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COUNTY ATLAS SERIES
ATLAS C-17
Plate 6—Subsurface Recharge and Surface Infiltration

SUBSURFACE RECHARGE AND SURFACE INFILTRATION

By

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2006

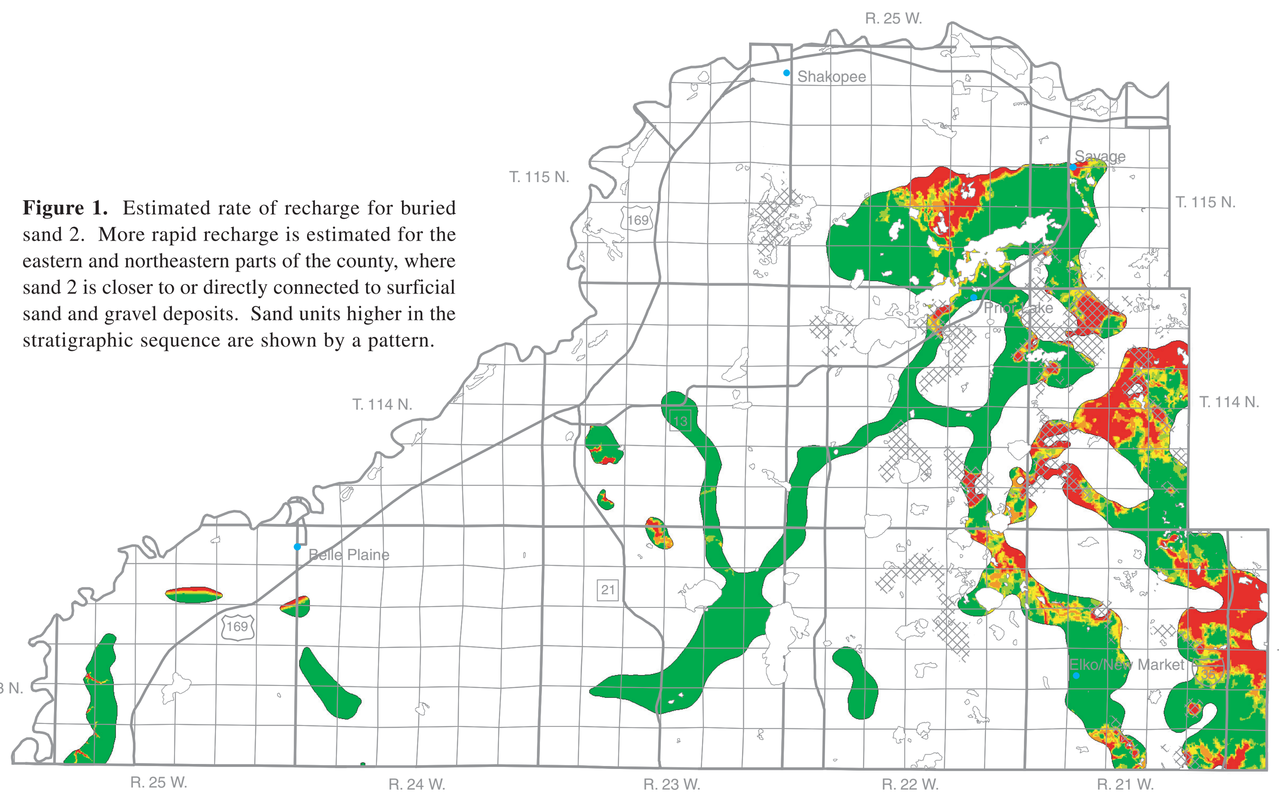

Figure 1. Estimated rate of recharge for buried sand 2. More rapid recharge is estimated for the eastern and northeastern parts of the county, where sand 2 is closer to or directly connected to surficial sand and gravel deposits. Sand units higher in the stratigraphic sequence are shown by a pattern.

