Groundwater Vulnerability Zoning
Pilot Project Final Report
June 2004

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EXECUTIVE SUMMARY

This report represents the results of the Groundwater Vulnerability Zoning Pilot Project (GWVZPP) completed in Nicollet, Brown and Cottonwood Counties between 2001 and 2004 for the purposes of: (1) developing tools to interpret the current status of localized resources for specific use in land management decisions; and (2) applying those tools to the decision making process regarding land management changes; and (3) evaluating the strengths and weaknesses of the pilot project and its effectiveness as a planning tool and the project's potential application for other areas. This project stemmed from the collection of over sixteen years of private well water data from residents in Nicollet, Brown and Cottonwood Counties. The well data was used in conjunction with hydrogeologic, land use and county well index data to develop county wide nitrate probability maps.

Nitrogen is commonly found in groundwater due to both natural and anthropogenic sources. The form that nitrogen takes in groundwater depends on the oxidation–reduction conditions of the water, dissolved oxygen content and organic carbon content. Nitrate (NO_3) is the predominant form of nitrogen in groundwater and surface water under oxidizing or aerobic conditions. Nitrate in a reducing or anaerobic environment is generally reduced to nitrogen gas. Nitrate concentration in oxygenated groundwater depends on loading of nitrogen into the system and nitrogen transport to the groundwater.

A drinking water standard of 10 mg/L nitrate-nitrogen has been established by the US EPA. Serious health risks are associated with consuming water containing levels of nitrate higher than the drinking water standard. Drinking water with high nitrate

concentrations can oxidize hemoglobin and reduce its oxygen carrying capacity. The resulting syndrome is known as methemoglobinemia or “blue baby syndrome.” Infants under six months of age are especially vulnerable due to higher stomach pH and smaller amounts of the enzyme methemoglobin reductase. Presence of nitrate-nitrogen in drinking water also indicates a vulnerability of the aquifer to other contaminants such as pathogens or pesticides.

Results of the application of the nitrate probability maps for land use decision making indicate that the maps can be used effectively as a tool to 1) identify areas that have a higher probability for nitrate-nitrogen groundwater contamination; 2) provide nitrate probability information for the land use application process, such as feedlot and subdivision establishment and expansion; 3) provide groundwater vulnerability information as a justification for the granting of land use permits; 4) alert Planning and Zoning personnel of groundwater concerns that merit adding conditions to land use permits in order to protect and/or improve water quality.

Based on the conclusions of this project, it is recommended that Planning and Zoning staff from Nicollet, Brown and Cottonwood Counties continue to use the nitrate probability maps as a tool for making land management decisions.

1.0 Introduction

1.1 Scope of Work

The following tasks were completed as part of the Groundwater Vulnerability Zoning Pilot Project between the years 2002 and 2004.

- Project methods and objectives presented to Planning and Zoning Commissions for Brown, Nicollet and Cottonwood Counties.
- County and township scale nitrate probability maps developed and distributed to Brown, Nicollet and Cottonwood Counties.
- Project methods and objectives presented at three state conferences and one national conference.
- Nitrate probability maps applied to 33 land use permit applications. For each application, Planning and Zoning Commissions received probability maps and narrative of factors contributing to probability score.
- Project summary poster (Appendix 1) developed and distributed to project stakeholders.
- Project summary developed for inclusion on BNC Water Quality Board website (http://mrbdc.mankato.msus.edu/org/bnc/index2.html).
- Planning and Zoning Commissions surveyed for opinions on effectiveness and value of nitrate probability maps as a tool for making land use decisions.
- Regular meetings of Groundwater Zoning Pilot Project Technical Committee.

- GIS file and hard copy maps provided to county planning and zoning staff to continue using maps for land use decisions.

1.2 Project Contributors

The following people contributed their time and talents to the Groundwater Vulnerability Zoning Pilot Project.

Charles Regan – Project Manager and Technical Committee, MPCA
Sheila Grow – Technical Committee, MDH
Bonnie Holz – Technical Committee, BNC Water Quality Board
Terry Bovee – Technical Committee, MDH
Karen Swenson – Technical Committee, BNC Water Quality Board
Tina Rosenstein – Technical Committee, Nicollet County Environmental Services
Mandy Landkamer – Technical Committee, Nicollet County Environmental Services
Pam Rivers – Technical Committee, Nicollet County Environmental Services
Jane Starz – Technical Committee, Brown County Planning and Zoning
Paul Davis – Technical Committee, Brown County Water Planner
Mike Hanson – Technical Committee, Cottonwood County Environmental Services
Kevin Kuehner – Technical Committee, BNC Water Quality Board
Marcy Pengilly – Office Administration, BNC Water Quality Board
Scott MacLean – Technical Implementation and Planning, BNC Water Quality Board
Brown, Nicollet and Cottonwood County Planning and Zoning commissions

1.3 Background

Brown Nicollet Environmental Health in St. Peter, Minnesota began a township testing program in 1988 in order to provide low-cost drinking water analysis to rural families in Brown and Nicollet counties. Each township in the two counties sponsored a water testing clinic between June 1988 and April 1989. Water was analyzed for nitrate-nitrogen and coliform bacteria. Since 1991, township testing has taken place every three years for Brown, Nicollet and Cottonwood Counties. The resulting database provides water quality information for 1,468 wells in Nicollet County, 1,701 wells in Brown County and 501 wells in Cottonwood County. Four hundred and sixteen or 11.3% of the 3670 wells tested had average nitrate concentrations above the drinking water standard of 10 mg/L. Brown Nicollet Environmental Health staff sought a way to present the large volume of data in a valuable and useful form.

MDH has developed nitrate probability maps for 16 counties across the state. These maps incorporate databases representing nitrate input and geologic sensitivity. A land use database represents nitrate input. Landforms, percent clay above the static water level, depth to bedrock and depth to static water level represent geologic sensitivity. Water quality data can provide a geochemical sensitivity layer to nitrate probability maps because nitrate in groundwater would only be detected in geochemically favorable environments. The extensive water quality database developed from the township testing program provided this geochemical layer for the Brown, Nicollet and Cottonwood probability maps. Washington County is the only other county in Minnesota with a water quality database layer.

1.4 Report Organization

This report is organized into 5 sections including this Introduction. Section 2 summarizes the township testing data collected, Section 3 summarizes the nitrate probability maps, Section 4 summarizes the application of the maps to land use management decisions in the three counties and Section 5 provides project conclusions and recommendations for future use of the tools developed.

2.0 Township Testing

This section summarizes the nitrate-nitrogen water quality database developed from over 16 years of rural well testing in Brown, Nicollet and Cottonwood Counties; how the data was collected; and geologic and geochemical factors underlying the groundwater results.

2.1 Collection Methods

Dating back to 1988, Brown Nicollet Environmental Health has offered free nitrate well testing for rural residents in Brown, Nicollet and Cottonwood Counties every three years. Staff set up in each county township and performed onsite testing of water samples brought in by township residents. Participants were provided immediate results from the water test and information regarding nitrates in drinking water. The data

collected was recorded in a water quality database along with well construction information and geologic data from the County Well Index.

Well construction can contribute to nitrate groundwater contamination. Wells with large casings (>10 in.) and/or shallow wells (< 50 ft) are especially susceptible to direct recharge from surface water which may have high nitrate concentrations. Therefore, these wells are not necessarily representative of the aquifer and were not included in the water quality database mapping layer. Table 2.1 shows the number of wells with water quality data and the actual number used in the water quality layer.

Table 2.1 Water quality database numbers and water quality layer numbers.

County	Wells in Database	Wells in Water Quality Mapping Layer
Brown	1701	879
Nicollet	1468	966
Cottonwood	501	172

2.2 County Summaries

Brown County

Over 1700 analyses have been performed on Brown County well water samples through the Township Testing Program. Of the wells tested, 199 or 12% of the wells had average nitrate concentrations greater than 10 mg/L, exceeding the national drinking water standard. MDH has established guidelines for different ranges of nitrate concentrations in drinking water (Table 2.2).

Table 2.2 MDH guidelines for nitrate concentrations.

Nitrate Conc. (mg/L)	MDH Guideline
0 – 0.99	Considered natural background concentration
1.0 – 2.99	Considered possible indication of contamination
3.0 – 9.99	Considered probable indication of contamination; likely anthropogenic source
10 and over	Considered contaminated; anthropogenic source

Table 2.3 shows the aquifers providing drinking water in Brown County. Distribution and composition of these aquifers affects the natural quantity and quality of drinking water. In general, shallow alluvial aquifers and the Sioux Quartzite aquifer are more likely to contain water with high nitrate concentrations. Also, some Brown County residents receive drinking water from the Red Rock Rural Water System established in 1985.

Table 2.3 Brown County aquifers and characteristics.

Aquifer	Characteristics
Glacial	*Sand, gravel, outwash*: 25-30% pore space results in highest yielding aquifers in county. Water travels through coarse material quickly. Provides high capacity wells for communities such as New Ulm. *Till*: High percentage of clay and silt. Low water capacity, but less susceptible to contamination.
Cretaceous	Sand layer generally yields good water for domestic wells as it is covered by clay and silt.
Sioux Quartzite	Low yielding aquifer; susceptible to contamination from land use practices because of fractures and joints in quartzite.
Precambrian	Groundwater found in fractures and zones where rocks have been heavily weathered. Low yielding.

Nicollet County

One thousand four hundred and sixty-eight well analyses have been performed on Nicollet County well water samples through the Township Testing Program. Of the wells tested, 83 or 5% of the wells had average nitrate concentrations greater than 10 mg/L, exceeding the national drinking water standard. In general, shallow glacial aquifers, the Jordan Aquifer, and wells located near the Minnesota River are more likely to have high nitrate concentrations.

Table 2.4 shows the aquifers providing drinking water in Nicollet County. Distribution and composition of these aquifers affects the natural quantity and quality of drinking water.

Table 2.4 Nicollet County aquifers and characteristics.

