## STATE OF MINNESOTA DEPARTMENT OF NATURAL RESOURCES **DIVISION OF WATERS**



Digital base modified from 1990 Census TIGER/Line Files of the U.S. Bureau of the Census (source scale 1:100,000); digital base annotation by the Minnesota Geological Survey.

Universal Transverse Mercator projection, grid zone 15, 1927 North American Datum. Vertical datum is mean sea level. Compiled 1994.

## **INTRODUCTION**

Groundwater Protection Act of 1989 states that a sensitive area is "a geographic area defined by natural to directly recharge another. features where there is a significant risk of groundwater degradation from activities conducted at or near the land surface." The "natural features" stated in the Act are the geologic conditions in an area, such as type of bedrock or surficial materials. This approach is called "intrinsic" or geologic sensitivity.

## GROUND WATER RESIDENCE TIME AND SENSITIVITY RATING

Geologic sensitivity is best understood if it is related to the age of the ground water. The age of the surface to the aquifer and the characteristics of geologic materials overlying the aquifer. water, also called residence time, is the approximate time that will elapse from the time a drop of water protection. These sensitivity and travel time relationships are shown on Figure 2. The cross section in United States using geographic information system (GIS) techniques. Fillmore County.

travel. In addition, contaminants are assumed to travel at the same rate as water. Very High sensitivity 20 feet, 20 to 50 feet, greater than 50 feet, and aquifer absent.

corrected, before serious ground water pollution develops. However, high sensitivity does not mean that movement of ground water than other types of rocks, the depth to water classes in karst areas were The sensitivity of an aquifer to pollution is the relative ability of geologic materials to restrict the water quality has or will be degraded. For example, if there are no contaminant sources, pollution will not adjusted to 0-50 feet and greater than 50 feet compared to non-karst areas where the depth to water quality has or will be degraded. For example, if there are no contaminant sources, pollution will not adjusted to 0-50 feet and greater than 50 feet compared to non-karst areas where the depth to water quality has or will be degraded. For example, if there are no contaminant sources, pollution will not adjusted to 0-50 feet and greater than 50 feet compared to non-karst areas where the depth to water quality has or will be degraded. downward migration of contaminants to an aquifer of interest. There are many ways to evaluate sensitivity occur. Also, low sensitivity does not guarantee that ground water is or will remain uncontaminated: for are 0-20 feet and greater than 20 feet. to pollution (Minnesota Department of Natural Resources, Division of Waters, 1991). The Minnesota example, leakage from an abandoned well may bypass natural protection, allowing water from one aquifer

surface, provided the distribution of the Prairie du Chien Group, and St. Peter and Jordan Sandstone rocks. infiltrating water. Contaminants were assumed to originate at or near the land surface and move vertically The limestones and dolostones of the Prairie du Chien Group were considered having quite high downward; lateral movement is ignored, except as indicated by the patterned area and discussed elsewhere FACTORS CONSIDERED sensitivity due to the flow of water through fractures in these rocks and also the potential of these rocks on this plate. The evaluation does not consider the effects of human activities, such as abandoned or leaky to develop karst features. The St. Peter and Jordan Sandstone rocks were considered sensitive due to their wells, large ground-water withdrawals, or construction excavations. This map cannot be used to show The pollution sensitivity assessment of the St. Peter-Prairie du Chien-Jordan aquifer was based on the relatively coarse texture. The bedrock geology map was also used to define the distribution of the where ground water in the aquifer is (or will be) contaminated or the sensitivity to pollution of a specific guidelines issued by the Minnesota Department of Natural Resources, Division of Waters (1991). This is Decorah-Platteville-Glenwood confining unit. The rocks of the Decorah Shale, Platteville Formation, and site. It serves as a screening tool to estimate the potential impact of certain activities and land uses on the an empirical, qualitative approach using geologic criteria such as the vertical distance from the land Glenwood Formation include shales and limestones that together behave as a confining unit. The geology ground-water quality at a county scale. map was modified to define three classes: confining unit not eroded, partially eroded, and completely Six geologic and hydrogeologic factors were used to evaluate pollution sensitivity in Fillmore eroded.

infiltrates the land surface to the time it is discharged or pumped from an aquifer. Radiometric dating County: depth to water, karst development, presence of the Decorah-Platteville-Glenwood confining unit, using isotopes of carbon and hydrogen can determine the residence time of ground water in an aquifer depth to bedrock, surficial geology, and bedrock geology. Figure 1 shows the corresponding map or near the land surface, was used to prepare a map of areas with similar estimated permeability. Three (Alexander and Alexander, 1989). Shorter residence times indicate recent recharge and higher sensitivity. components that were generated for each of the factors. Four similar "components, and bedrock. Till is an unsorted mixture of glacial Longer residence times may represent both a greater travel time and an increased level of geologic and Berg (1992) in their regional assessment of aquifer contamination potential of the north-central

