Appendix A.

Determining Hydrogeologic Sensitivity

Town of Hillsdale Hydrogeologic Sensitivity Ratings

In this plan, the *hydrogeologic sensitivity* of a location is a relative measure of the ease and speed with which a contaminant could migrate into and within the upper-most water-bearing unit. A rating of low hydrogeologic sensitivity indicates that local groundwater is naturally well protected from contaminants at or near the land surface. High to very high hydrogeologic sensitivity ratings indicate that, in general, groundwater could be easily and quickly impacted by surface activities.

The hydrogeologic sensitivity is a function of the naturally occurring hydrogeologic characteristics of an area. The nature and extent of potential sources of groundwater contamination are not factored into hydrogeologic sensitivity ratings. Instead, the two factors controlling the hydrogeologic sensitivity are the site's geologic materials (the hydraulic characteristics of the uppermost water-bearing unit and the overlying soils) and the site's topographic position (the topographic factors influencing the vertical migration of groundwater). Resultant hydrogeologic sensitivity ratings based upon geologic materials and topographic position ratings are given below.

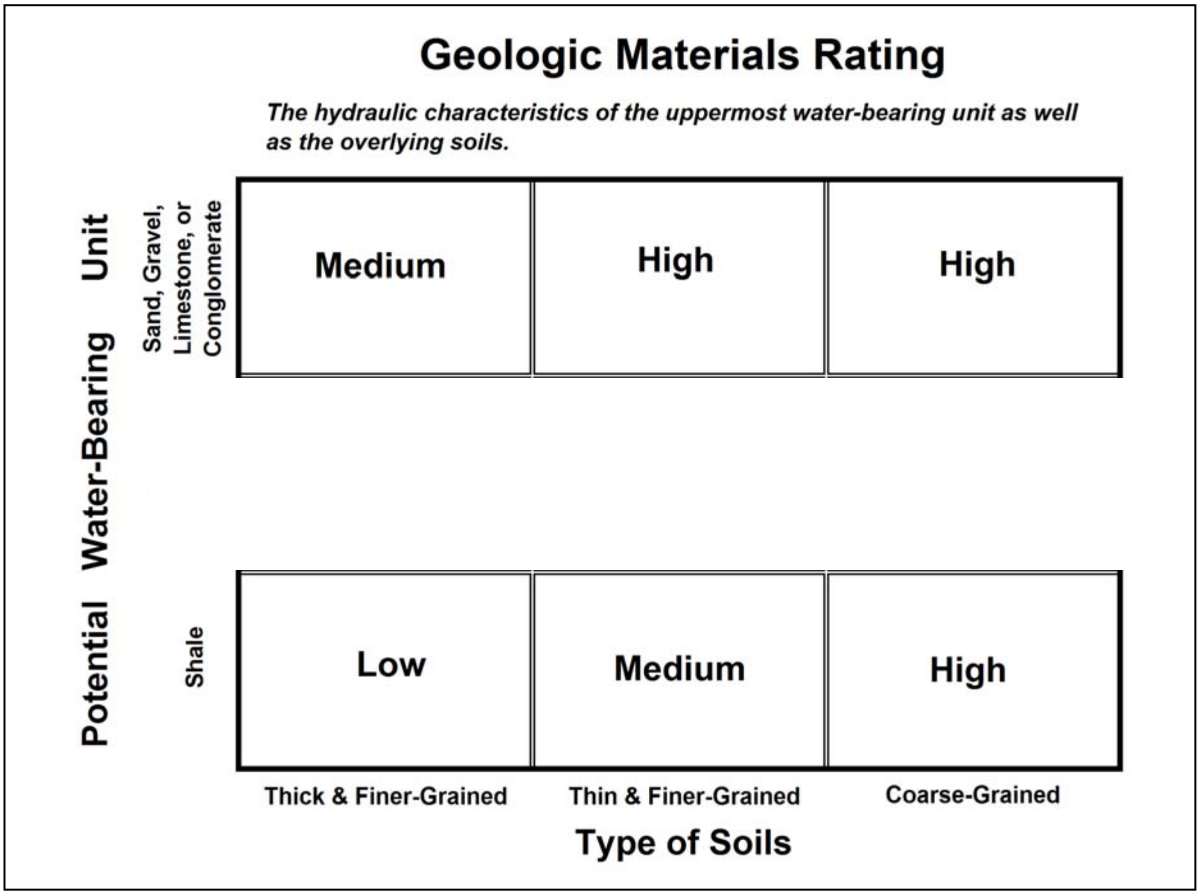
Hydrogeologic Sensitivity

The relative ease and speed that a contaminant on or near the land surface at a given location can migrate into and within the upper-most water-bearing unit.