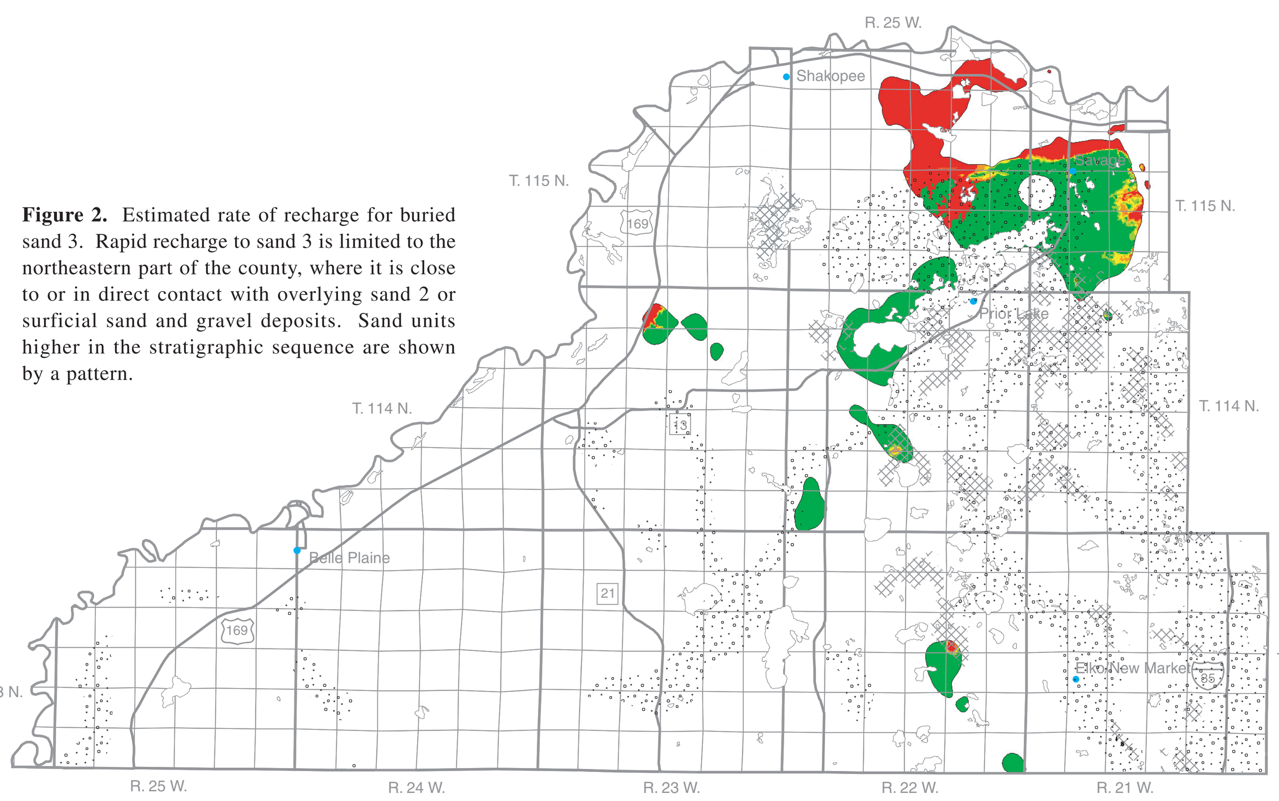

Figure 2. Estimated rate of recharge for buried sand 3. Rapid recharge to sand 3 is limited to the northeastern part of the county, where it is close to or in direct contact with overlying sand 2 or surficial sand and gravel deposits. Sand units higher in the stratigraphic sequence are shown by a pattern.

