

# Using soil surveys to delineate stratified drift deposits for groundwater protection

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**ABSTRACT:** In glaciated regions of New England, planners use surficial geology maps, specifically the location of stratified drift deposits, to assess the extent of recharge areas for groundwater aquifers. Surficial geology maps are not available for the entire Northeast and, where available, are not always at a scale that is of value to local land managers. In New England, surficial geology is one criterion used to delineate soil map units depicted on soil surveys. Detailed soil surveys (1:15,840-scale) have been completed for much of New England and may represent a valuable source of data on the location of stratified drift deposits. Geographic information system analytical methods can be used to determine the correspondence of soil survey maps to U.S. Geological Survey (USGS) maps with respect to the location of stratified drift deposits. Throughout a five 7.5-minute-quadrangle study area [68,480 ha (169,212 acres)], 85% of the area mapped by USGS as stratified drift or till concurred with the designations of the soil survey maps. This result suggests that soil survey maps provide an accurate indication of stratified drift deposits and can provide planners with a widely available tool for groundwater protection programs.

**T**O protect groundwater quality, state and local officials must be able to identify the boundaries of areas that contribute recharge water to municipal well fields. Ideally, planners then can direct potential sources of groundwater contamination, such as landfills, heavy industry, or dense unsewered residential developments, away from important groundwater recharge areas.

In New England and portions of New York State, municipal well fields often are located in stratified drift deposits. Soil surveys describe these deposits as glacial outwash or glaciofluvial deposits. The deposits frequently are composed of deep, well-sorted, and stratified sands and gravel. Where thick, saturated deposits of these materials occur, individual wells may yield in excess of 32 l/s (500 gallons/minute). Transmissivities of these aquifers often exceed 950,000 l/day/m (75,000 gallons/day/foot) (9).

Researchers have developed analytical and numerical methods, such as pump-test analysis or computerized time-of-travel models, to specifically define areas contributing water to municipal wells (3, 7). These approaches generally require site-specific information and considerable time and exper-

tise on the part of the investigator.

To initiate groundwater protection programs, many local and state governments in New England and New York State have equated stratified drift deposits with areas of groundwater recharge. The boundaries of such recharge areas often are defined as the boundary between stratified drift and glacial till deposits (5, 14).

Stratified drift deposits are depicted on surficial geology maps produced by the U.S. Geological Survey (USGS) or various state agencies. Surficial geology maps at scales of 1:24,000 and 1:62,500 have been prepared by national or state geological surveys for 5% to 10% of the United States.

Soil surveys represent an additional geographic data base that may be useful for initial mapping of groundwater recharge areas. Detailed soil survey reports have been published for about 66% of the designated soil survey areas in the United States (personal communication, W. Reybold, Soil Conservation Service, Washington, D.C.). In the southern New England states of Massachusetts, Rhode Island, and Connecticut, most of these surveys are mapped at a scale of 1:15,840. This scale is large enough to locate activities that might degrade an aquifer, such as landfills, salt storage piles, underground storage tanks, or bulk storage of hazardous liquids. Soil surveys are developed through extensive field work and usually represent the most detailed mapping of the landscape that is widely available.

Soil classification is based on the physical, chemical, mineralogical, and morphological properties of the upper 1-2 m of a soil (12, 13). Many of these characteristics are inher-

ited from the soil's parent material; thus, most differences in geologic material are reflected in mapping units depicted on detailed soil survey reports. In all of New England, soils developed from stratified drift deposits are mapped separately from those developed in glacial till. Even if the soil solum did not develop from the underlying material, surficial geology is an important criterion for soil map unit distinctions (12). For example, the Bridgehampton soil, which developed entirely from loess deposits commonly exceeding 1 m (3.3 feet) in thickness (15), may overlie either stratified drift or glacial till deposits. Soil scientists recognize that this underlying material greatly influences soil behavior. Therefore, in Rhode Island, those Bridgehampton soils occurring over stratified drift are mapped as Bh, while those found over glacial till are designated Bm. If it can be demonstrated that soil survey mapping units are reliable indicators of stratified drift deposits, state and local officials will have access to a widely available data base to facilitate identification of groundwater recharge areas.