Aquifer	Characteristics
Glacial	*Sand, gravel, outwash*: 25-30% pore space results in highest yielding aquifers in county. Water travels through coarse material quickly. Provides high capacity wells for communities and farm wells. *Till*: High percentage of clay and silt. Low water capacity, but less susceptible to contamination.
Cretaceous	Sediment deposited during Cretaceous Period covered by glacial deposits. Spotty distribution; not one continuous aquifer. Wells in western 1/3 of county completed in bedrock obtain water from Cretaceous Aquifer.
Paleozoic	Aquifers formed through deposition of materials in and around inland sea during Paleozoic Era. *Jordan Sandstone*: Uppermost Paleozoic Aquifer; high quantity of water but susceptible to contamination. *St. Lawrence*: Mudstone, shale, fine grained sandstone, dolomite. Acts as confining layer. *Franconia*: Fine grained sandstone, shale, mudstone, dolomite. *Ironton and Galesville*: Sandstone formations; high water capacity. *Eau Claire*: Mudstone and shale. Poor source of water. *Mt. Simon*: Sandstone; very deep.

Cottonwood County

Five hundred and one well analyses have been performed on Cottonwood County well water samples through the Township Testing Program. Of the wells tested, 134 or 27% of the wells had average nitrate concentrations greater than 10 mg/L, exceeding the national drinking water standard. In Cottonwood County, shallow alluvial aquifers and

the Sioux Quartzite aquifer are more likely to contain water with high nitrate concentrations.

Table 2.5 shows the aquifers providing drinking water in Cottonwood County. Distribution and composition of these aquifers affects the natural quantity and quality of drinking water. Also, some Cottonwood County residents receive drinking water from the Red Rock Rural Water System established in 1985.

Table 2.5 Cottonwood County aquifers and characteristics.

Aquifer	Characteristics
Glacial	*Sand, gravel, outwash*: 25-30% pore space results in highest yielding aquifers in county. Water travels through coarse material quickly. Provides high capacity wells for communities and farm wells. *Till*: High percentage of clay and silt. Low water capacity, but less susceptible to contamination.
Cretaceous	Sand layer generally yields good water for domestic wells as it is covered by clay and silt.
Sioux Quartzite	Low yielding aquifer; susceptible to contamination from land use practices because of fractures and joints in quartzite.

Table 2.6 shows a breakdown of the nitrate-nitrogen test results used in the probability mapping for each county. In circumstances where particular wells have been analyzed more than once, an average nitrate concentration is reported.

Table 2.6 Breakdown of nitrate concentrations used for mapping per county.

Nitrate-Nitrogen	Brown County	Nicollet County	Cottonwood County
Wells with NO_3 less than 3 mg/L	820 (93%)	895 (92.6%)	141 (82%)
Wells with NO_3 between 3 and 10 mg/L	29 (3.3%)	44 (4.6%)	12 (7%)
Wells with NO_3 greater than 10 mg/L	30 (3.4%)	27 (2.8%)	19 (11%)
Total wells	879	966	172

3.0 Nitrate Probability Mapping

This section describes the development of the nitrate-nitrogen probability maps.

3.1 Background

The Minnesota Department of Health (MDH), under direction of the United States Environmental Protection Agency (US EPA) developed nitrate probability maps to help identify areas susceptible to groundwater nitrate contamination. The goal is to help protect public and private drinking water supplies and to help prevent further nonpoint source contamination.

Several factors contribute to the probability an aquifer will be contaminated by nitrate-nitrogen. Nitrogen input, aquifer sensitivity, and water quality databases are used

to predict an area's probability for nitrate contamination. The databases of each factor contributing to an area's probability for nitrate contamination can be graphically represented using a Geographic Information System (GIS). The resulting maps provide a visual representation of each factor and how it might contribute to groundwater nitrate vulnerability.

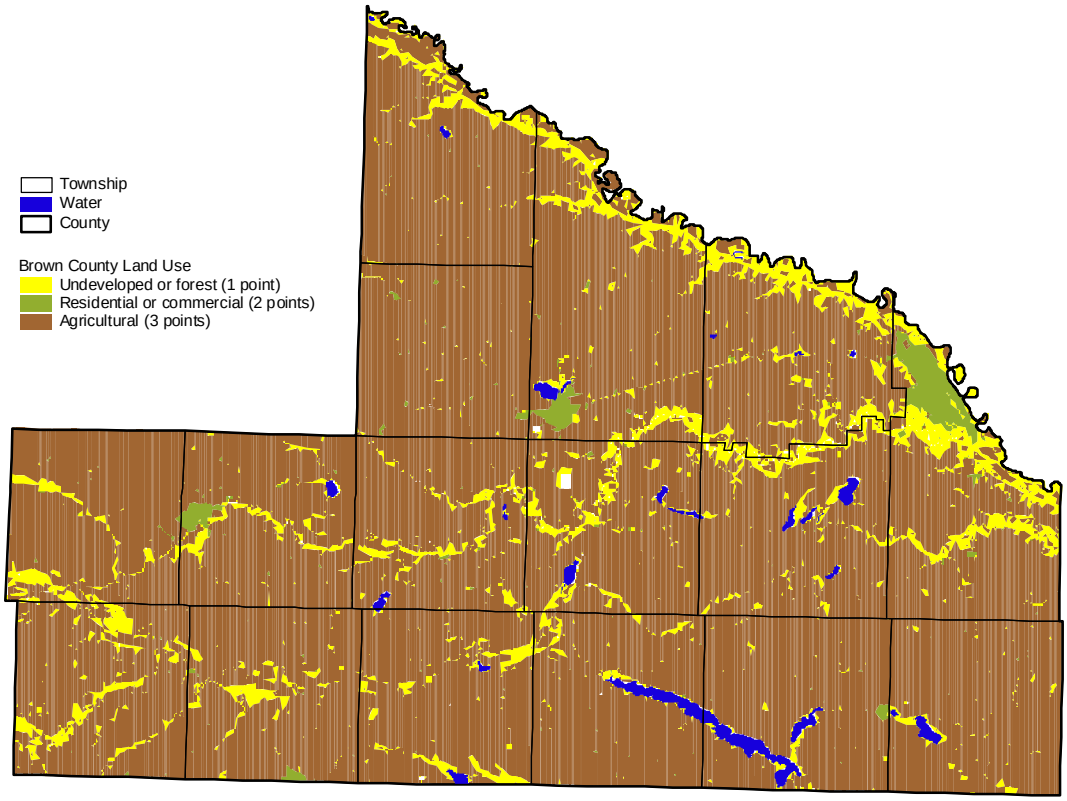
3.1.1 Nitrogen Input

Nitrogen input is closely linked to land use. Land use resulting in higher nitrogen concentrations in surface water increases the potential for ground water contamination. For the purpose of generating the nitrate probability maps, land use was divided into three categories and each category was assigned a point value: forested or undeveloped (1 point), residential or commercial (2 points), and agricultural (3 points). Higher point values indicate a greater potential for nitrate input. The land use database, "Land Use-Minnesota, Agricultural and Transition Areas" was developed by the International Coalition for Land and Water Stewardship in the Red River Basin using 1988 – 1990 inventory aerial photography. Table 3.1 shows how land uses were classified into the three groups. The three county land use maps are shown in Maps 3.1, 3.2 and 3.3.

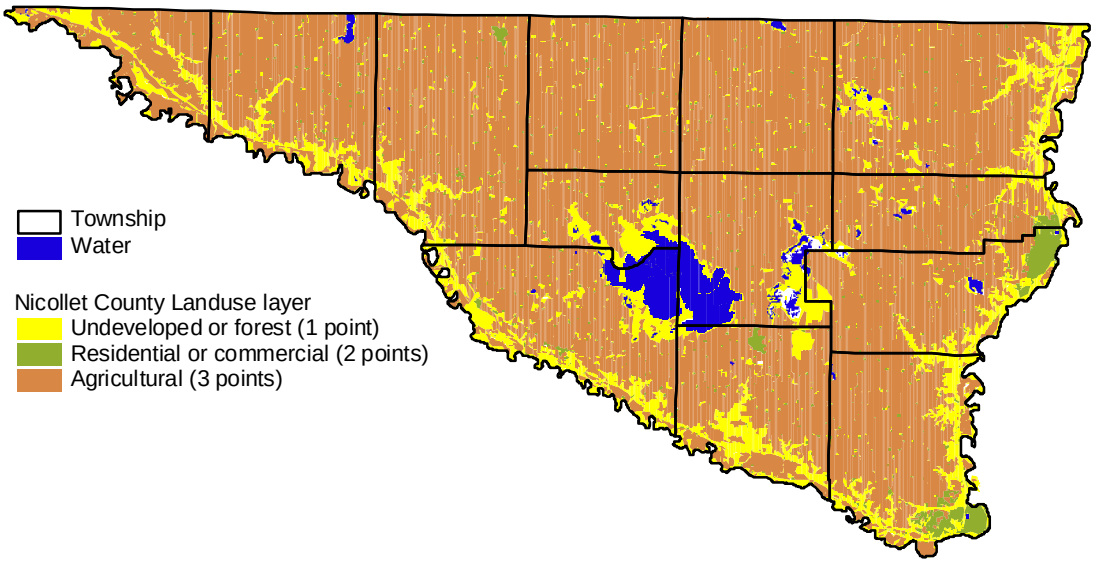
Table 3.1 Land use classifications.