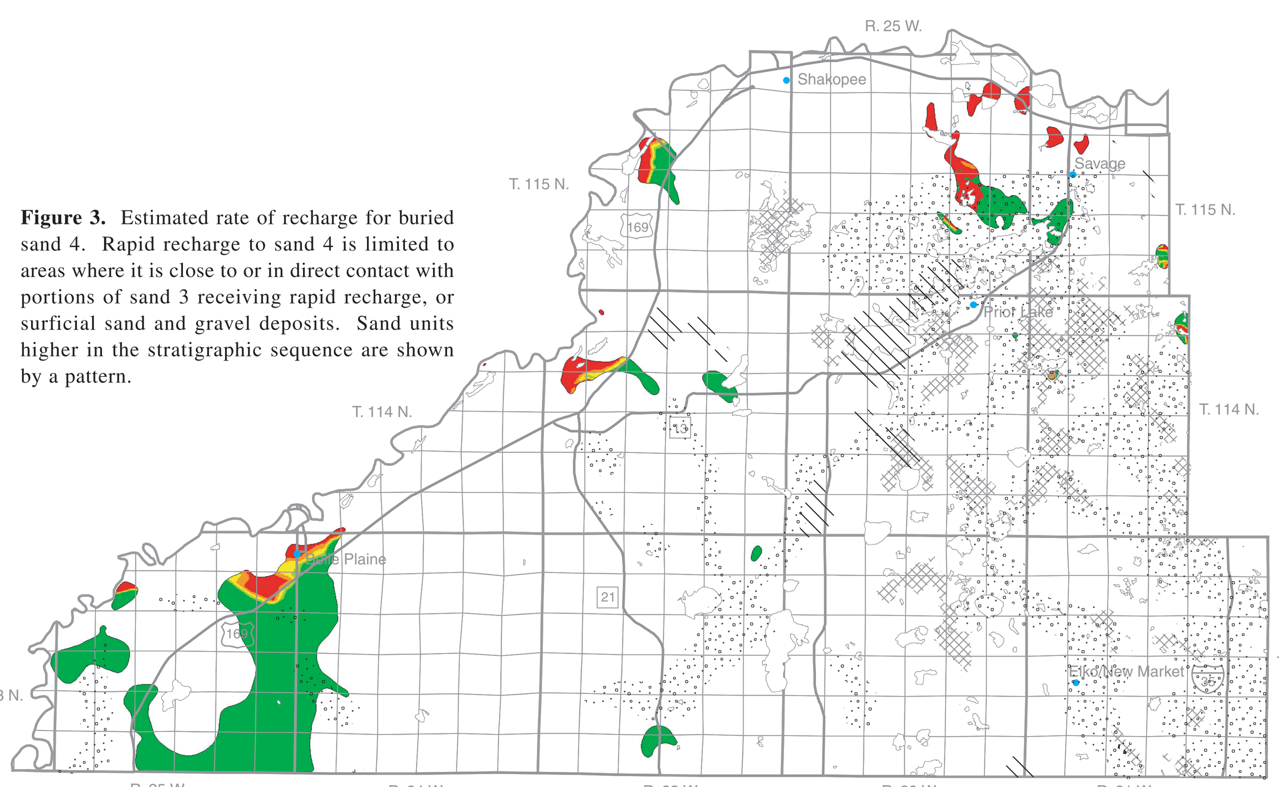

Figure 3. Estimated rate of recharge for buried sand 4. Rapid recharge to sand 4 is limited to areas where it is close to or in direct contact with portions of sand 3 receiving rapid recharge, or surficial sand and gravel deposits. Sand units higher in the stratigraphic sequence are shown by a pattern.