Figure 2 on Plate 6 shows the distribution of residence times of ground water in several aquifers in Depth to water is an important consideration. Generally, the closer an aquifer is to the land surface, the faster contaminants can reach the aquifer. The depth to water map was generated by subtracting the The pollution sensitivity rating is classified into five categories on this plate: Very High, High, a ground-water potentiometric surface elevation for the St. Peter-Prairie du Chien-Jordan aquifer as shown mapped at the surface on the surface on the surface confining unit and, in Moderate, Low and Very Low. The corresponding ranges of ground-water travel time are shown in on Plate 6 from the land surface elevation. The U.S.G.S. 1:24,000 digital elevation model (DEM) was bedrock below. Maps of each of the factors were digitally combined into a composite map and a GIS program applied the removed. Isotope data indicate the presence of recent water in the Franconia-Ironton-Galesville aquifer indicates that water moving vertically downward from the surface may reach the aquifer within hours to matrix ratings to produce the sensitivity map. A special zone indicated by the diagonal pattern on the map months. In these areas there is little time to respond and prevent aquifer contamination. Conversely, a Low 8. Six classes of sinkhole probability are defined in Fillmore County: no, low, low to moderate, moderate was defined (as described elsewhere on this plate) to show areas where younger than expected waters have confining layers throughout the county and is not sensitive.

Figure 2. The pollution sensitivity of an aquifer is assumed to be inversely proportional to the time of used to model the land surface elevation. Four classes were defined for the depth to water factor: less than

## Prepared and Published with the Support of THE MINNESOTA ENVIRONMENT AND NATURAL RESOURCES TRUST FUND

SCALE 1:100 000 6 MILES 0 1 2 3 4 5 6 KILOMETERS 

sensitivity rating indicates that a surface contamination source can likely be investigated, and possibly to high, high, and sinkhole plains. Since the karsted rocks in Fillmore County permit much more rapid been found or might be found due to factors not considered in the rating matrix.

The surficial geology map on Plate 3 in Part A, which depicts the type of sedimentary rock found at deposits. It is relatively impermeable because fine particles fill void spaces between larger clasts. Till-

Partial funding for this project approved by the Minnesota Legislature M.L. 91, Ch. 254, Art. 1, Sec. 14, Subd. 4(f) and M.L. 93, Ch. 172, Sec. 14, Subd. 11(g) as recommended by the Legislative Commission on Minnesota Resources from the Minnesota Environment and Natural Resources Trust Fund. Base funding established by the 1989 Groundwater Protection Act, M.L. 89, c. 326, art. 10, sec. 1, subd. 6, item a. and b.

When using this sensitivity map, the limitations inherent in the sensitivity method should be kept in detailed hydrogeologic information must be collected for a site-scale investigation. The map does not The bedrock geology map on Plate 2 in Part A, which shows the first bedrock beneath the land evaluate any specific contaminant. The sensitivity evaluation assumes that contaminants travel with

SENSITIVITY OF OTHER AQUIFERS IN FILLMORE COUNTY

Quaternary deposits were not evaluated because these sediments are not a significant source of ground water in Fillmore County. The upper carbonate aquifer in Fillmore County is generally sensitive, primarily due to extensive karst development. The high or elevated concentrations of nitrate, as well as covered areas were considered less sensitive. Areas with coarse-textured sediments such as colluvium and the recent age (by tritium dating) of all upper carbonate aquifer samples (see Part C), support Moderate, High or Very High sensitivity ratings for the aquifer. Only in the southwest corner of the county where the The thickness of surficial deposits was portrayed on Plate 4 in Part A. If till or other sediment was upper carbonate aquifer is overlain by thicker drift is it less sensitive. The Franconia-Ironton-Galesville the southwest half of the county, by the Decorah-Platteville-Glenwood confining unit. An exception is the The rating matrix shows how each of the six factors were considered in assigning sensitivity ratings.