Land Use	Classification	Classification Score
Cultivated land	Agricultural	3
Deciduous forest	Forested or undeveloped	1
Exposed soil; sandbars and sand dunes	Forested or undeveloped	1
Farmsteads and rural residences	Residential or commercial	2
Grassland	Forested or undeveloped	1
Grassland – Shrub – Tree (deciduous)	Forested or undeveloped	1
Gravel pits and open mines	Forested or undeveloped	1
Other rural developments	Residential or commercial	2
Rural residential development complex	Residential or commercial	2
Transitional agricultural land	Agricultural	3
Urban and industrial	Residential or commercial	2
Water	Water	0
Wetlands	Forested or undeveloped	1

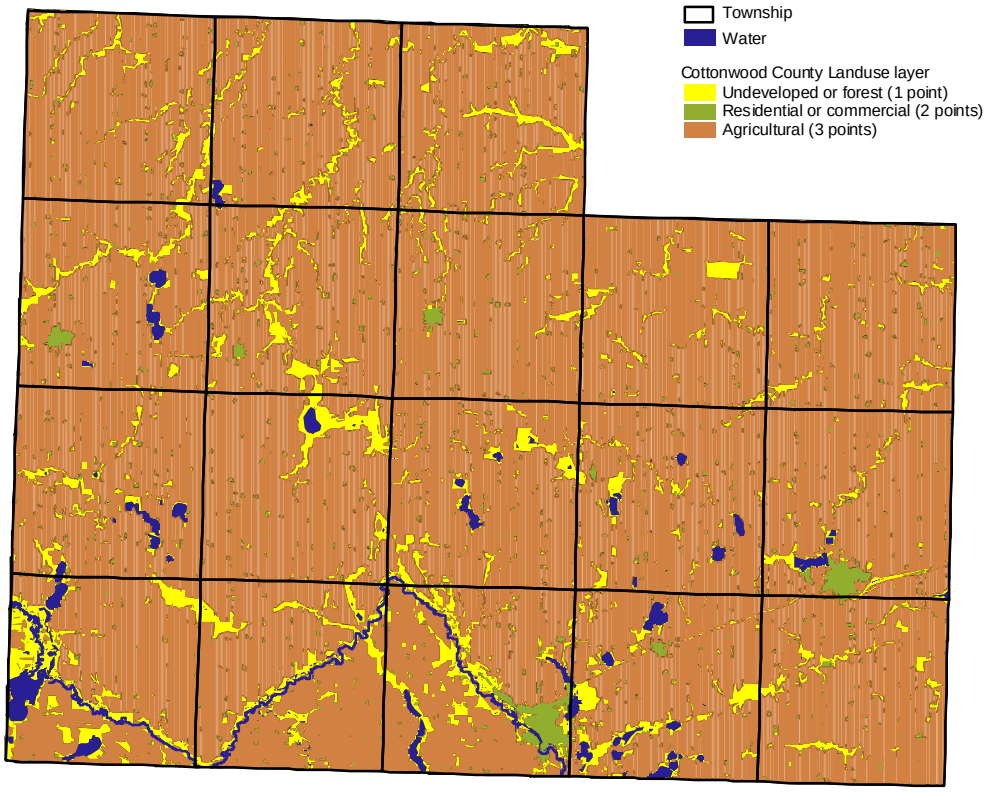
Map 3.1 Brown County Land Use layer.



Map 3.2 Nicollet County Land Use layer.



Map 3.3 Cottonwood County Land Use layer.



3.1.2 Aquifer Sensitivity

Aquifer sensitivity represents the potential for nitrate to migrate from the surface to the water supply source. For the purpose of generating the nitrate-nitrogen probability maps, aquifer sensitivity is represented by landforms, percent clay above the static water level, depth to bedrock and depth to static water level.

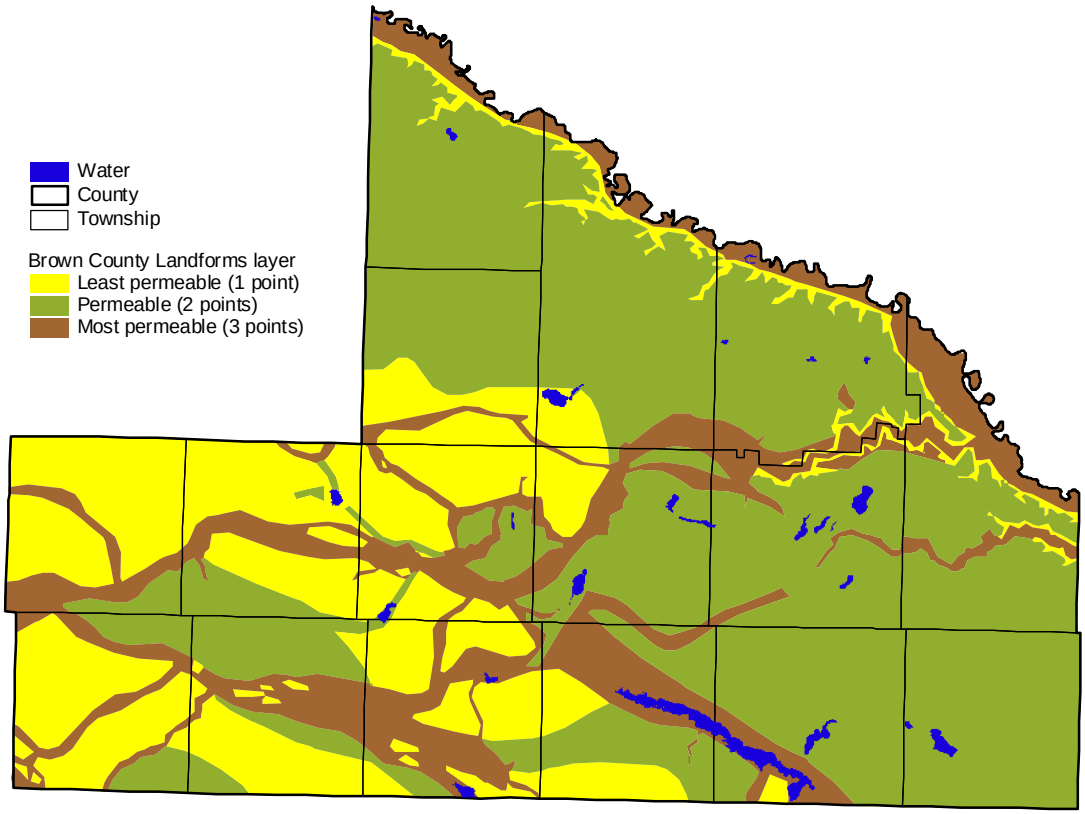
3.1.2.1 Landforms

The landforms database accounts for the surface permeability of an area based on surface geology. Because landforms only account for surface geology, underlying layers might significantly affect aquifer sensitivity. Surface geology with fractures, joints or coarse material allows surface water to infiltrate quickly increasing the potential for nitrate input to water sources, whereas fine soils such as silt and clay retard water transport reducing the potential for contamination. The landform database provided by the Minnesota Geological Survey Landform Associations of Minnesota was divided into three categories: least permeable, permeable and most permeable. Table 3.2 shows the permeability assigned to various landforms and the associated point value. Maps 3.4, 3.5 and 3.6 show the county landform maps.

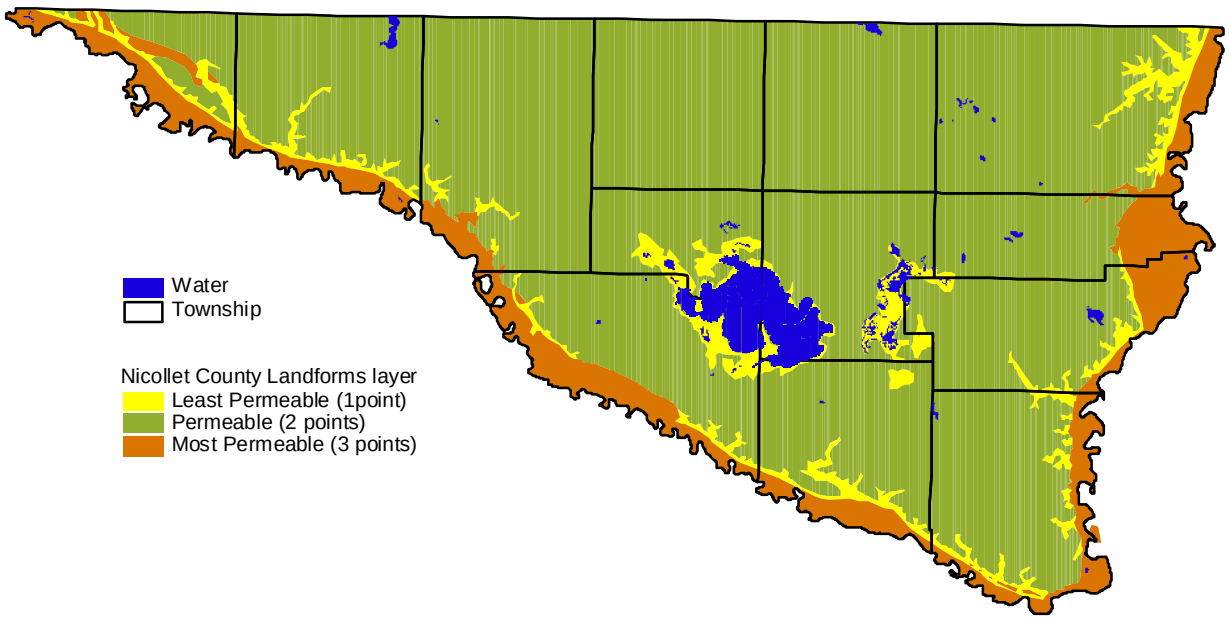
Table 3.2 Landform permeabilities.

Landform Classification	**Reclassification Name**	**Ranking Score**
Alluvium	Most permeable	3
Bedrock dominated	Most permeable	3
Ice contact	Most permeable	3
Lacustrine	Least permeable	1
Outwash	Most permeable	3
Peat	Least permeable	1
Supraglacial drift complex	Permeable	2
Terrace	Most permeable	3
Till plain	Least permeable	1
Undifferentiated	Permeable	2

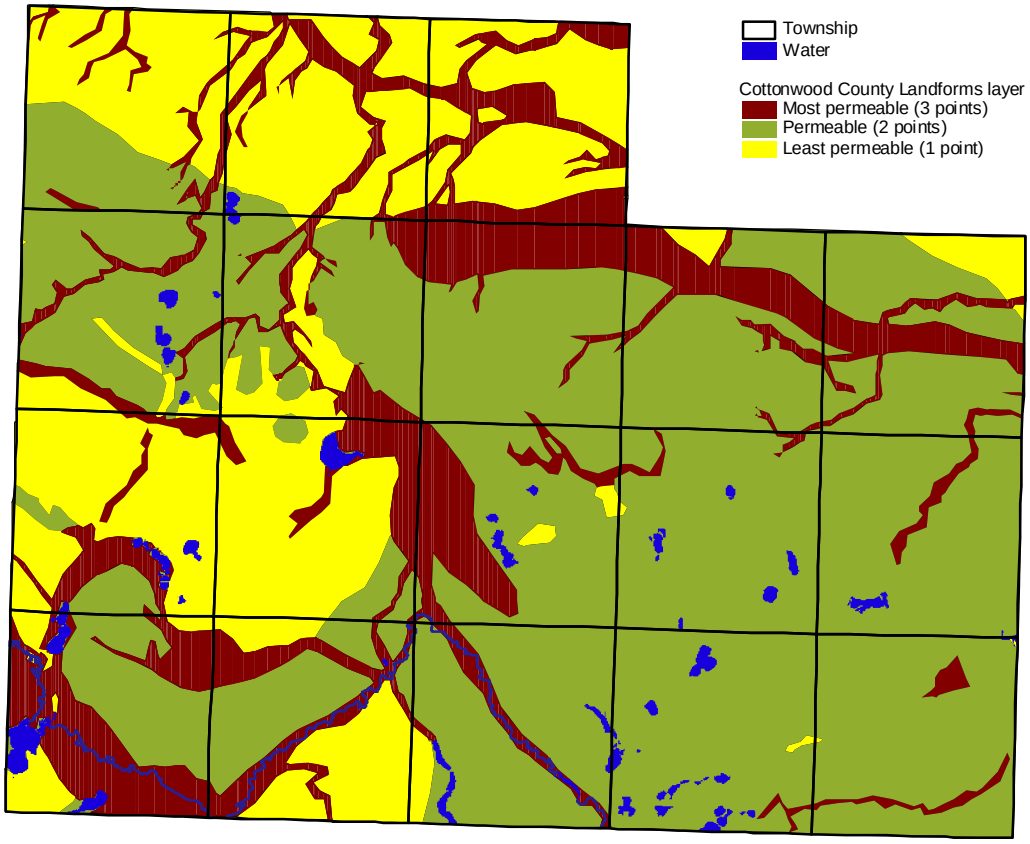
Map 3.4 Brown County Landforms layer.