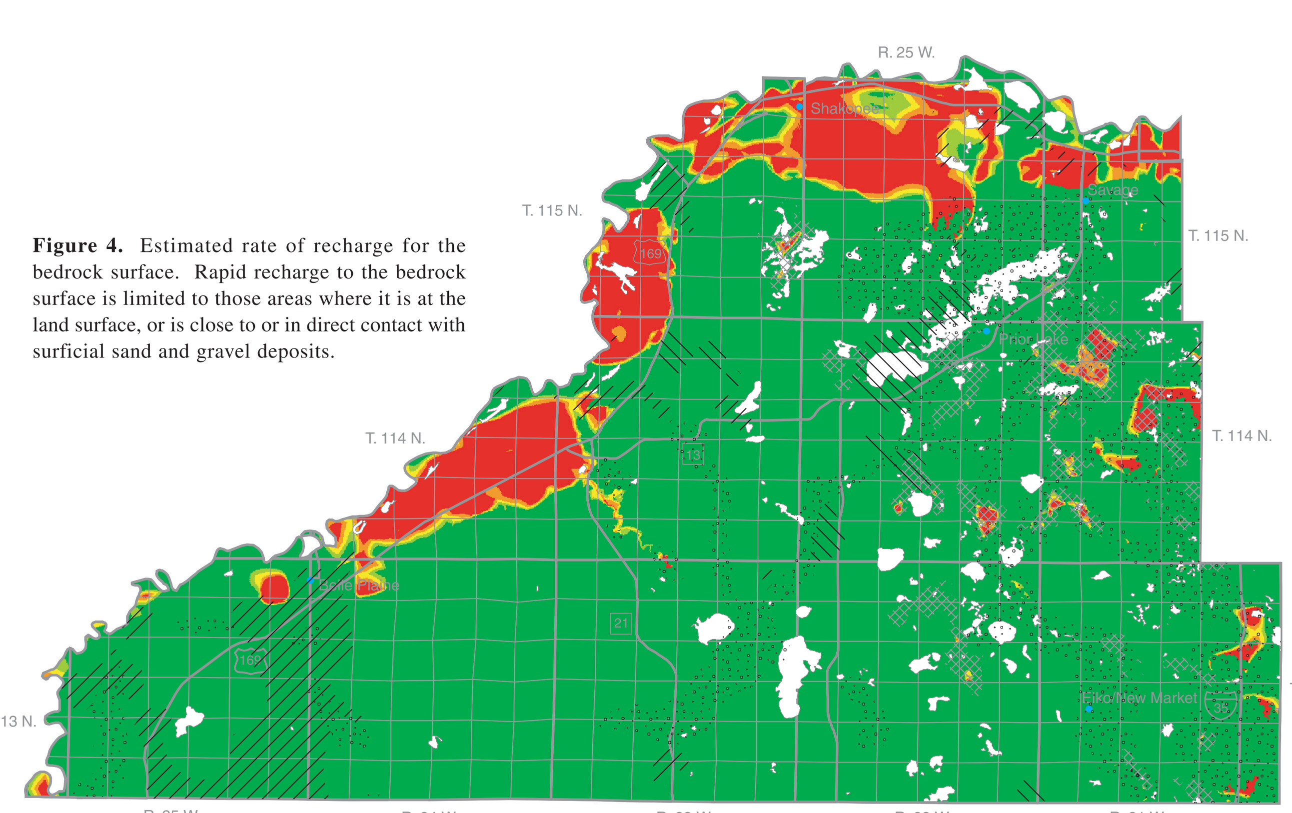

Figure 4. Estimated rate of recharge for the bedrock surface. Rapid recharge to the bedrock surface is limited to those areas where it is at the land surface, or is close to or in direct contact with surficial sand and gravel deposits.

EXPLANATION

Sand and gravel units

- **S1**—Near surface sand and gravel associated with till 1
- **S2**—Buried sand and gravel associated with till 2
- **S3**—Buried sand and gravel associated with till 3
- **S4**—Buried sand and gravel associated with undefined units at considerable depth

Recharge ratings—Estimated vertical travel time for water to move from the land surface to a buried aquifer.

- **Very fast**—Hours to months
- **Fast**—Weeks to years
- **Moderate**—Years to decades
- **Slow**—Decades to a century or more
- **Very slow**—A century or more

INTRODUCTION

These maps describe land-surface water infiltration and potential rate of recharge to buried glacial and bedrock aquifers. Infiltration, recharge, and runoff are complex phenomena involving depth to water, permeability of soil and subsurface material, degree of saturation, topography, land use, and other factors (Aller and others, 1987). This plate provides a qualitative analysis of vertical infiltration and recharge that is largely materials based. Soil types, surficial geologic materials, and the mapped sequence of buried glacial deposits are used to estimate relative rates of infiltration and recharge. The term "infiltration" is used to describe the downward movement of water through the unsaturated (vadose) zone. The term "recharge" is used to describe downward movement of water through the saturated (phreatic) zone. The methods used here are based on vertical movement of water only, and does not consider lateral (horizontal) flow, which may dominate in many settings (Geologic Sensitivity Workgroup, 1991). The recharge maps deal primarily with the larger, mappable units of buried sand and gravel. There are many other smaller units that may impact recharge rates locally.

SUBSURFACE RECHARGE

METHODS

Maps shown in Figures 1 through 4 are based on methods developed by Berg (2006). A vertical succession of overlapping, sometimes intersecting buried aquifers are thought to provide a complex pathway for water to move downward through unconsolidated deposits. Using Berg's approach of a "recharge surface," each buried aquifer receives focused vertical recharge from the base of the overlying aquifer if an intervening confining layer is thin or absent. This conceptual approach is illustrated in Figure 5.

Calculations used to construct these maps were done using the digital surfaces constructed as part of the three-dimensional geologic framework model (Plate 4). Recent infiltration from precipitation that reaches the water table moves downward through sand and gravel deposits until it intersects a confining unit (buried till) or reaches the bottom of a surficial sand deposit (recharge surface 1). In places where the intersected till layer is less than 10 feet (3 meters) thick or absent, water moves downward into the underlying sand body and becomes recharge surface 2. The process is repeated until either the bedrock surface is reached or there are no longer any less-than-10-foot till layers. It should be noted that the unit "undefined" below till 3 and sand 4 is arbitrarily treated as a confining layer, although the composition of this unit is unknown (Plate 4).

Areas of buried aquifers with faster recharge rates are shown in red or orange. These are portions of the buried aquifer that are either overlain by a combination of sand and gravel deposits and/or thin till units that extend back to the land surface. The rates of recharge are adapted from previous mapping where qualitative estimates are inversely proportional to the thickness of the overlying confining layer (Fig. 6; for example Geologic Sensitivity Workgroup, 1991). Using this approach, those areas where the thickness of the confining layer between the top of a buried aquifer and the next overlying recharge surface is less than 10 feet (3 meters) receive a "very fast" rating; where the thickness is greater than 40 feet (12 meters), the area receives a "very slow" rating. Intermediate ratings and associated thicknesses are shown in Figure 6.