Geologic Materials Rating \ Topographic Position Rating	Low	Medium	High
High	Medium	High	Very High
Medium	Medium	Medium	Medium-High
Low	Low	Low	Medium

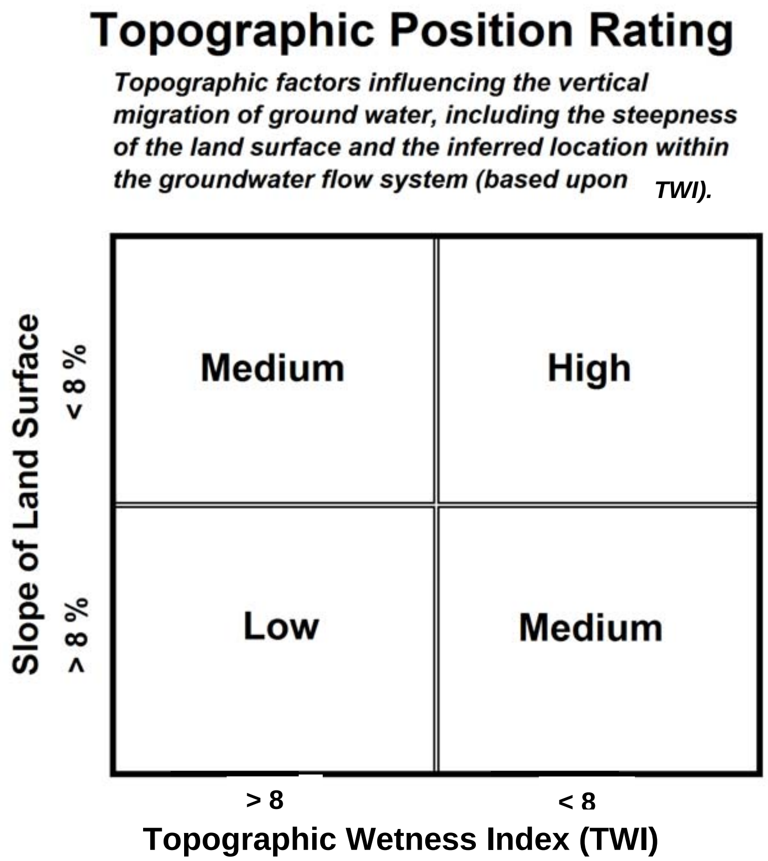
Geologic Materials Rating

The geologic materials ratings used to define the overall hydrogeologic sensitivity are based upon the following rating matrix:



Topographic Position Rating

Topography is an important, often overlooked factor related to the vertical groundwater flow. Areas with a low topographic wetness index (TWI) are situated in upland areas where typically there is a downward component of groundwater flow. Similarly, areas with lower slopes can promote greater downwards percolation of water.



Appendix B

Calculation of Annual Groundwater Recharge Rates

Rates of shallow groundwater recharge in Hillsdale have been estimated by based on base flow estimates and mean annual runoff in the region. Base flow is the component of stream flow that can be attributed to groundwater discharge into streams. The commonly-held assumption is that water that discharges to a stream as base flow originated as local shallow groundwater recharge. The United States Geological Survey (USGS) has calculated a variable known as the base flow index (BFI) for the watersheds of each of its stream gages. BFI is the ratio of base flow to total flow, and values were computed using an automated hydrograph separation computer program called the BFI program. BFI values for current and historical USGS stream gages in the conterminous U.S. are available from Wolock (2003a).

Working in the Great Lakes Basin, Neff et al. (2005) developed an empirical relation between measured base flow characteristics at gaging stations and the surficial geologic materials in the surrounding drainage area. In this study, a value of BFI was assigned to each surficial geologic material. The BFI for the gage watershed was calculated by the following equation taken from Neff et al. (2005):

$$y_{g,i} = \sum_j A_{g,i,j} \, x_{g,j} ,$$

where:

$y_{g,i}$ is the value of BFI for watershed *i* that results because of geological factors,
$A_{g,i,j}$ is proportion of geology class *j* within watershed *i*, expressed as a decimal between 0 and 1, and
$x_{g,j}$ represents ground-water discharge to the stream and is the value of BFI assigned to geology class *j*.

The value of BFI for each different surficial geologic material, x_{gj}, is indicated below from Neff et al. (2005):

Table 1. Values of $x_{g,j}$, the value of BFI assigned to geologic class *j*, used in equations 1 and 2 to calculate base-flow index used in this study.

Surficial-Geologic Material	$x_{g,j}$
Bedrock	0.78
Coarse-textured sediments	.89
Fine-textured sediments	.25
Till	.52
Organic sediments	.09

The surficial geologic materials for the Neff et al. (2005) study were taken from a 1:1,000,000-scale map of Quaternary deposits developed by Soller (1993) and digitized as Soller and Packard (1998). By studying watersheds in the region that have BFI data and iteratively comparing the surficial geology percentages of these watersheds using more detailed mapping, the following mean values of x_{gj} were found:

Surficial Material	Mean x_{gj}
Thin till and bedrock	0.33
Till	0.35
Coarse-textured sediments	0.75
Wetland deposits	0.09

The smaller value of x_{gj} for bedrock & till compared with the findings of Neff et al. (2005) is likely due to the lower permeability of local till and bedrock, as compared with that found in the Great Lakes Basin.

Mean annual groundwater recharge can be calculated by multiplying a grid of local base flow index (BFI) values by a grid of local mean annual runoff values. This approach is consistent with that of Wolock (2003b) to estimate mean annual natural groundwater recharge. The approach assumes that: (1) long-term average natural groundwater recharge is equal to long-term average natural ground-water discharge to streams, and (2) the BFI reasonably represents, over the long term, the percentage of natural groundwater discharge in stream flow. NYRWA constructed a grid of BFI values in Hillsdale using the detailed surficial geology dataset that was derived for the Town. Note that in Hillsdale, coarse-grained stratified sediments were assumed to include alluvial fan deposits, alluvium, and glaciofluvial deposits. Mean annual runoff is long-term average stream flow expressed on a per-unit-area basis. A USGS GIS dataset by Cohen and Randall (1998) was used to define a grid of mean annual runoff across the Town.