Map 3.5 Nicollet County Landforms layer.



Map 3.6 Cottonwood County Landforms layer.



3.1.2.2 Percent clay above the static water level

Fine particle soils contain less pore space than sandy soils or bedrock, slowing down the rate of water infiltration. Therefore, soils with a high percentage of clay or other relatively impermeable materials can isolate aquifers from contaminants such as nitrate-nitrogen. Areas within the three counties with a relatively high percentage of clay above the static water level should have well protected aquifers. Nearly 1900 well logs for the three counties provided the lithology to develop this layer. Well driller's descriptions of the lithology in the well logs were reclassified with respect to the permeability of the materials. Materials that retard migration of water were classified as clay, and all other lithologies were classified as sand. Table 3.3 shows the breakdown of the classifications.

Table 3.3 Lithology classification scheme.

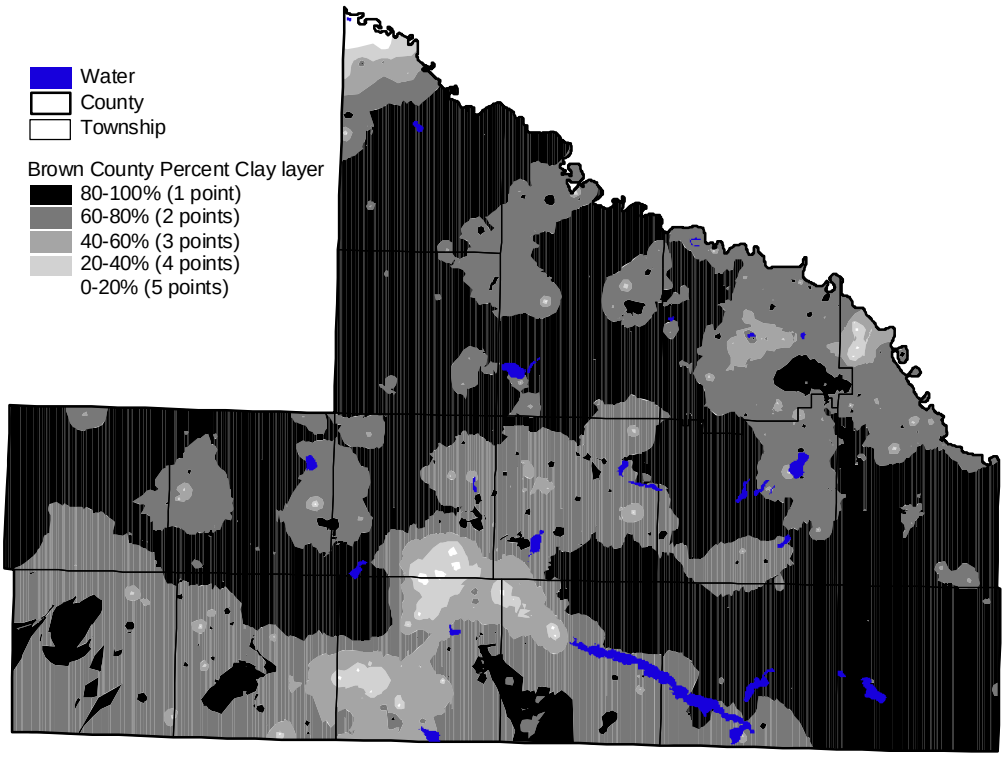
Lithology	Sand	Clay
Bedrock	X	
Boulder	X	
Clay		X
Coal	X	
Cobble	X	
Conglomerate	X	
Dolomite	X	
Drift	X	
Fill	X	
Granite	X	
Gravel	X	
Hardpan		X
Limestone	X	
No record	X	
Organic deposits		X
Peat		X
Pebble	X	
Pit	X	
Quartz	X	
Regolith		X
Sand	X	
Shale		X
Silt		X
Sandstone	X	
Soil	X	
Blank	X	

MDH contends percent clay above the static water level has the largest influence on water quality because the databases were developed from data specifically related to the three counties. Therefore, the layer was divided into five categories with respect to an area's nitrate contamination vulnerability (Table 3.4). Maps 3.7, 3.8 and 3.9 show the Percent Clay Layer map.

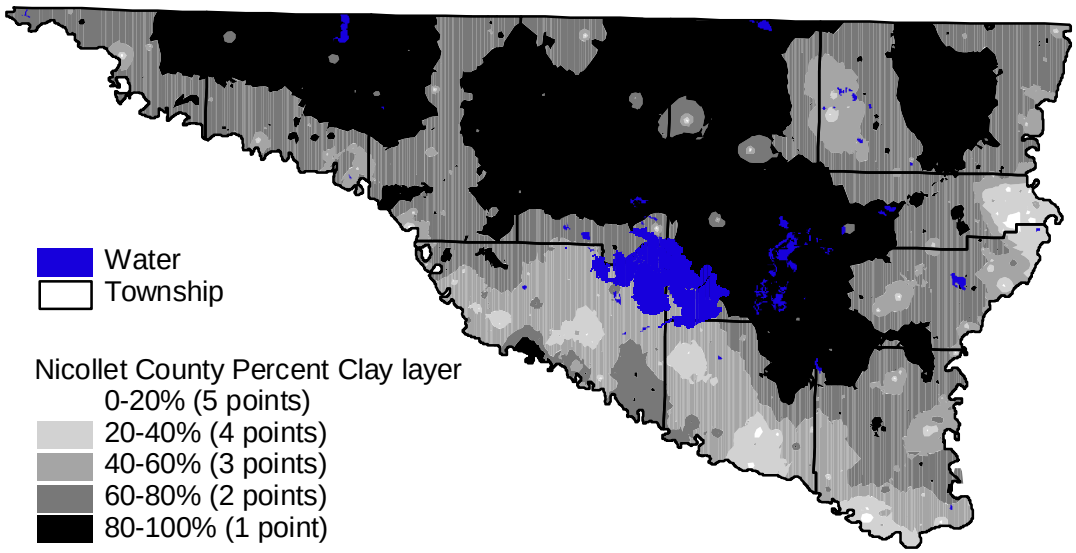
Table 3.4 Percent clay and associated scores.

Percent Clay Above the Static Water Level	**Ranking Score**
0 – 20	5
20 – 40	4
40 – 60	3
60 – 80	2
80 - 100	1

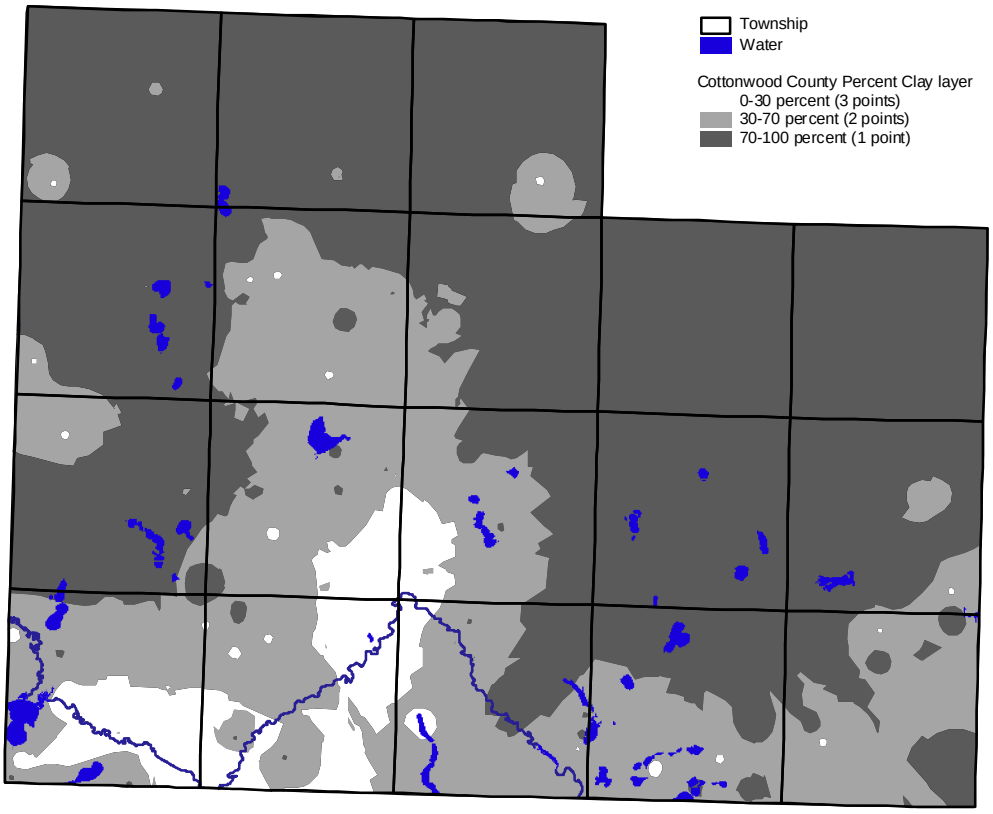
Map 3.7 Brown County Percent Clay Above the Static Water Level layer.



Map 3.8 Nicollet County Percent Clay Above the Static Water Level layer.