## SENSITIVITY RATINGS Estimated travel time for water-borne surface contaminants to reach the aquifer

Verv High Hours to months



**Moderate** Years to decades







Recent or mixed age water (see Part C) present or expected beneath Decorah-Platteville-Glenwood confining unit





# SENSITIVITY OF THE **ST. PETER-PRAIRIE DU CHIEN-JORDAN AOUIFER TO POLLUTION**

Hua Zhang and Jan Falteisek

This plate shows the geologic sensitivity to pollution of the St. Peter-Prairie du Chien-Jordan aquifer in Fillmore County. This aquifer underlies most of the county and is the main source of ground water. The pollution sensitivity evaluation considered several factors assumed to enhance or restrict downward movement of water. The map was constructed using geographic information system (GIS) techniques. These techniques efficiently capture, store, manipulate, and display geographically referenced information and also assist analysis of spatial information. Six geological and hydrogeological data layers were digitally combined to form a composite layer as shown in Figure 1. This composite layer is made of many small areas, each with its own combination of the six geologic and hydrogeologic factors. A GIS program assigned sensitivity ratings based on the ratings matrix shown below. For example, an area with characteristics representing depth to water of less than 20 feet in an area with no sinkholes, the Decorah-Platteville-Glenwood confining unit completely eroded, and with no till at the surface was assigned a sensitivity rating of Very High. In contrast, an area was assigned a sensitivity rating of Very Low if it had the following characteristics: Decorah-Platteville-Glenwood confining unit not eroded, depth to bedrock greater than 50 feet, till at the land surface, and No or Low sinkhole probability. About 27 percent of the area of Fillmore County is rated Very High, 11 percent is High, 5 percent is Moderate, 38 percent is Low, and 15 percent is Very Low (see rating matrix). The St. Peter-Prairie du Chien-Jordan aquifer is absent in parts of the Root River and South Fork Root River valleys, totaling about three percent of the county.

The rating matrix assumes that the presence of the Decorah-Platteville-Glenwood confining unit and till at the surface are the major controls on the pollution sensitivity of the St. Peter-Prairie du Chien-Jordan aquifer. In the northeast half of the county, where the confining unit has been completely removed by erosion, the area has pollution sensitivity ratings of generally either High or Very High. However, some limited areas, where till is present at the surface or the confining unit is not completely eroded, received Moderate pollution sensitivity ratings. In the southwest half of the county, the assigned sensitivity ratings of Low and Very Low reflect the importance of the confining unit and till factors.

The presence of karst features has less effect on the pollution sensitivity map of the St. Peter-Prairie du Chien-Jordan aquifer than might first be expected. However, the higher sinkhole probabilities are associated with rocks comprising the upper carbonate aquifer which are underlain by the protective Decorah-Platteville-Glenwood confining unit. (See the discussion of upper carbonate aquifer sensitivity elsewhere on this plate.) Depth to bedrock is an important factor only in the southwest corner of the county where the drift thickness is greater than 50 feet.

The pollution sensitivity map was checked using tritium and nitrate data. The tritium and nitrate data are generally in agreement

FIGURE 1. The geologic and hydrogeologic information layers and process used to develop the sensitivity map. The composite layer is created from the information layers using geographic information system (GIS) techniques. The model (rating *matrix*) is applied to the composite layer using GIS techniques to produce the interpretation. The interpretation is checked using physical, chemical, and isotope data.

with the pollution sensitivity ratings. Recent (tritium greater than 10 Tritium Units or TU) or mixed (0.8-10 TU) age water is found mostly in Moderate, High, or Very High sensitivity areas. Vintage water (tritium less than 0.8 TU) is found mostly in Low or Very Low sensitivity areas. There are, however, some exceptions. Recent or mixed age water was found in the area between Harmony and Canton where the geologic sensitivity, as determined by the matrix, is Low. As illustrated by the cross section in Figure 2 on Plate 6, it is believed that ground water is moving laterally westward under the Decorah-Platteville-Glenwood confining unit from areas in southeastern Fillmore County unprotected by the confining unit. Seasonal recharge at the eroded edge of the confining unit (Delin, 1991; Smith and Nemetz, 1996), a partially eroded or leaky confining unit, or leakage through poorly constructed wells may also be contributing to the presence of recent or mixed age water or elevated nitrate beneath the Decorah-Platteville-Glenwood confining unit. The diagonal pattern on the map, comprising about one-quarter of the county's area, indicates, in general, where recent or mixed age waters or elevated nitrates have been found or are expected to be found in the upper few hundred feet of the aquifer beneath the confining unit. If a contaminant is found in the St. Peter-Prairie du Chien-Jordan aquifer where it is protected by the Decorah-Platteville-Glenwood confining unit, the contaminant may be from a more sensitive area beyond the eroded edge of the confining unit (Setterholm and others, 1991). The ground-water chemistry section in Part C, Text Supplement to the Fillmore County Geologic Atlas, includes additional discussion of tritium in Fillmore County.