The resulting grid of estimated mean annual groundwater recharge is depicted below.

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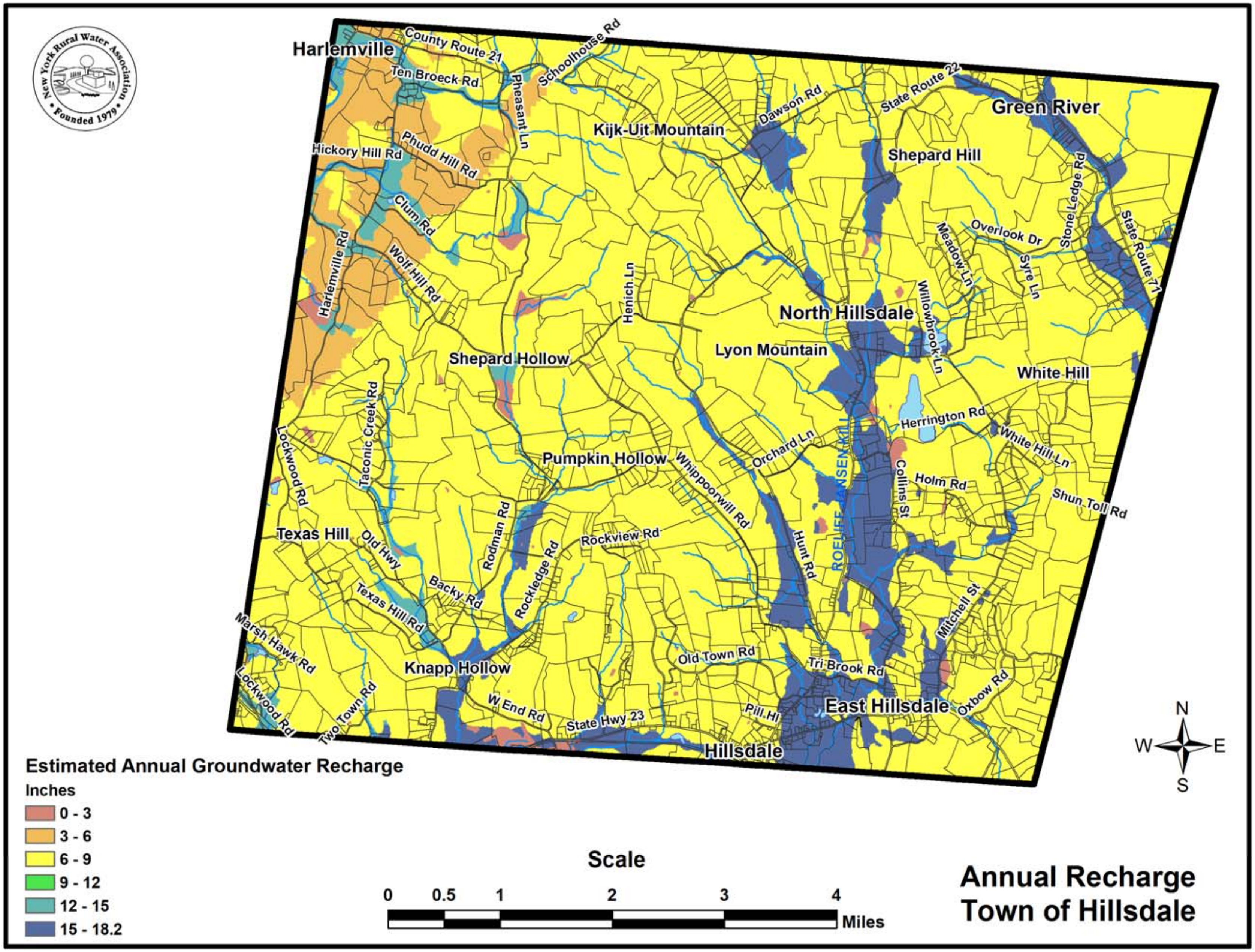
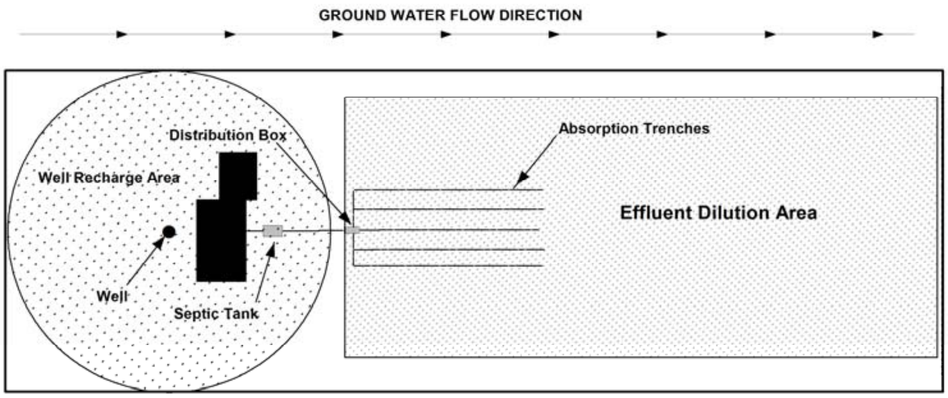