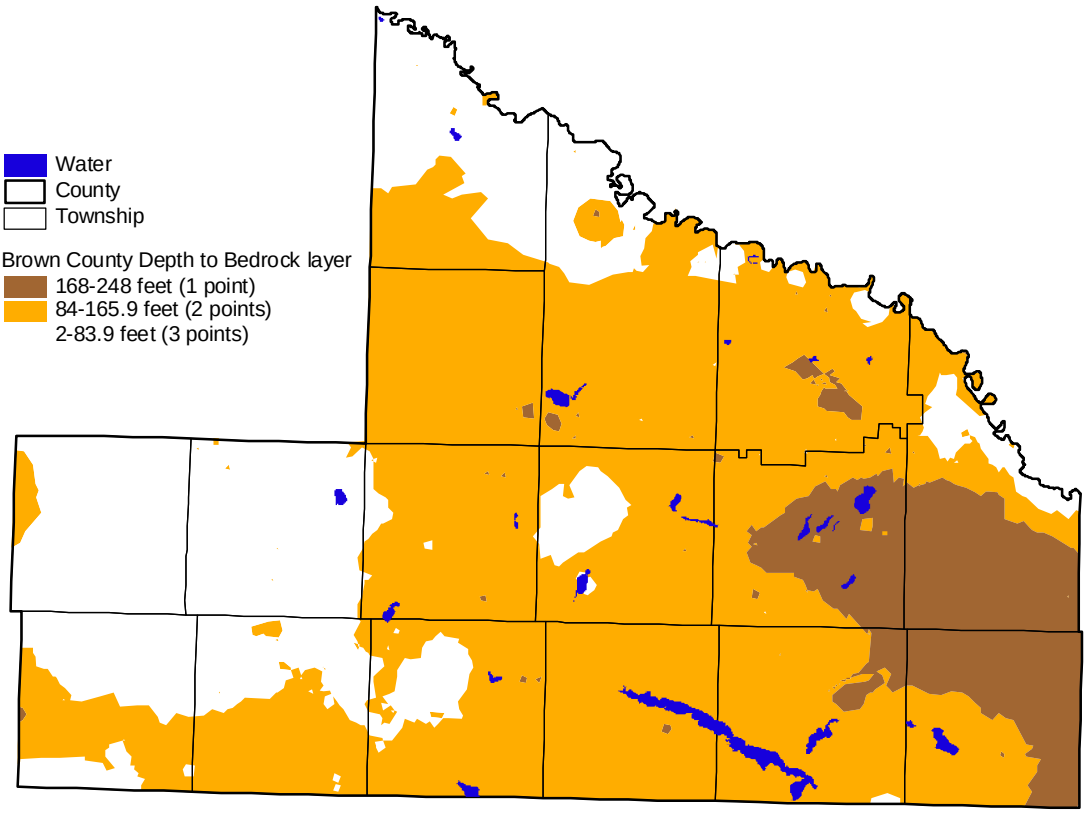
Map 3.9 Cottonwood County Percent Clay Above the Static Water Level layer.



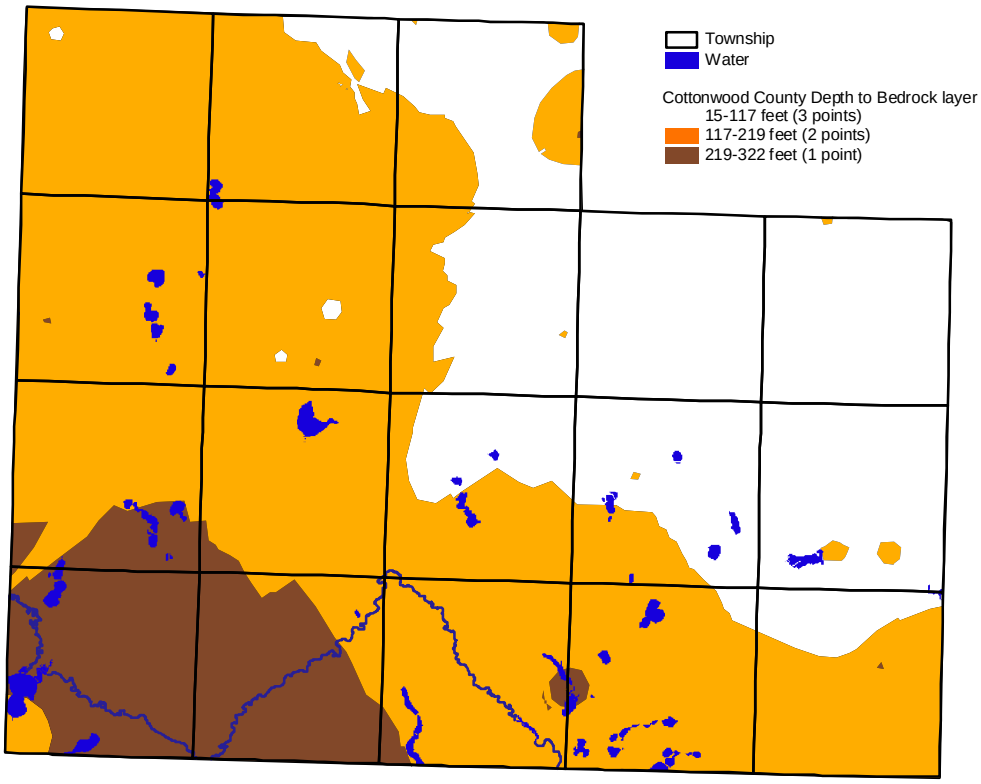
3.1.2.3 Depth to bedrock

The cracks and fissures in bedrock allow surface water to quickly migrate to aquifers, increasing the probability for nitrate contamination. Therefore, areas with shallow bedrock can be especially vulnerable. Over 470 well logs from Cottonwood and Brown Counties provided the database for this layer. Depth to Bedrock was divided into three categories, with shallow assigned 3 points, medium assigned 2 points and deep assigned 1 point. Maps 3.10 and 3.11 illustrate the Depth to Bedrock layer. Most wells in the County Well Index were finished above the bedrock layer.

Map 3.10 Brown County Depth to Bedrock layer.



Map 3.11 Cottonwood County Depth to Bedrock layer.



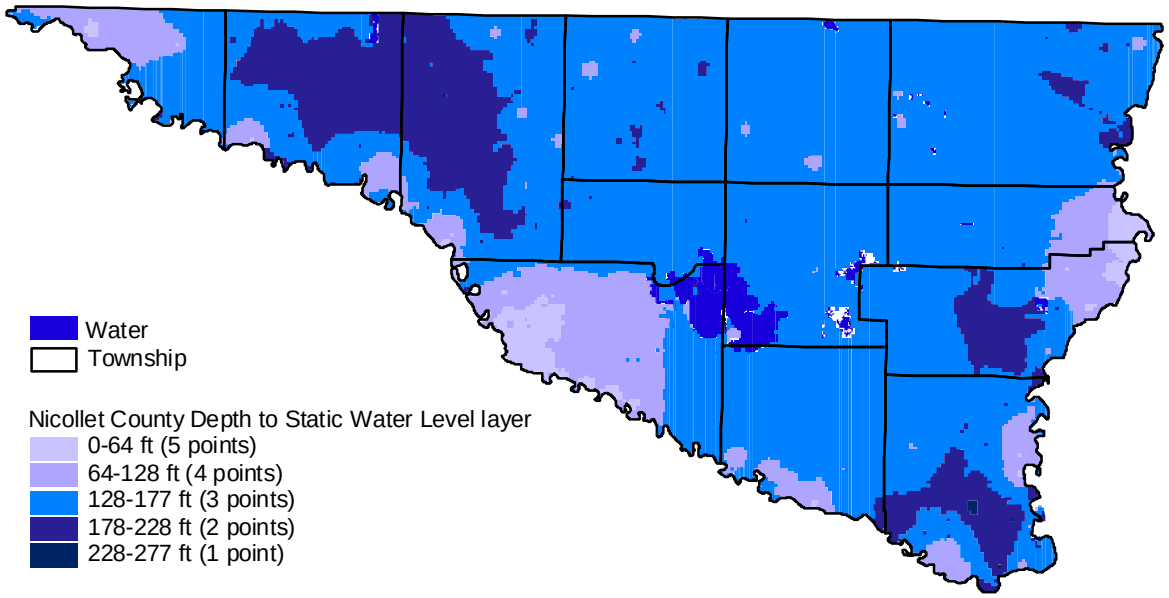
3.1.2.4 Depth to Static Water Level

Groundwater close to the surface is more susceptible to contamination due to its proximity to the contaminant source. Therefore, the non-pumping level of water in a well casing (the static water level), provides a measure of the groundwater's vulnerability to contamination. Nearly 430 well logs in Nicollet County were used to develop a database of Static Water depths. This layer was divided into five categories with associated scores (Table 3.5). Map 3.12 illustrates the Static Water Level layer.

Table 3.5 Static water level depths and associated scores.

Depth to Static Water Level (feet)	Ranking Score
0 – 64	5
64 – 128	4
128 – 178	3
178 – 228	2
228 - 277	1

Map 3.12 Nicollet County Depth to Static Water Level layer.