RESULTS AND DISCUSSION

In northeastern Scott County, a series of overlapping and intersecting sand and gravel deposits from repeated glacial advances extends down to the bedrock surface (see Plate 4). These deposits provide a pathway for more rapid recharge to move vertically to deeper buried sand and gravel and to the bedrock surface, as illustrated in Figures 1 through 4. In series, the maps also show a decrease in recharge potential with depth.

Existing water chemistry and isotopic data support the conceptual model of enhanced vertical recharge in the northeastern part of the county. Burman (1995) found evidence of recent recharge (water younger than 50 years) in both bedrock (the Prairie du Chien Group) wells and wells completed in the buried bedrock valley in the vicinity of Prior Lake. Chloride levels from Burman (1995), commonly used as indicators of recent recharge, were also elevated in this part of the county. Minnesota Department of Health isotopic data also indicate recent recharge in the northeastern part of the county (S. Robertson, unpub. data). Additional recent recharge was detected in wells along the Minnesota River. Similar patterns of enhanced vertical recharge to the northeast and along the Minnesota River were found in nitrate data provided by the Scott County Environmental Health Department (P. Schmitt, unpub. data).

SURFACE INFILTRATION

METHODS

The map shown in Figure 7 combines Natural Resources Conservation Service hydrologic group ratings (Natural Resources Conservation Service, 2006a) from a digitized version of the Scott County soils atlas (Metropolitan Council, 1998), with textures derived from the surficial geology map (Plate 3). This approach has been successfully applied to analyze surface water/ground water interaction elsewhere in the metro area, and provides an important component to ground-water recharge models (Zhu and Mohanty, 2002; Barr, 2005). The map units are used to represent vadose (above water table) conditions. Much of Scott County is covered with clay-rich glacial till that restricts the downward movement of water. As a result, perched water table conditions are pervasive and an integrated water table aquifer does not exist countywide.

Because of the lack of an integrated countywide water table, infiltration rates were estimated to a hypothetical water depth (vadose zone thickness) of 10 feet (3 meters). Infiltration rates from Natural Resources Conservation Service publications (Natural Resources Conservation Service, 2006b) were applied to textures from the soils map and the surficial geology map (Table 2) to construct the recharge ratings shown in Figure 8. If no hydrologic group rating was available for a given area on the soils map, then the soil zone estimate was made using the infiltration rate assigned to the surficial geology map texture. Peat on the surficial geology map was assigned an intermediate infiltration rate of 0.15 inch (3.8 millimeters) per hour. These ratings provide an estimated rate of infiltration through 3 feet (1 meter) of soil zone and 7 feet (2 meters) of underlying parent material, assuming that the total 10 foot thickness is unsaturated. This method follows the approach applied to Natural Resources Conservation Service dual hydrologic group ratings, where ratings such as A/D, B/D, and C/D, shown in Table 2, are given for certain wet soils that can be adequately drained; the first letter applies to the drained condition, and the second to the undrained condition (Natural Resources Conservation Service, 2006a). In this way, the infiltration map, like the recharge map, is based primarily on geologic materials only and does not account for temporal hydrologic conditions.

RESULTS AND DISCUSSION

Textures of Quaternary deposits in the eastern and northeastern parts of the county are coarser-grained than the rest of the county. Superior provenance till and Des Moines lobe till mixed with Superior provenance till to the east have greater sand content than other surficial tills (see Plate 3). As a result, infiltration ratings are higher in the eastern and northeastern parts of the county than in places where till is present at the land surface.

Dual hydrologic group ratings for hydric soils result in fast infiltration ratings in areas that overlie units mapped as peat on the surficial map (Plate 3). As discussed above, dual hydrologic ratings result in high infiltration ratings, even in areas where water is near or at the land surface as indicated by hydric soils and the presence of peat. This is to account for areas where water table conditions could change due to drainage modifications, pumping, or natural changes in the hydraulic gradient.

Ratings do not take into account secondary conditions, such as oxidation and fracturing, that can affect till permeability. Oxidation in tills commonly extends downwards as much as 49 feet (15 meters), increasing permeability of the till by as much as three orders of magnitude (Schilling and Tassier-Surine, 2006). In Scott County, areas rated slow may experience infiltration at greater rates than mapped due to secondary porosity and permeability in surficial tills. Other secondary conditions not included in the rating method are the presence of drain tiles, which also would result in greater infiltration rates than are shown here. In Scott County, tiling occurs primarily west of Minnesota Highway 21 (P. Beckius, Scott County Soil and Water Conservation District, unpub. data).