New York Rural Water Association
Founded 1979
Harlemville
County Route 21
Schoolhouse Rd
Ten Broeck Rd
Pheasant Ln
Kijk-Uit Mountain
Dawson Rd
State Route 22
Green River
Shepard Hill
Hickory Hill Rd
Phudd Hill Rd
Clum Rd
Wolf Hill Rd
Harlemville Rd
Henich Ln
Meadow Ln
Overlook Dr
Syre Ln
Stone Ledge Rd
State Route 71
North Hillsdale
Willowbrook Ln
Lyon Mountain
Shepard Hollow
White Hill
Herrington Rd
White Hill Ln
Taconic Creek Rd
Lockwood Rd
Pumpkin Hollow
Whippoorwill Rd
Orchard Ln
Roeliff Jansen Kill
Collins St
Holm Rd
Shun Toll Rd
Texas Hill
Old Hwy
Rodman Rd
Rockview Rd
Rockledge Rd
Hunt Rd
Backy Rd
Texas Hill Rd
Mitchell St
Marsh Hawk Rd
Knapp Hollow
Old Town Rd
Tri Brook Rd
Lockwood Rd
Two Town Rd
W End Rd
State Hwy 23
Pill Hl
East Hillsdale
Oxbow Rd
Hillsdale
N
W
E
S
Estimated Annual Groundwater Recharge
Inches
0 - 3
3 - 6
6 - 9
9 - 12
12 - 15
15 - 18.2
Scale
0
0.5
1
2
3
4
Miles
Annual Recharge
Town of Hillsdale

Appendix C

Calculations for Recommended Lot Sizes for Septic Systems

The basis of the recommended lot size for septic systems is that the separation of homes is sufficient to supply enough groundwater recharge to dilute the effluent from the lot's septic system effluent to acceptable levels. This is illustrated in the figure below.



The effluent dilution area can be calculated from an equation known as the modified Trela-Douglas nitrate dilution equation (Hoffman and Canace, 2001). This equation is:

$$R = 4.4186HM / (C_q A(1-0.179A^{-0.5708}))$$

Where: H equals persons per home;
M equals pounds per person per year
Cq is the target concentration in mg/L of nitrate-nitrogen;
A is the effluent dilution area in acres per home; and
R equals the groundwater recharge rate in inches per year.

Since A is difficult to directly solve for, various values of A are chosen in order to solve for the recharge rate, R. Note that the following constants are used:

H = 2.42 persons per home (U.S. Census, 2000)
M = 10 pounds per person per year
C_q = 5 mg/L (½ of the nitrate MCL).

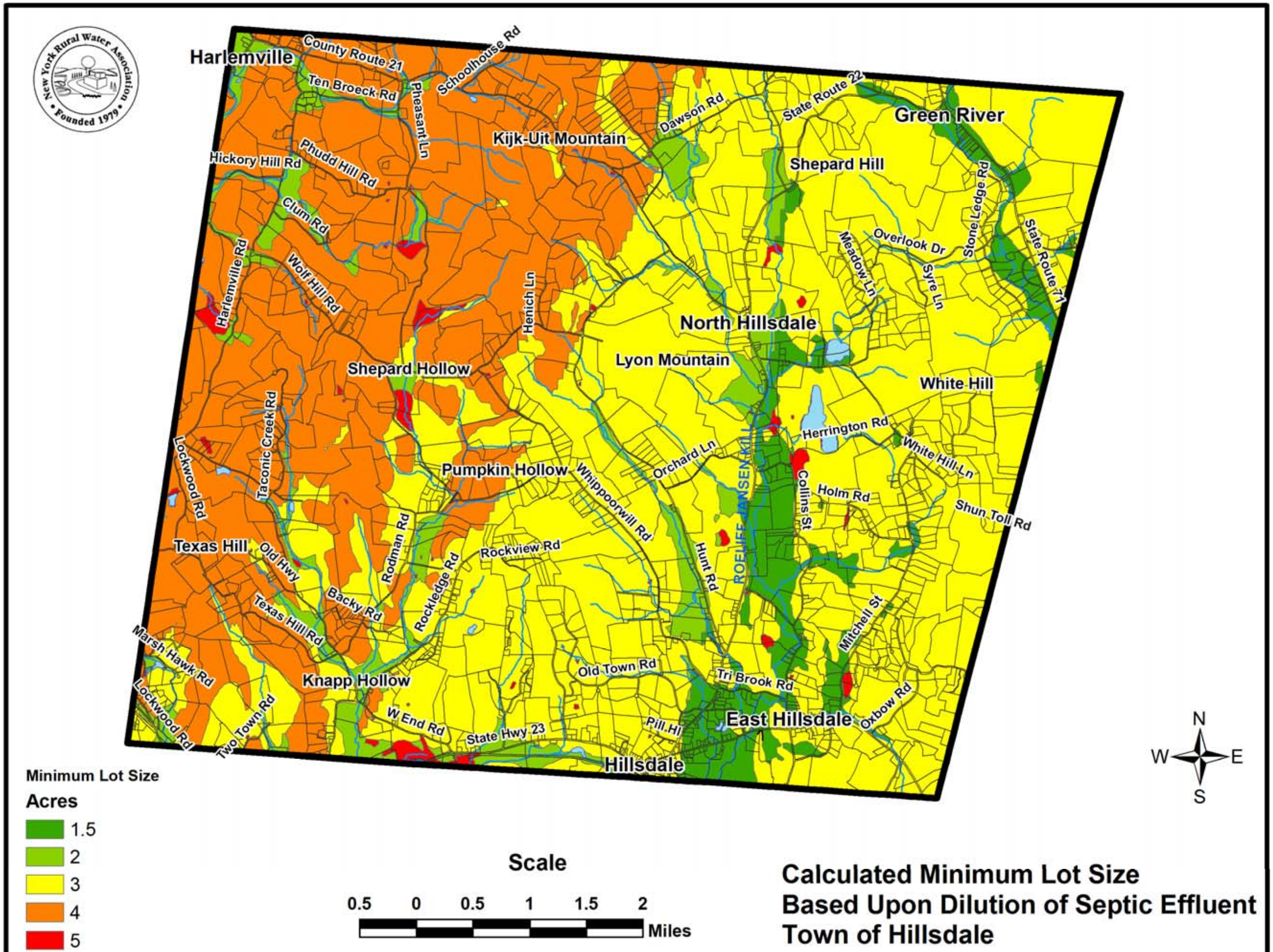
The effects of impervious cover were taken into account using a relationship between estimated impervious cover and lot size that was developed by the Soil Conservation Service. The modified Trela-Douglas equation was solved using a Microsoft Excel spreadsheet program.