Comparing spatial associations between soil survey maps and surficial geology maps would be a laborious task if done manually. However, geographic information system (GIS) computer tools can rapidly assess correspondence among map data sets and display areas for further analysis and field work (1). The goal of our study was to test the viability of developing aquifer recharge maps from soil survey report data. Our specific objectives were to compare soil survey data to surficial geology maps and to assess the ability of GIS techniques to enhance comparisons of soil survey information with other spatial data sets.

## Study methods

The fundamental spatial units of analyses for this study were 7.5-minute USGS topographic quadrangle maps and 1:15,840-scale soil survey maps (11). We used the following Rhode Island quadrangles in our analyses: Kingston, Carolina, Slocum, Clayville, and North Scituate. We recompiled the soil survey to a 1:15,840-scale orthophoto quad base to ensure spatial accuracy. We obtained information on surficial geology from USGS 1:24,000-scale groundwater maps; one exception was the Kingston quadrangle, which was published at a scale of 1:31,680 (2, 4, 6, 8, 10).

We digitized soils and geology maps using the software product ARC/INFO (Environmental Systems Research Institute, Redlands, California) on a Prime 9955 II computer located at the University of Rhode Island Academic Computer Center. All digitizing was done on Calcomp 9100 digitiz-

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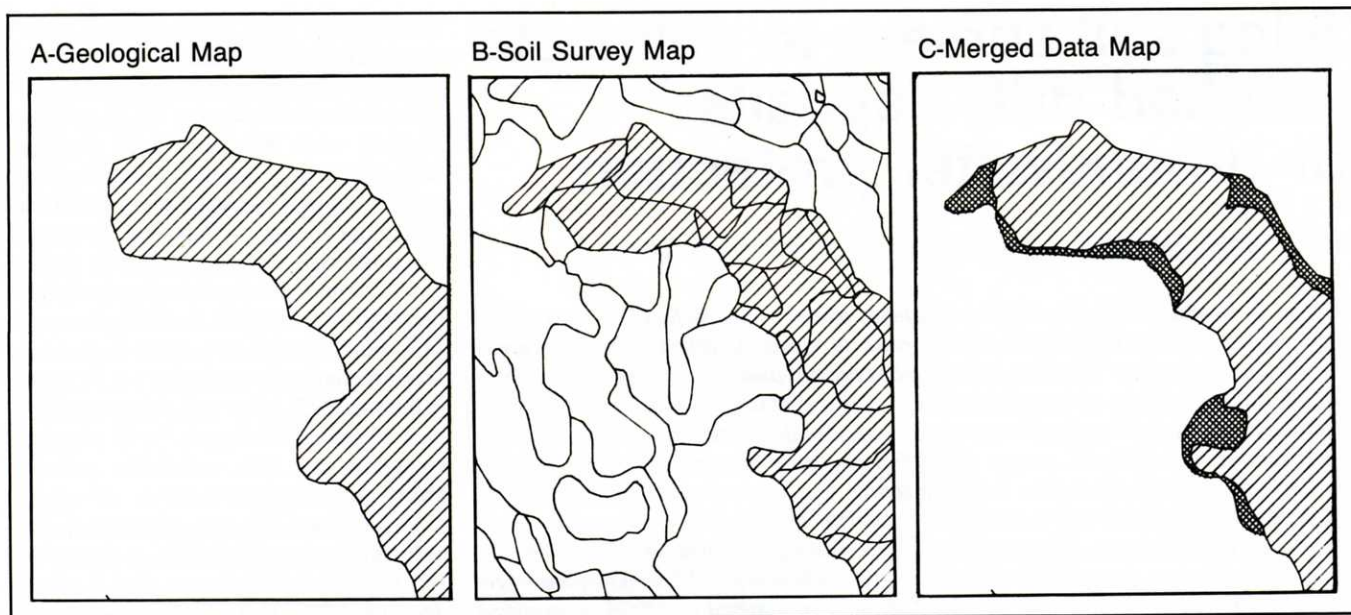


Figure 1. Schematic representation of the analytical approach. (A) Geological map: areas designated as stratified drift by USGS glacial geology maps. (B) Soil survey map: soil map units identified by soil survey as derived from or overlying stratified drift. (C) Merged data map: hatched

lines indicate areas identified as stratified drift by both the soil survey and USGS glacial geology maps; cross-hatched regions indicate conflicting designations of surficial geology between the two data sets.

ing tablets to within 0.254 mm (0.01 inch) of the selected maps (1). We coded soil polygons by their soil map unit name from the published soil survey. Surficial geology polygons were coded as stratified drift or till (Figure 1A).