SUMMARY AND CONCLUSIONS

The recharge to buried aquifers and infiltration maps on this plate provide a qualitative assessment of how quickly water moves vertically downward into the subsurface. The estimates are considered qualitative because they have not been field verified, do not consider heterogeneities in the soils or subsurface, and do not account for actual water table conditions or lateral water movement. The geologic model of unconsolidated deposits, based on our current understanding of glacial stratigraphy within the county, agrees favorably with existing water chemistry and isotope data. Specifically, enhanced vertical recharge occurs in the northeastern part of the county and along the Minnesota River, where sequences of buried sand bodies provide pathways for water to move more quickly to bedrock aquifers. There is less vertical recharge in the central and western parts of the county, where thick till sequences and lack of well-connected buried sand bodies restrict the downward movement of water.

The maps do not account for all water wells in unconsolidated deposits; many wells were completed in sands that are not shown as buried sands 1, 2, 3, or 4 (see discussion of building the three-dimensional model— Plate 4). Instead, the maps provide guidance for where more rapid downward vertical movement of water is expected to occur, and where recharge to buried aquifers is restricted due to the presence of thick overlying glacial tills.

Aquifer	Thickness of confining layer between the aquifer and the nearest overlying recharge surface (in feet)				
S2, S3, S4, bedrock	0-10	10-20	20-30	30-40	greater than 40

Table 1. Recharge rate conceptual model matrix. One of the variables that determines the rate of recharge is the thickness of the confining layer between the top of the aquifer and the overlying recharge surface as defined in Figure 5. These estimates are qualitative and based on comparable travel time estimates from previous studies for similar geologic materials (Berg, 2006).