The recharge rate, R, is calculated as shown in Appendix B.

Results are below:

Recharge	Rec. Minimum Lot Size
0.00	0
16.62	1.50
12.16	2.00
7.88	3.00
5.82	4.00
4.61	5.00

Using the grid of recharge values from Appendix B, a map of minimum lot sizes was mapped (see map below).



Calculated Minimum Lot Size
Based Upon Dilution of Septic Effluent
Town of Hillsdale

Appendix D

Calculation of Sustainable Minimum Lot Sizes Based Upon Conservation of Drought Baseflow

By
Steven Winkley
New York Rural Water Association

Background

One of the fundamental questions that communities ask while planning for the future is: how much future development can be safely sustained? In rural areas there must be sufficient groundwater resources to successfully sustain development. Excess withdrawal of ground water can lead to unacceptable consequences. These consequences could be a reduction of ground water held in storage and/or a decrease of natural groundwater discharge to streams and other surface water bodies. This discharge to streams, known as baseflow, sustains streamflow in the absence of precipitation and may represent up to 50 percent of the total annual streamflow. A loss of baseflow means that some streams would not flow during dry periods. Other streams would not flow sufficiently to maintain aquatic life. Water quality would also suffer with insufficient dilution.

As indicated in Figure 1, most ground water produced by pumping is initially from water held in storage between the grains of unconsolidated material or within fractures of rock. With time, the percentage of water that is delivered to the well is increasingly from surface water. This source of surface water could either be decreased discharge to the surface water body (stream, lake, pond, and/or wetland) or increased recharge from the surface water body to ground water. In the case of a stream, the resulting reduction in streamflow is referred to as streamflow capture. The timeframe depicted on Figure 1 could be measured in weeks to years depending upon aquifer characteristics, the nature of the surface water/groundwater interaction, and pumping history.

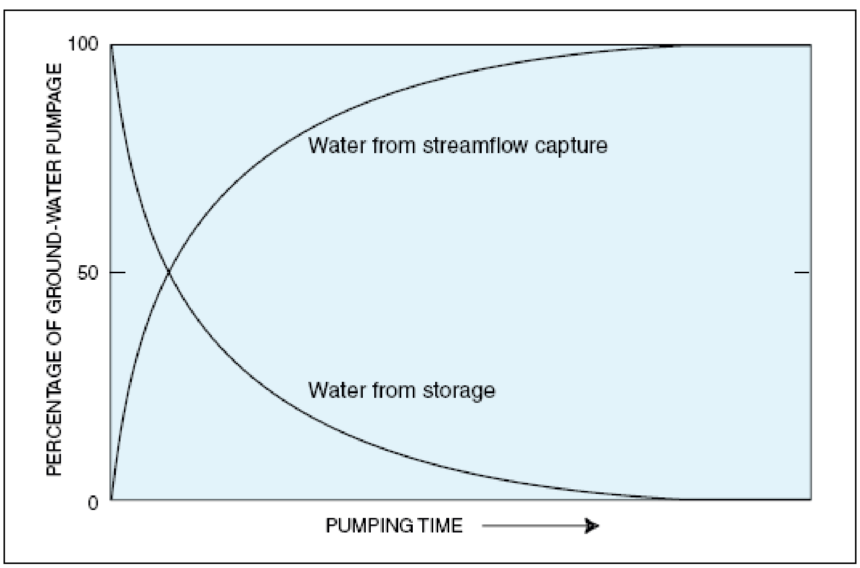


Figure 1. Sources of Water to a Pumping Well (from Alley et. al, 1999).