## REFERENCES

- Alexander, S.C., and Alexander, E.C., Jr., 1989, Residence times of Minnesota groundwaters: Minnesota Academy of Sciences Journal, v. 55. no. 1. p. 48-52.
- Delin, G.N., 1991, Hydrogeology and simulation of ground-water flow in the Rochester area, southeastern Minnesota, 1987-88: U.S. Geological Survey Water-Resources Investigations Report 90-4081, p. 21.
- Minnesota Department of Natural Resources, Division of Waters, 1991 Criteria and guidelines for assessing geologic sensitivity of ground water resources in Minnesota: The Division, p. 9. Setterholm, D.R., Runkel, A.C., Cleland, J.M., Tipping, R.G., Mossler, J.H.,
- Kanivetsky, R., and Hobbs, H.C., 1991, Geologic factors affecting the sensitivity of the Prairie du Chien-Jordan aquifer: Minnesota Geological Survey Open-File Report 91-5, p.13. Smith, S.E., and Nemetz, D.A., 1996, Water quality along selected flow paths
- in the Prairie du Chien-Jordan aquifer, southeastern Minnesota: U.S. Geological Survey Water-Resources Investigations Report 95-4115, p. 44-45.
- Soller, D.R., and Berg, R.C., 1992, Using regional geologic information to assess relative aquifer contamination potential-an example from the central United States: U.S. Geological Survey Open-File Report 92-694, 1 map



GROUND-WATER TRAVEL TIME IN LOG10 HOURS

FIGURE 2. Geologic sensitivity ratings are based on the time required for surface water to travel vertically to an aquifer. Longer travel times imply a lower sensitivity to pollution. Dye trace, tritium, and carbon-14 studies can indicate the relative ages of ground water.

St. Feter France du Cinen Sordan Aquiter in Finnore County					
Surficial material	Sinkhole probability*				
	No or Low		Greater than Low	Low-Moderate or Moderate-High	High or Sinkhole Plains
	Depth to water (feet)				
	Less than 20	Greater than 20	Less than 50	Greater than 50	
	Decorah-Platteville-Glenwood confining unit completely eroded				
Prairie du Chien Group bedrock	0.5%	1.8%	2.2%	17.8%	
St. Peter or Jordan Sandstone or mostly coarse-textured sediment		3.4%		7.7%	
Till		<0.1%	<0.1%	0.7%	
	Decorah-Platteville-Glenwood confining unit partially eroded				
Bedrock or mostly coarse- textured sediment		<0.1%	<0.1%	4.2%	
Till				<0.1%	
	Decorah-Platteville-Glenwood confining unit not eroded				
Bedrock or mostly coarse- textured sediment			<0.1%	36.2%	
Till				11.4%	2.4%

Matrix for Rating the Sensitivity of the St. Peter-Prairie du Chien-Jordan Aquifer in Fillmore County

\*See Plate 8, Sinkholes and Sinkhole Probability, for map and discussion. Note: Percent values indicate percent area of Fillmore County. The area in eastern Fillmore County mapped as Aquifer, mostly dewatered on Plate 6 is rated Very High (5.1%). In addition, all areas with drift thickness of greater than fifty feet over the Decorah-Platteville-Glenwood confining unit are rated Very Low (3.8%). Matrix boxes with gray pattern indicate this condition was not found by the model.



The DNR Information Center Twin Cities: (612) 296-6157 MN Toll Free: 1-800-766-6000 Telecommunication Device for the Deaf: (612) 296-5484 MN Toll Free: 1-800-657-3929

This information is available in an alternative format upon request

This map was compiled and generated using geographic information system technology. Digital cartography and design by DNR staff, base by the Minnesota Geological Survey, and digital layout and assembly by the Land Management Information Center. Digital data products are available from the Land Management Information Center, Minnesota Planning Office

This map was prepared from publicly available information only. Every reasonable effort has been made to ensure the accuracy of the factual data on which this map interpretation is based. However, the Department of Natural Resources does not warrant the accuracy, completeness, or any implied uses of these data. Users may wish to verify critical information sources include both the references here and information on file in the offices of the Minnesota Geological Survey and the Minnesota Department of Natural Resources. Every effort has been made to ensure the interpretation shown conforms to sound geologic and cartographic principles. This map should not be used to establish legal title, boundaries or locations of improvements.

Equal opportunity to participate in and benefit from programs of the Minnesota Department of Natural Resources is available to all individuals regardless of race, color, national origin, sex, sexual orientation, marital status, status with regard to public assistance, age or disability. Discrimination inquiries should be sent to: MN/DNR, 500 Lafayette Road St. Paul, MN 55155-4031; or the Equal Opportunity Office, Department of the Interior, Washington, D.C. 20240.

©1996 State of Minnesota, Department of Natural Resources