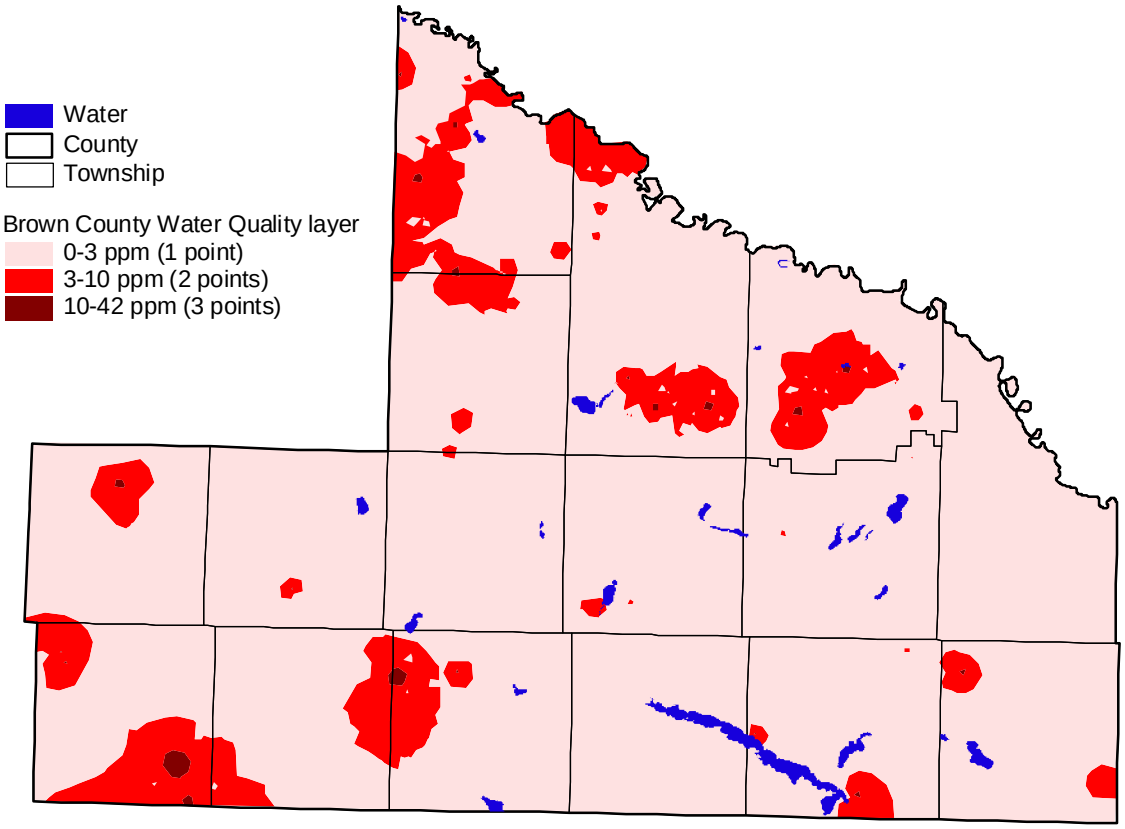
3.1.3 Geochemical Sensitivity

The previous layers have been used to develop nitrate probability maps for 16 counties in Minnesota. However, the maps developed for Brown, Nicollet and Cottonwood Counties (and Washington County) are unique in that they have also incorporated actual nitrate-nitrogen concentration results from over 2000 private drinking wells. Because nitrate is only detected in geochemically favorable environments, the water quality database can be used to generate a geochemical sensitivity layer. Real well analyses greatly help to predict areas vulnerable to contamination. The Water Quality Layer was divided into three categories as shown in Table 3.6. Maps 3.13, 3.14 and 3.15 illustrate the Water Quality layer for each county.

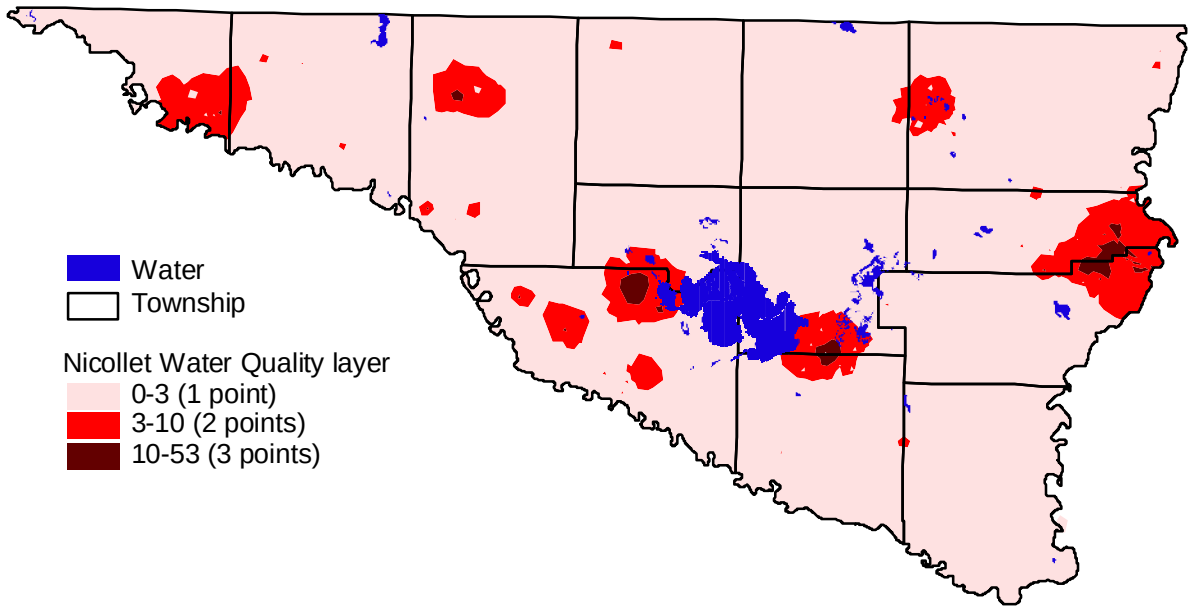
Table 3.6 Water Quality and associated scores.

Average Nitrate-Nitrogen Concentration (mg/L)	**Ranking Score**
0 -2.9	1
3.0 – 9.9	2
> 10	3

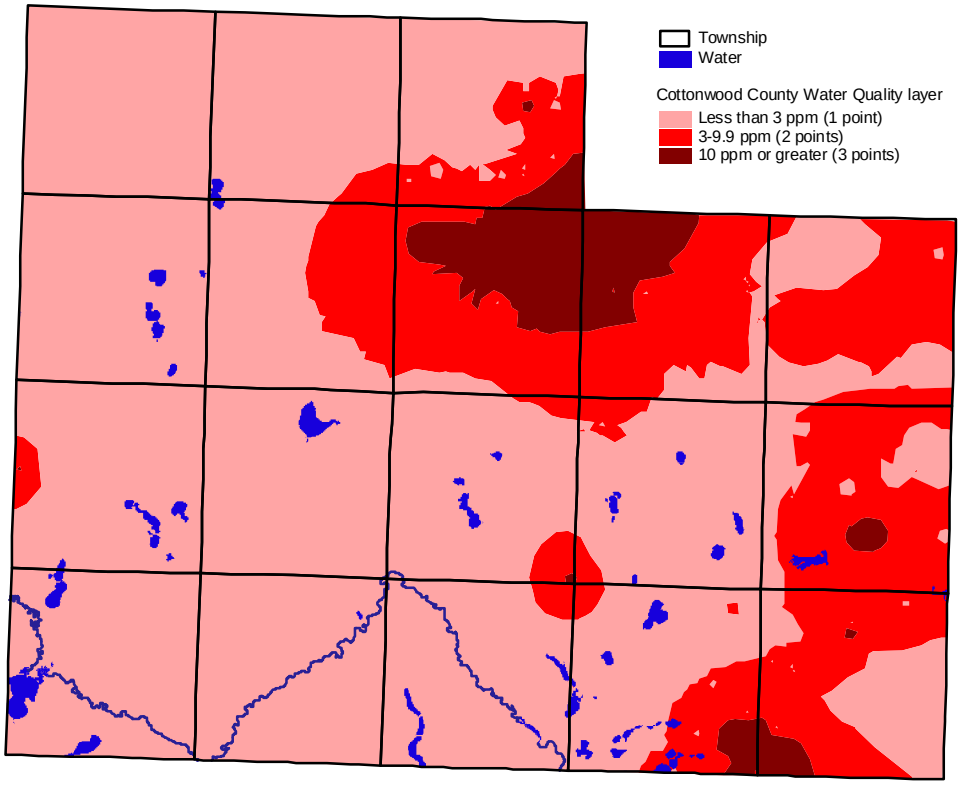
Map 3.13 Brown County Water Quality layer.



Map 3.14 Nicollet County Water Quality layer.



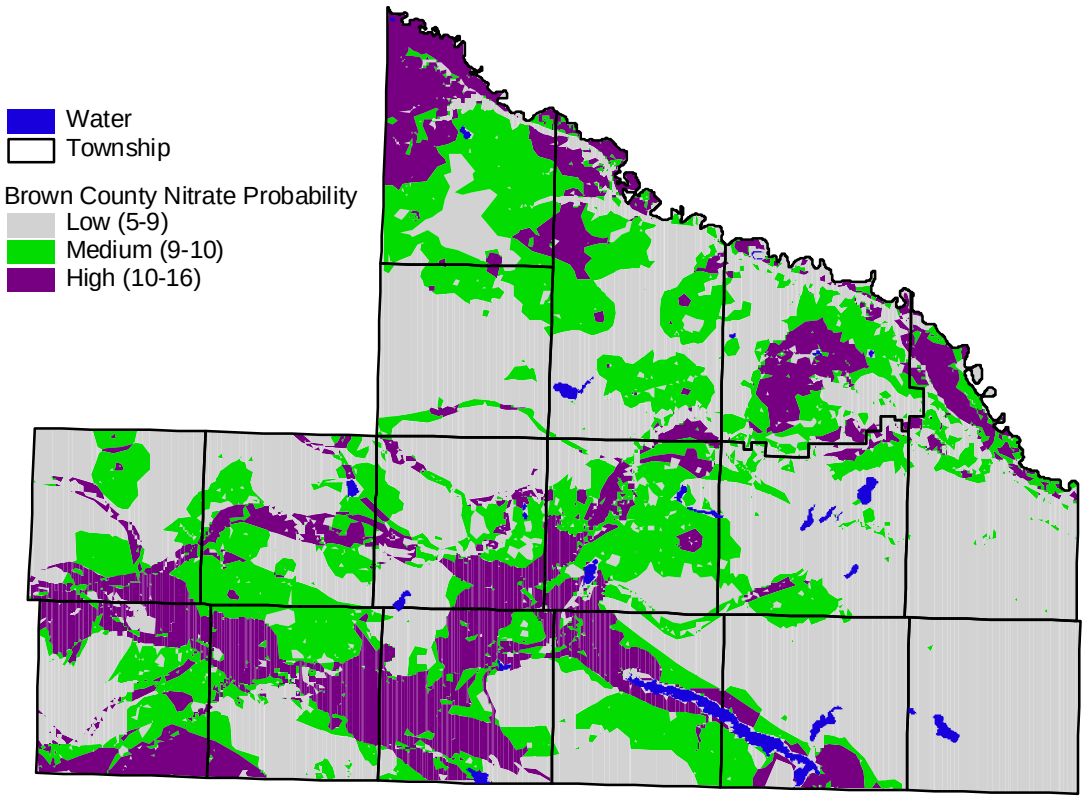
Map 3.15 Cottonwood County Water Quality layer.