The most critical time to study the impact of pumping upon surface water is during drought. During prolonged dry periods, surface water flow is drastically reduced and the any reduction in baseflow would be most noticeable. During drought, it is critical that sufficient streamflow is maintained for ecological resources and to dilute possible wastewater discharges. One of the key stream flows to note during drought is the 7Q10 flow. Statistically, this is the lowest 7-day average flow that occurs (on average) once every 10 years. The 7Q10 flow is used by NYSDEC in designing and regulating wastewater discharges.

The conservation of baseflow is a reasonable standard against which to measure the sustainable yields of cumulative well pumping. To ensure that pumping does not produce an undesirable reduction in streamflow, even during drought periods, the following planning standard should be considered for the Town of Hillsdale: *the net loss of ground water as a result of cumulative consumptive use in each drainage basin should not exceed 50 percent of the 7Q10 flow for the principal stream draining the basin.*

Consumptive Use

In Hillsdale, most water that is withdrawn by wells is eventually returned to the environment through septic systems or discharges to streams. However, some water is consumed. Consumptive use refers to water that evaporates or is incorporated into a product during use and, therefore, is removed from the immediate environment. For residential areas, consumptive use is largely from evaporation losses during summer outside water use. Averaged over an entire year, the USGS National Handbook of Recommended Methods for Water Data Acquisition estimates that this consumptive water use is approximately 14 percent of an average total daily water use of 80 gallons per day per person. (Templin et al, USGS). A recent quantitative use of water use in Southeastern NH (Horn et al., 2007) indicated water evaporated during domestic water demand averaged 16 percent of annual per capita water demand (75 gallon per person per day).

The household consumptive use rate in the Town of Hillsdale is calculated by the following:

Household consumptive use rate (gallons/day/household) =
$0.15 \cdot 80$ gallons/day/person $\cdot$ 2.42 person/household (U.S. Census) = 29.04 gallons/day/household.

Drainage Basins

In order to determine 7Q10 flows for streams in Hillsdale, the Town was divided into four drainage basins and 55 sub-basins. A drainage basin (i.e. watershed) is an area of land drained by a particular stream and its tributaries (see Figure 2). A large drainage basin such as the Roeliff Jansen Kill can be divided into a number of sub-basins (Figure 3). As Figure 4 indicates, drainage basins and sub-basins are nested, with two or more 1st-order sub-basins composing 2nd-order sub-basin(s), and a variety of 1st-order, 2nd-order, and higher sub-basins composing the overall drainage basin.

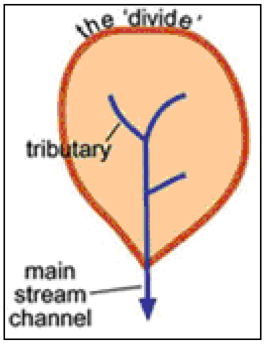


Figure 2. Drainage Basin.

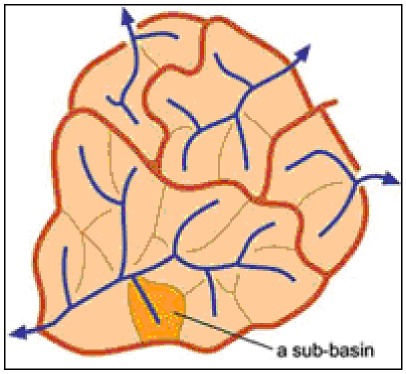


Figure 3. Sub-Basin.

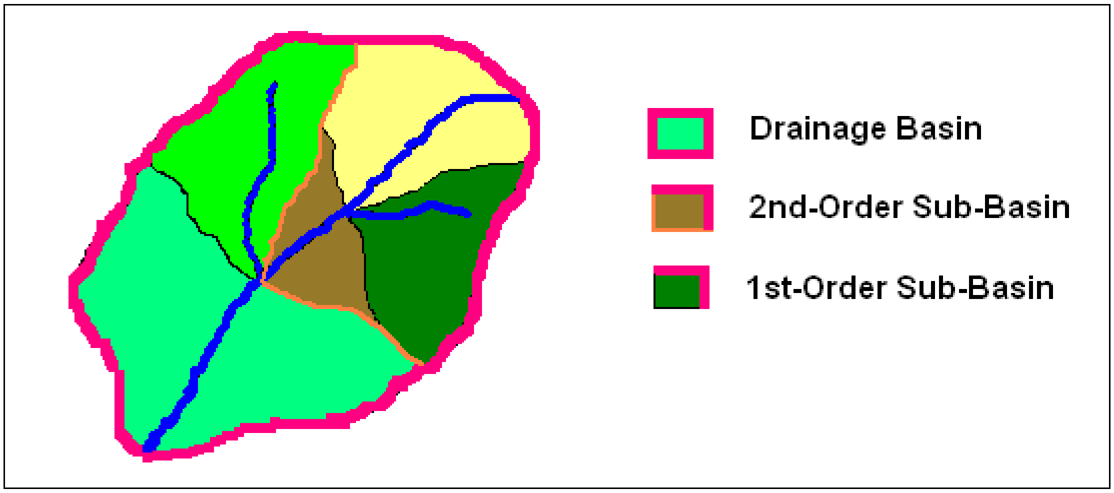


Figure 4. Nested Basins.

Figure 5 is a map of the various nested basins mapped in Hillsdale. As indicated, some of these areas lie outside of Town boundaries.

