Isenhart TM (2003) Optimizing the placement of riparian practices in a watershed using terrain analysis. Journal of Soil and Water Conservation 58(4):198-206.

U.S. Department of Agriculture (USDA) (2009) *Summary Report: 2007 National Resources Inventory*, Natural Resources Conservation Service, Washington, DC, and Center for Survey Statistics and Methodology, Iowa State University, Ames, Iowa. 123 pages. http://www.nrcs.usda.gov/technical/NRI/2007/2007_NRI_Summary.pdf.

U.S. Environmental Protection Agency (USEPA) (2010*) Identifying and Protecting Healthy Watersheds: A Technical Guide (draft)*. EPA Office of Wetlands, Oceans, and Watersheds 1200 Pennsylvania Avenue, N.W. (4503T) Washington, D.C. 20460.

Walter MT, Brooks ES, Walter MF, Steenhuis TS, Scott CA, Boll J (2001) Evaluation of soluble phosphorus loading from manure-applied fields under various spreading strategies. Journal of Soil and Water Conservation 56(4):329-335.

Walter MT, Steenhuis TS, Mehta VK, Thongs D, Zion M, Schneiderman E (2002) A refined conceptualization of TOPMODEL for shallow-subsurface flows. Hydrological Processes 16(10):2041-2046.

Walter MT, Walter MF, Brooks ES, Steenhuis TS, Boll J, Weiler K (2000) Hydrologically sensitive areas: Variable source area hydrology implications for water quality risk assessment. Journal of Soil and Water Conservation 55(3):277-284.

Walter, MT, Mehta VK, Marrone AM, Boll J, Gérard-Merchant P, Steenhuis TS, Walter MF (2003) A simple estimation of the prevalence of Hortonian flow in New York City's watersheds. *ASCE J. Hydrol. Eng*. 8(4):214-218.

Wood EF, Sivapalan M, Beven KJ (1990) Similarity and scale in catchment storm response. Review of Geophysics 28(1):1-18.