Figure 1 illustrates our analytical procedures. Based on the soil descriptions listed in the *Soil Survey of Rhode Island (II)*, we identified those soil units that were derived from or which overlay stratified drift deposits. Each polygon in the soils data set was coded as indicative of stratified drift or till (Figure 1B). We then removed boundary lines between adjacent soil polygons that shared a common code of stratified drift or till. The resulting data set was merged with the surficial geology data for the same quad (Figure 1C). This provided a map showing (a) all areas identified as stratified drift by both the soil survey and the surficial geology maps, (b) all areas that the soil survey identified as stratified drift but the surficial geology maps labeled as till, (c) all areas that the soil survey identified as till but the surficial geology maps assessed as stratified drift, and (d) all areas that both the soils and geology data identified as till. We excluded polygons coded as water (lakes, ponds, or sea) from the analyses. Correspondence between the soils and the geological data is the percentage of the total area of the quadrangle that was identified by both data sets as being till or stratified drift.

### Results and discussion

There was  $84.6\% \pm 1.3\%$  ( $\bar{x} \pm SD$ ) correspondence between the soils and geolo-

gical data in identifying areas of stratified drift and till in the five quadrangles (Table 1). The Kingston quadrangle had the lowest percentage agreement (82.4%); the North Scituate quadrangle had the highest (86.0%).

We conducted field investigations on 14 sites to determine the cause of discrepancies between the two data sets. Visiting sites of disagreement, we determined soil series and surficial geology through visual inspection of borings, road cuts, and general land features. Disagreement in classification generally occurred along boundary areas between stratified drift and glacial till deposits or in glacial ice contact deposits characterized by a complex of geological features. At every site we visited for field verification, the soil survey correctly identified the surficial geology.

Some of the discrepancies between classifications based on soils and geological data were caused by sliver polygons resulting from the merging of the two data layers.

When the soils and geological data were misaligned slightly along the edge of a polygon, an area of disagreement resulted. These types of errors should not be considered as mistakes in soil or geological maps, but rather the topological manifestation of merging data layers that were entered into the GIS at different base map scales. Corroborating this hypothesis is the fact that the Kingston quadrangle had the highest percentage of area disagreement between soils and geological data and the largest difference between base map scales (1:15,840 scale for soils versus 1:31,680 scale for glacial geology).

### Conclusions

GIS computer technology permitted rapid comparison of spatial data of varying scale, complexity, resolution, and detail. In southern New England, soil surveys provide an accurate and detailed depiction of stratified drift deposits. The GIS-derived comparisons and field investigations clearly demonstrate

Table 1. Percentage of total land area in the five study quadrangles where soils and geological data concur or differ on the location of stratified drift and till. Water features are excluded.

Soils/Geological Identification	Quadrangle				
	Kingston	Clayville	Slocum	N. Scituate	Carolina
Area (ha)	13,530	13,900	14,270	12,840	13,940
	Percentage of land area				
Data concur					
Stratified drift/stratified drift	41.3	5.9	27.8	10.9	40.8
Till/till	41.1	80.0	56.8	75.2	43.7
Data differ					
Stratified drift/till	9.8	2.6	6.7	2.4	3.5
Till/stratified drift	7.8	11.5	8.7	11.5	12.0
Percent total area in agreement	82.4	85.9	84.6	86.1	84.5

the usefulness of soil surveys as an aid in identifying potential groundwater recharge areas. The use of soil surveys in groundwater protection programs can expand the importance of this tool for land use planners and decision-makers.

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