Calculating 7Q10 Flows

Using multiple regression analysis, Barnes (1986) formulated an equation estimating the 7Q10 flow for ungaged streams in the Lower Hudson River Basin (from Troy south to New York City). For the 7Q10 flow, the two basin characteristics Barnes (1986) found to most significant are the percentage of basin underlain by stratified drift and mean basin elevation. Barnes (1986) counted stratified drift as unconsolidated material other than till and lacustrine deposits. To accurately determine the basin percentage underlain by stratified drift, the 1:24,000 surficial map of Hillsdale that NYRWA developed was utilized. Outside of the Town of Hillsdale, the parent material of NRCS SSURGO soils mapping was used. The mean elevation of the basin was calculated by Barnes (1986) as 34 percent of the range between minimum and maximum basin elevations maps added to the minimum basin elevation.

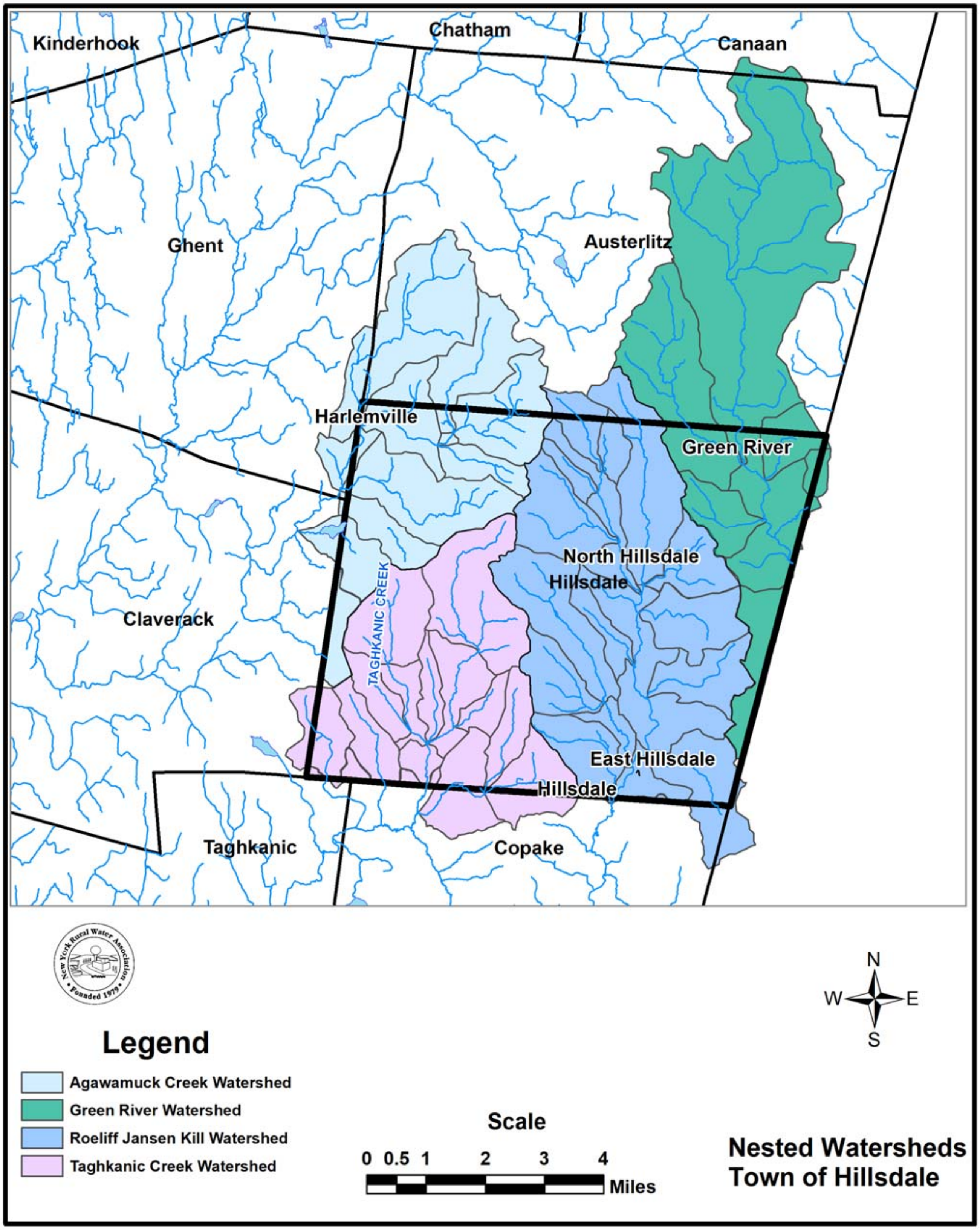


Figure 5. Nested Basins in Hillsdale.

Barnes (1986) developed the following equation:

$$7Q10 \text{ flow (in ft}^3\text{/s)} = A \cdot (0.0047 \cdot Sd + 0.0013 \cdot E - 0.030)$$

A = drainage area, in mi^2.
Sd = percentage of drainage basin overlain by stratified drift.
E = mean basin elevation above sea level, in hundreds of feet.

$$E = \text{the mean basin elevation} = \frac{(\text{(Highest Basin Point – Lowest Basin Point)} \cdot 0.34 + \text{Lowest Basin Point})}{100}$$

The 7Q10 flow is then converted to gallons per day by the following:

$$7Q10 \text{ flow (gallons/day)} = 7Q10 \text{ flow (in ft}^3\text{/s)} \cdot 7.48 \text{ gallons/ft}^3 \cdot 86{,}400 \text{ s/day}$$

Finally, the 7Q10 is equated to an amount of water per acre by dividing by the acreage of the drainage area.