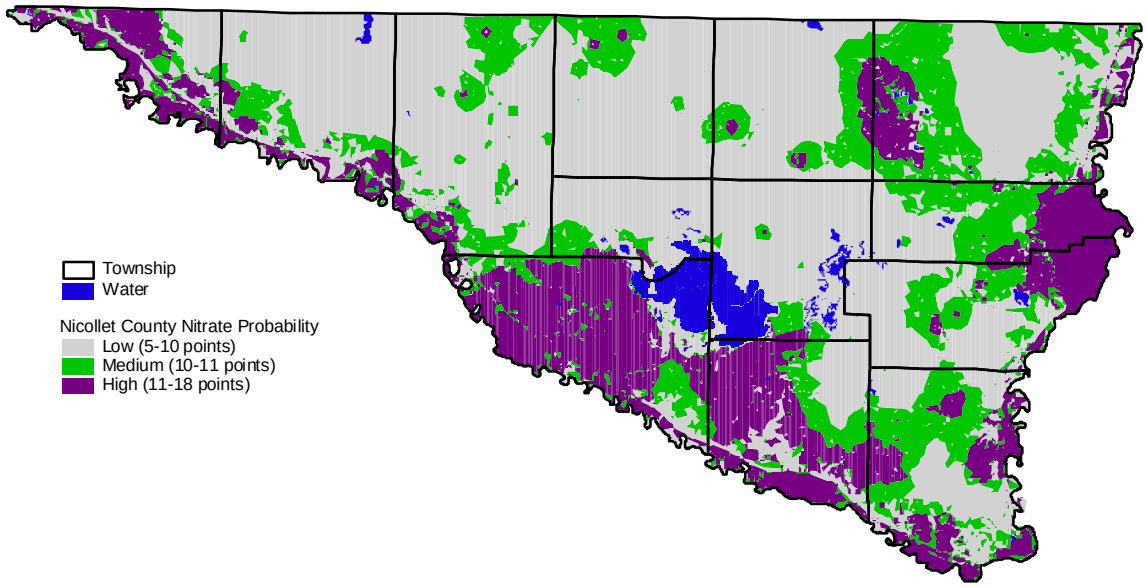
3.1.4 Nitrate Probability Maps

The layers developed for each county were merged in GIS to make a composite map representing each of the factors contributing to an area's probability for ground water nitrate contamination. Overall nitrate probability of an area was determined by the combined score of each of the contributing factors. Nitrate probability was divided into three categories: low, medium and high. For example an area in Nicollet County scoring 3 points for Land Use, 1 point for Landforms, 2 points for Percent Clay, 2 points for Static Water Level and 1 point for Water Quality would have a total score of 9 points. This falls within the range of low probability for nitrate contamination on the probability map. Maps 3.16, 3.17 and 3.18 show the probability maps for the three counties.

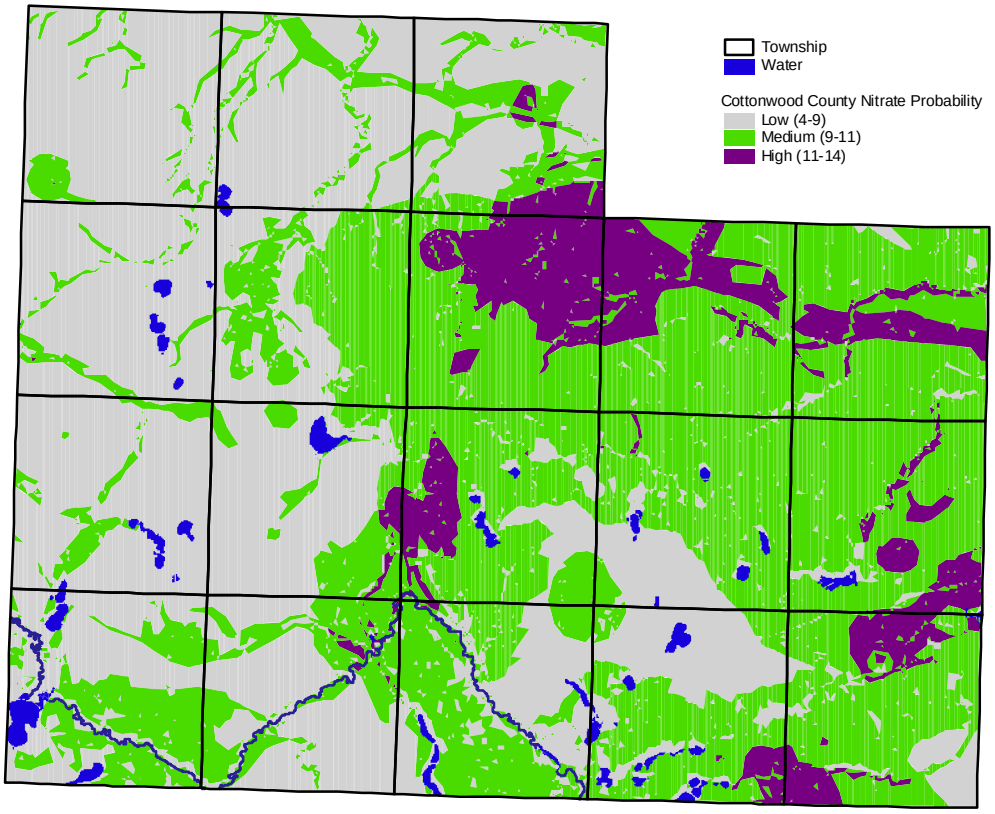
Map 3.16 Brown County nitrate probability map.



Map 3.17 Nicollet County Nitrate Probability Map.



Map 3.18 Cottonwood County Nitrate Probability Map.



In the three counties, nearly 83% of the wells in the water quality database with nitrate concentrations 3.0 mg/L or higher were located in areas with medium or high probability for nitrate contamination. High and medium probability areas are less than 50% of the total county areas. Nearly 70% of wells in the water quality database with nitrate concentrations higher than 10 mg/L were located in high probability areas. High probability areas are less than 20% of the county areas. Therefore, wells with high nitrate concentrations are clearly more likely to be located in areas with medium or high

probability for nitrate contamination. However, suitable drinking water can be found in medium and high probability areas. Of the 395 wells located in high probability areas, only 53 (13.4 %) had nitrate concentrations greater than 10 mg/L. The absence of nitrate in groundwater indicates small nitrogen loading, nitrogen taking a different form (ammonia), or denitrification of nitrate. Deep wells generally have lower nitrate concentration regardless of the area's vulnerability because of the anaerobic environment of most deep wells.

4.0 Application of Nitrate Probability Maps

The Groundwater Vulnerability Zoning Pilot Project was developed as a tool for land use decision makers when considering granting land use permits in Brown, Nicollet and Cottonwood Counties. These counties are entirely dependent on groundwater for their drinking water supplies. The ability to visualize the effects of current and changing land use practices on water resources might help when designing new residential, agricultural and industrial developments to have minimal impacts on water quality. This section summarizes the Conditional Use Permit Process and how the nitrate probability maps were used to help with land use decisions.

4.1 Conditional Use Permit Procedures

Land use proposals, such as the establishment of subdivisions or the establishment or expansion of feedlots, must go through a conditional use permit process overseen by County Planning and Zoning Commissions. Applicants are required to supply a site plan

with soils information, neighboring land and water uses, existing and proposed structures, architectural plans, drainage, water supply systems and a number of other details for the proposed land use. Certain conditions are attached to proposals depending on the intended land use in order to ensure the health, safety and general welfare of surrounding residents. The conditions vary by county but typically include requirements for landscaping, type of construction, completion dates, fencing, and other conditions. If it is determined that standard conditions are not sufficient to meet protection goals, additional conditions can be added. These might include limiting the height, size or location of buildings, controlling the location and number of vehicle access points, requiring diking or landscaping to protect nearby property, or establishing a time limit for a conditional use. Planning and Zoning Commissions hold regularly scheduled meetings during which public comment is welcome for proposed land uses. The commission can then vote yes or no to recommend granting the use permit with any attached conditions. The recommendation then goes before the county board which votes on whether or not to grant the permit.

4.2 Nitrate Probability Maps as Tools

Land use changes are a potential threat to water quality as the new land use might introduce increased levels of nitrates. Being able to identify the vulnerability of an area to groundwater nitrate contamination could be a valuable tool for land use decision makers. The nitrate probability maps were used in this capacity.

4.2.1 Project Presentations

Prior to applying the maps to land use decisions, the project was presented before each of the Brown, Nicollet and Cottonwood County Planning and Zoning Commissions. The presentation focused on the threat of nitrates in drinking water, the development of the maps and how to apply them to land use decisions. Feedback from the commissions helped to refine the application of the tool. The project was also presented at the spring 2002 State Planning and Zoning conference, the spring 2002 Minnesota Environmental Health Association conference, the spring 2002 Minnesota Rocks and Waters conference and the summer 2002 National Environmental Health Association conference.

4.2.2 Using Probability Maps for Land Use Decisions

Beginning in March of 2002, nitrate probability maps were used as a tool by Planning Commissions for granting use permits. All but two of the permits to which the maps were applied were feedlot establishments or expansions. Project staff were provided with use permit applications, which include maps, building designs, spreading acres and animal units prior to the public hearing. The location for the land use permit was determined on the county nitrate probability maps. The probability score for the location was determined by adding the score of each of the contributing factors. Members of the Planning Commissions received a written narrative (Appendix 2) describing the score for each factor and a copy of the nitrate probability map with the location of the use permit identified. Project staff attended the public hearing to answer questions regarding the area's nitrate vulnerability. Planning Commissions then chose whether or not to add conditions to the permit based on the potential for groundwater nitrate contamination.

Table 4.1 shows the applications, locations, scores and planning decisions during the project's application. The names of the applicants are not shown to protect their anonymity.