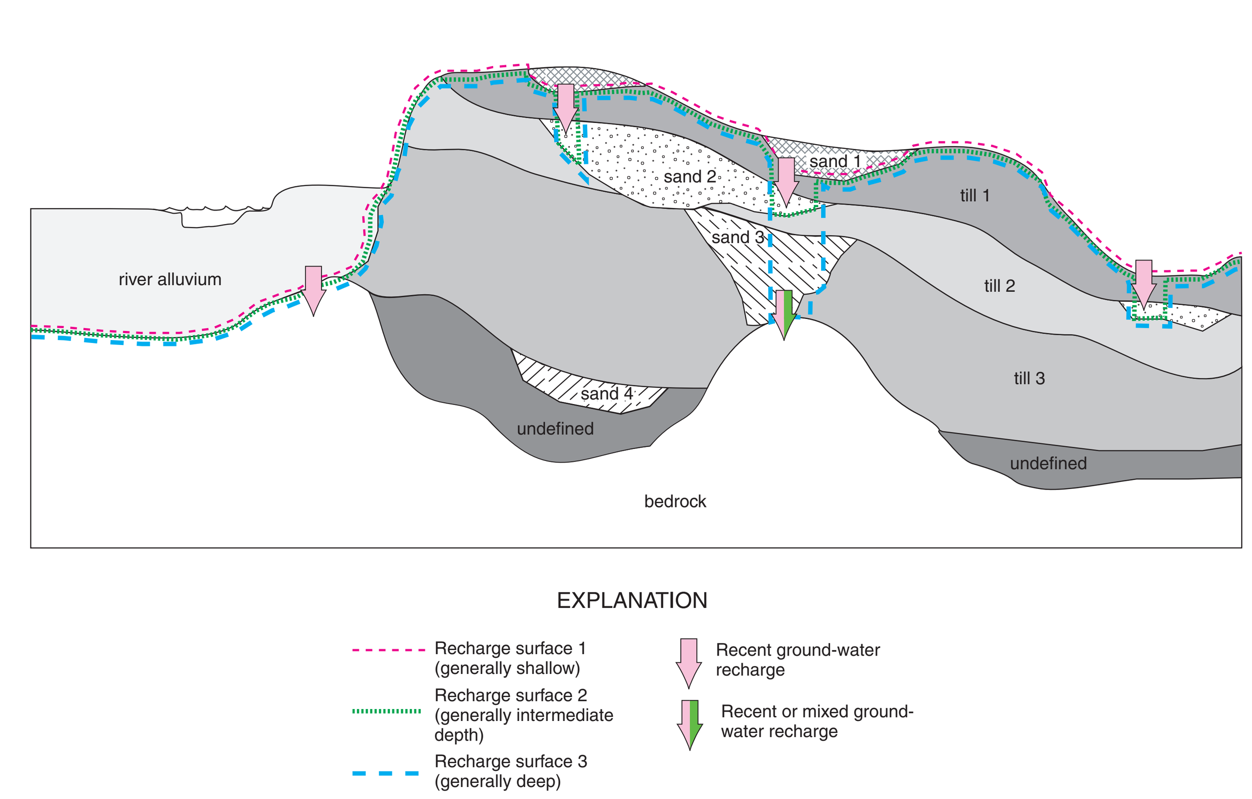

Figure 5. Generalized cross section of northwestern Scott County showing conceptual recharge for buried sand and gravel and bedrock aquifers. Recent infiltration from precipitation that reaches the water table moves downward through sand and gravel deposits until it intersects a confining unit (buried till) or reaches the bottom of a surficial sand deposit (recharge surface 1). In places where the intersected till layer is less than 10 feet (3 meters) thick or absent, water moves downward into the underlying sand body and becomes recharge surface 2. The process is repeated until either the bedrock surface is reached or there are no longer any less-than-10-foot till layers. It should be noted that the unit "undefined" below till 3 and sand 4 is arbitrarily treated as a confining layer, although the composition of this unit is unknown (Plate 4).

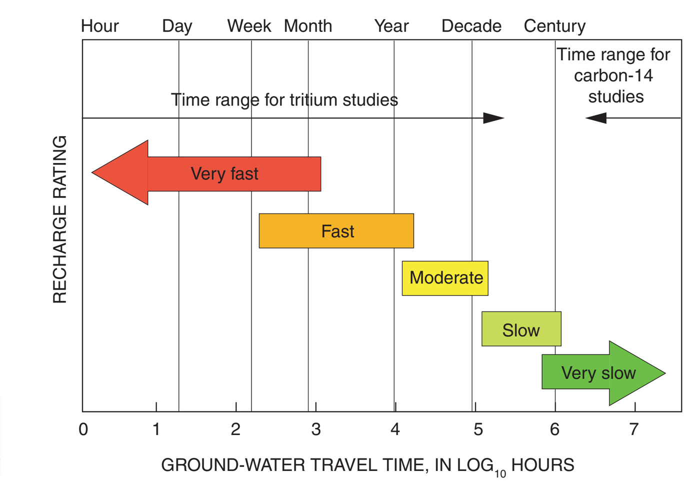

Figure 6. Recharge ratings for Figures 1 through 4 as defined by vertical travel time. This rating comes from earlier geologic sensitivity ratings (Geologic Sensitivity Workgroup, 1991). Ratings are based on the time range required for water at or near the surface to travel vertically downward to an aquifer. Tritium and carbon-14 studies indicate the relative ages of ground water. Ground-water age data were not collected as part of this study; these estimates are qualitative and based on comparable travel time estimates from previous studies for similar geologic materials (Berg, 2006).