7Q10 flow (in gallons/day/acre) =

$$7Q10 \text{ flow (in ft}^3\text{/s)} \cdot 7.48 \text{ (in gallons/ft}^3\text{)} \cdot 86{,}400 \text{ (in s/day)} \div \text{Drainage area (acres).}$$

Sustainable Minimum Lot Size

The Sustainable Minimum Lot Size (SMLS) is the average number of acres per household in the basin or sub-basin such that 50 percent of the 7Q10 flow for the principal stream in the given basin or sub-basin is not exceeded by projected consumptive use.

SMLS is calculated by the following:

SMLS (in acres/household) =
Household consumptive use rate (in gallons/day/household) ÷ 0.5 · 7Q10 flow (in gallons/day/acre).

The SMLS for each basin and sub-basin is mapped on the following figure. Note that some sub-basins have insufficient stratified drift to calculate a 7Q10 flow and hence a SMLS. This indicates that the principal stream in the sub-basin may be dry or critically low during drought periods.

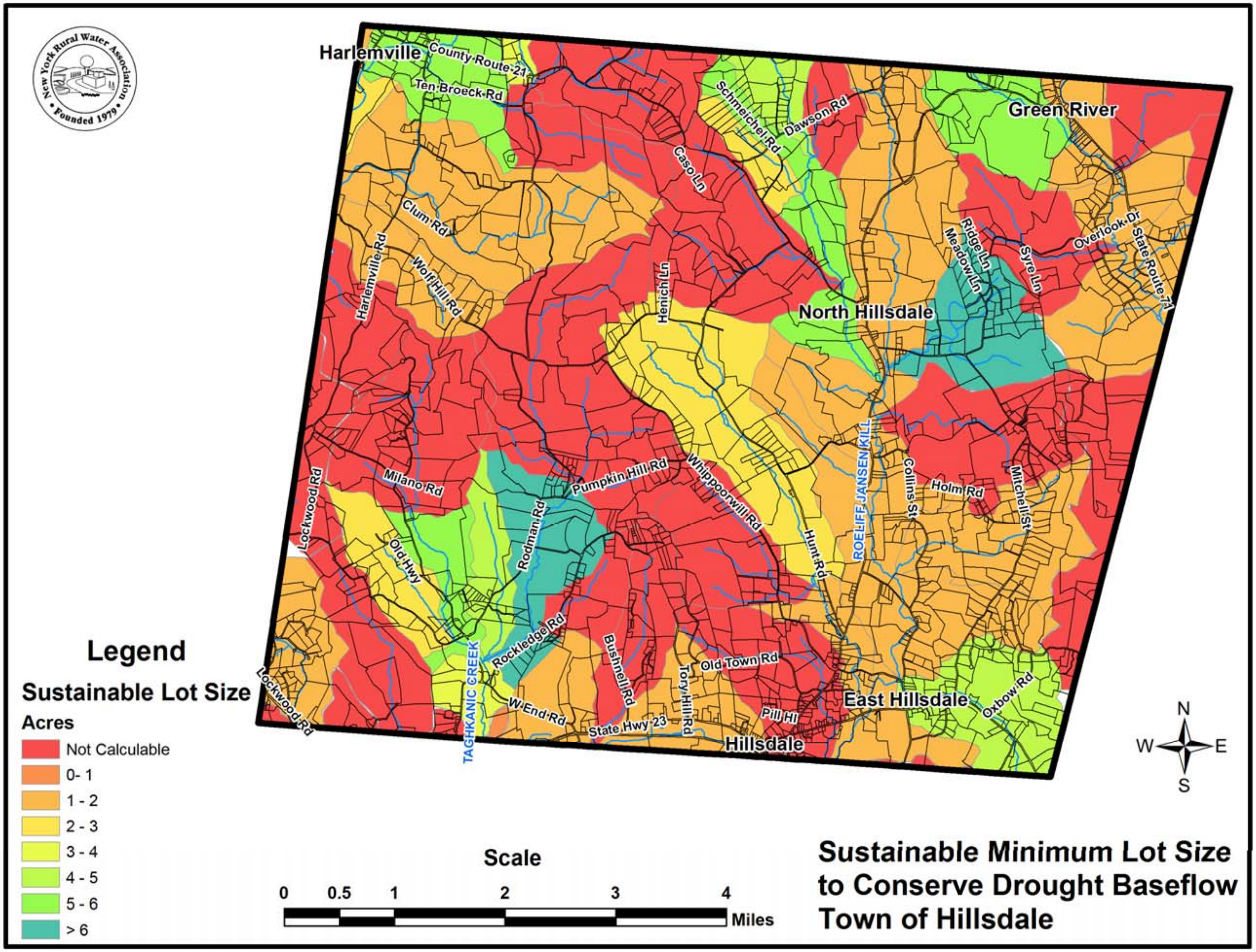


Figure 6. Calculated Sustainable Minimum Lot Size.

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