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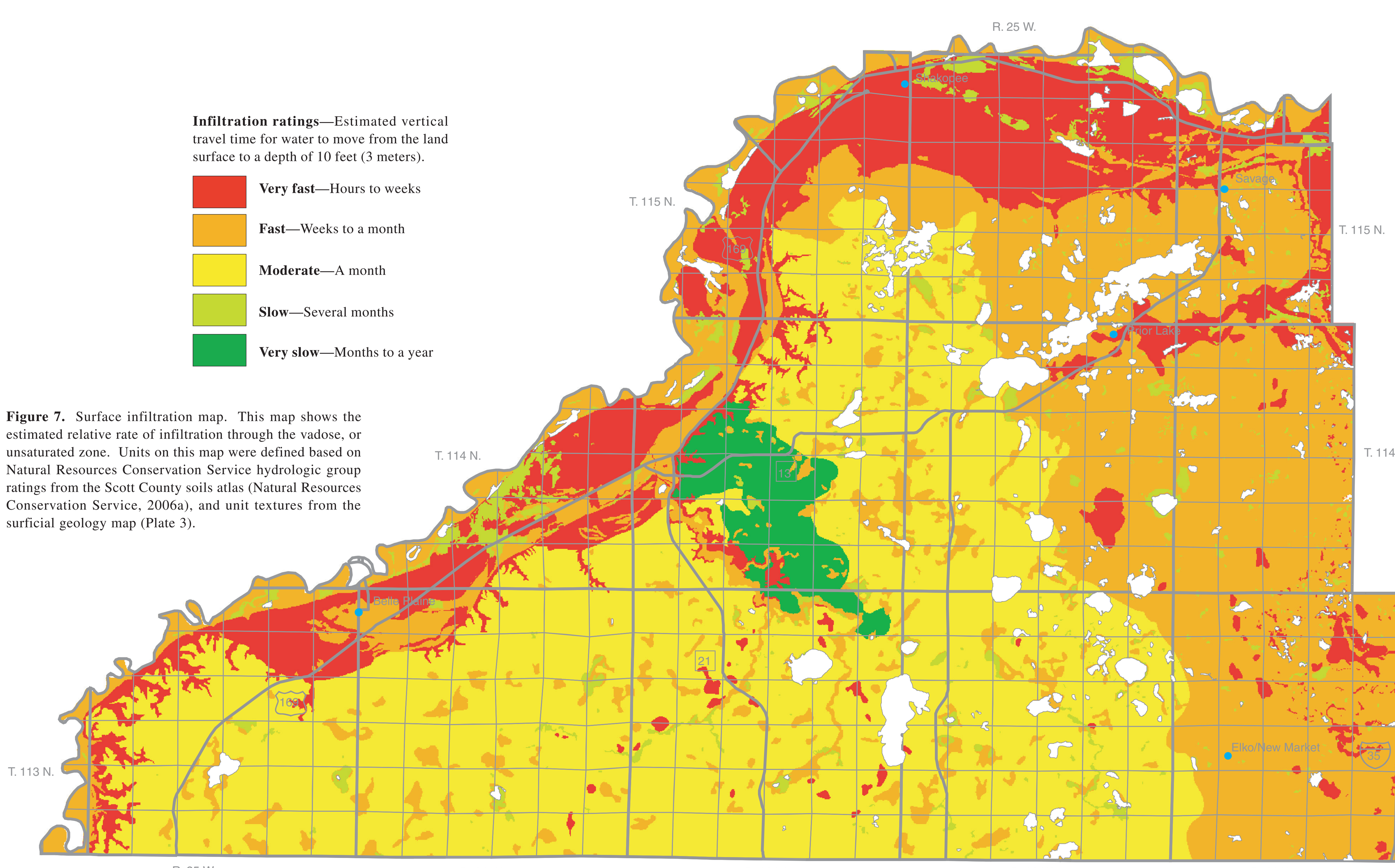

Figure 7. Surface infiltration map. This map shows the estimated relative rate of infiltration through the vadose, or unsaturated zone. Units on this map were defined based on Natural Resources Conservation Service hydrologic group ratings from the Scott County soils atlas (Natural Resources Conservation Service, 2006a), and unit textures from the surficial geology map (Plate 3).

SCALE 1:150 000

1 0 1 2 3 4 5 MILES

1 0 1 2 3 4 5 6 7 8 KILOMETERS

NRCS (2006b) hydrologic group rating	Texture	Minimum transmission rate (inches/hour)
Group A, A/D	sand, loamy sand, sandy loam	0.3
Group B, B/D	silt loam or loam	0.15
Group C, C/D	sandy clay loam	0.05
Group D	clay loam, silty clay loam, sandy clay, silty clay, clay	0.01

Surficial map unit (Plate 3)	Texture	Minimum transmission rate (inches/hour)
Qj, Qpc, Qc, Qci, Qdi, Qdo, Qe, Qtg, Qtl, Qtr, Qtw	sand, sand and gravel, bedrock	0.5
Qdd, Qds, Qdt, Qf	loamy fine-grained sand to sandy loam	0.3
Qa, Qdl, Qpc, Qp	loam to silty clay loam	0.15
Qd	loam to clay loam	0.05
Qdc	clay loam	0.01

Table 2. Infiltration rates for Figure 7 for soil hydrologic groups and surficial geology map textures. The rate of infiltration through the vadose zone is estimated using Natural Resources Conservation Service soils atlas hydrologic group ratings (Natural Resources Conservation Service, 2006a) and textures from the surficial geology map (Plate 3) as a model for materials below the soil layer to the water table.

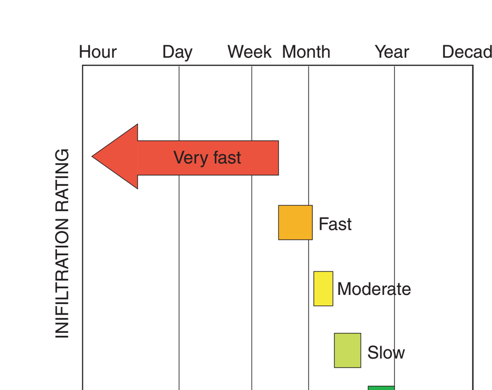

Figure 8. Infiltration ratings as defined by vertical travel time. Ratings are calculated from minimum estimated transmission rates for soil hydrologic groups (Natural Resources Conservation Service, 2006b) applied over a distance of 10 feet (3 meters).

Edited by Lori Robinson