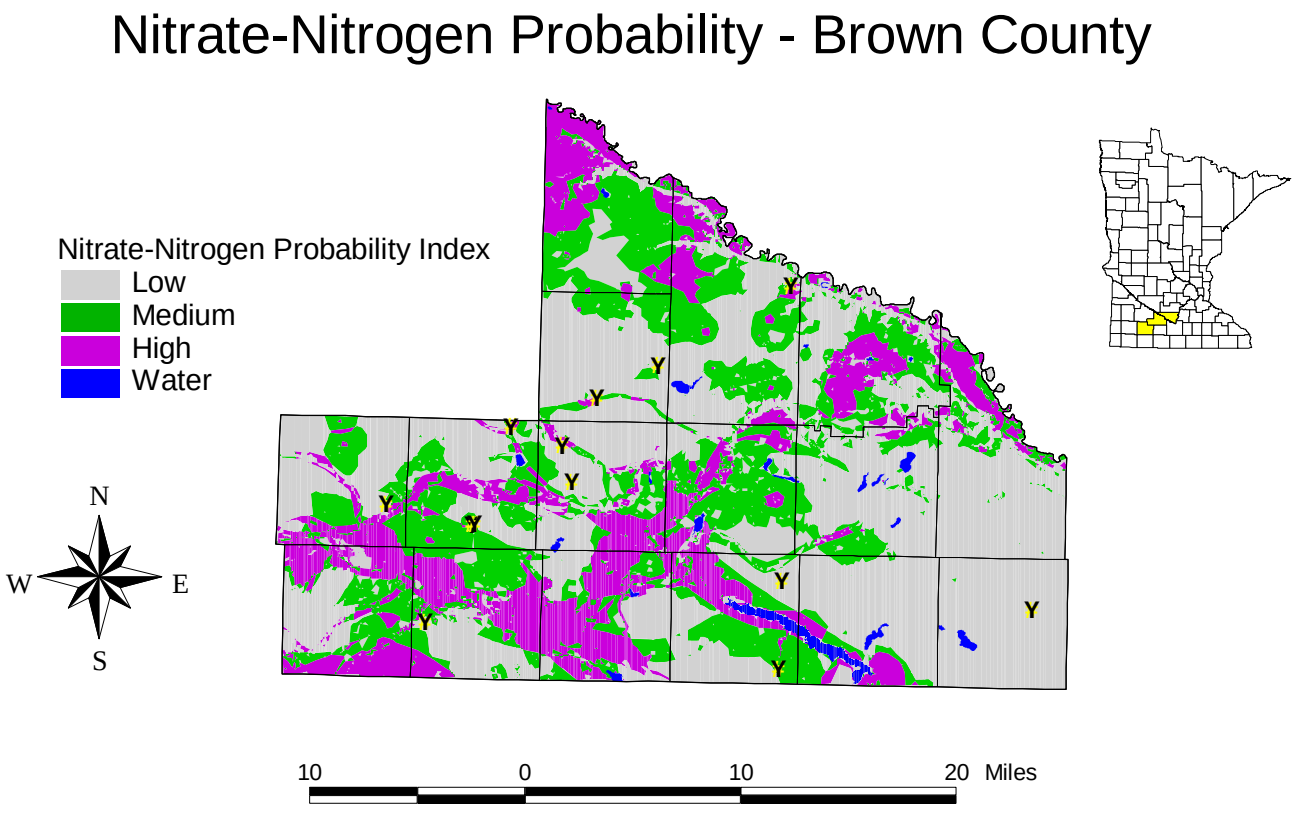
Table 4.1 Land use permit applications during project.

Applicant	Date of Hearing	County	Location	Section Township Range	Issue	Nitrate Score	Planning Decision	Comments
1	3/18/02	Nicollet	S2ofNE4	20-110-27	Expansion	10 - low	Approved	High % clay, good water qual
2	4/15/02	Nicollet	SE4ofSW4	31-111-27	Expansion	10 - low	Approved	High % clay, good water qual
3	5/20/02	Nicollet	SE4ofNE4	05-111-31	Expansion	10 - low	Approved	High % clay, good water qual
4	5/20/02	Nicollet	SE4ofNE4	21-109-27	Expansion	10 – low	Approved	High % clay, good water qual
5	6/17/02	Nicollet	S2of SW4	08-111-30	New feedlot	9 – low	Approved	High %clay, good water qual, SWL
6	5/14/02	Brown	NE4	24-110-33	New feedlot	9 – low	Denied	Denied for air qual concerns
7	5/14/02	Brown	NW4ofNW4	36-111-32	Expansion	10 – med	Approved	Shallow bedrock, high % clay
8	5/14/02	Brown	NW4ofNW4	12-108-32	New feedlot	9 – low	Approved	High % clay, good water qual
9	5/20/02	Nicollet	S2ofNE4	15-111-27	New feedlot	10 – low	Approved	High % clay
10	6/11/02	Brown	NW4ofNW4	8-109-33	New feedlot	9 – low	Approved	Good landforms and water qual
11	6/11/02	Brown	S2ofSE4	17-109-33	Reduction	8 – low	Approved	High % clay, good water qual
12	6/20/02	Cttwd	SW4	25-105-34	Subdivision	8 – low	Approved	High % clay, good water qual
13	8/13/02	Brown	W2ofSW4	27-109-34	Reduction	9 – low	Approved	High % clay, good water qual
14	9/10/02	Brown	NW4ofNW4	25-109-35	Landfill	7 – low	Approved	All factors low scoring
15	9/16/02	Nicollet	SW4ofSW4	19-111-27	New barns	12 – high	Approved	Med % clay, med water qual
16	2/3/03	Nicollet	NE4ofSW4	14-111-30	Expansion	10 - low	Approved	High % clay, good water qual

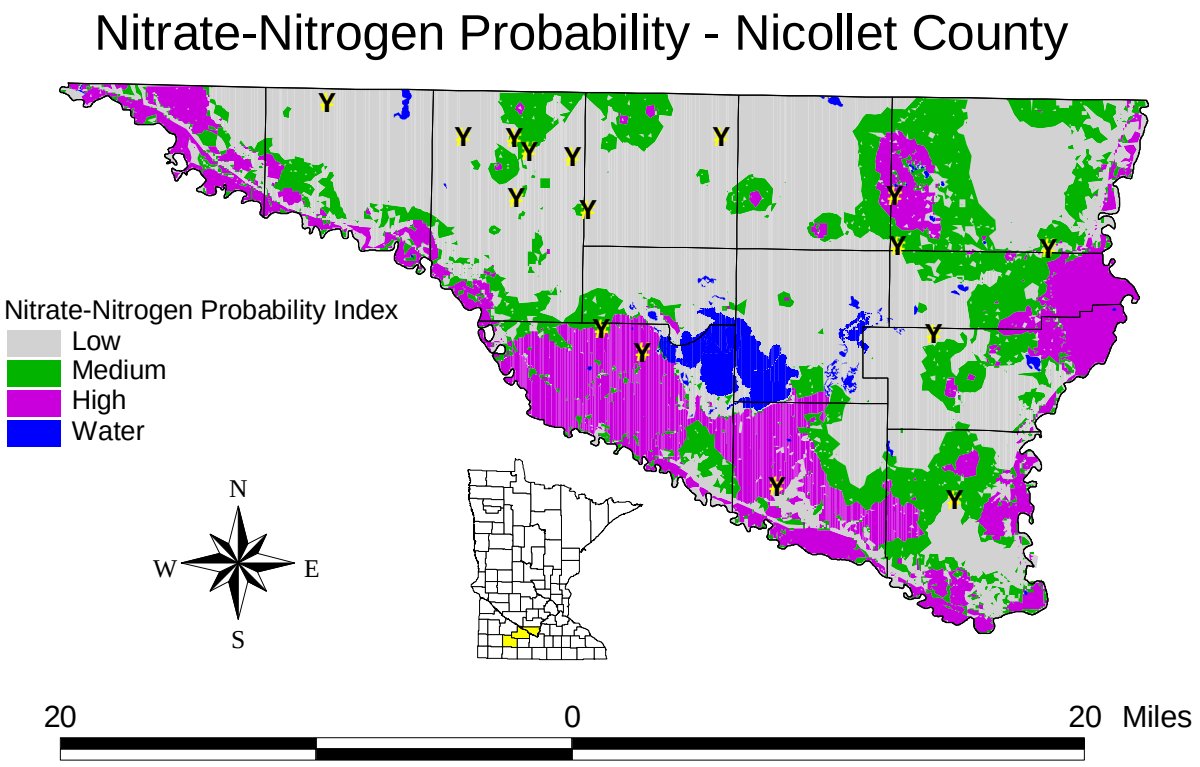
Applicant	Date of Hearing	County	Location	Section Township Range	Issue	Nitrate Score	Planning Decision	Comments
17	3/11/03	Brown	W2of SW4	27-109-34	Reduction	8 - low	Approved	High % clay, good water qual
18	4/8/03	Brown	NW2ofNE4	2-109-34	Expansion	12 – high	Approved	Good % clay, good water qual
19	4/21/03	Nicollet	NE4ofNW4	28-110-29	New feedlot	15 – high	Approved	Conditions added to permit
20	5/19/03	Nicollet	W2of SW4	31-111-27	Expansion	10 – low	Approved	High % clay, good water qual
21	5/19/03	Nicollet	NE4ofNW4	27-111-30	Expansion	10 – low	Approved	High % clay, good water qual
22	5/19/03	Nicollet	NE4of SE4	19-110-29	New feedlot	11 – med	Approved	Good % clay, good water qual
23	5/19/03	Nicollet	NW4of SW4	30-111-29	New feedlot	9 – low	Approved	High % clay, good water qual
24	6/20/03	Brown	SE4ofSW4	28-110-33	Expansion	11 – high	Approved	High % clay, med water qual
25	6/20/03	Brown	SE4ofNW4	14-108-30	Expansion	8 – low	Approved	High % clay, good water qual
26	7/21/03	Nicollet	SE4of SW4	12-111-29	New feedlot	10 – low	Approved	High % clay, good water qual
27	7/21/03	Nicollet	SW4ofNE4	20-109-28	Expansion	12 – high	Approved	Medium % clay, good water qual
28	8/11/03	Brown	SW4of NW4	36-108-32	Expansion	10 – med	Approved	Good % clay, good water qual
29	9/10/03	Nicollet	SW4	10-111-30	Expansion	11 – med	Approved	Good % clay, good water qual
30	10/14/03	Brown	NW4ofNE4	19-108-34	New feedlot	9 – low	Approved	Good % clay, good water qual
31	2/23/04	Nicollet	SW4	5-109-28	New feedlot	12 – high	Approved	Med % clay, good water qual
32	NA	Nicollet	NE4	19-109-29	New barn	12 - high	EAW	Shallow SWL, good water qual
33	4/13/04	Brown	NW4	4-108-35	New feedlot	11 – high	Approved	Good % clay, good water qual

Of the 33 use permit applications, 21 (63.6%) were located in low probability areas and 25 (75.7%) were located in low or medium probability areas. Eight (24.2%) of the use permit applications were located in high nitrate probability areas. Maps 4.1, 4.2 and 4.3 show the county nitrate probability maps with the use permits application locations.

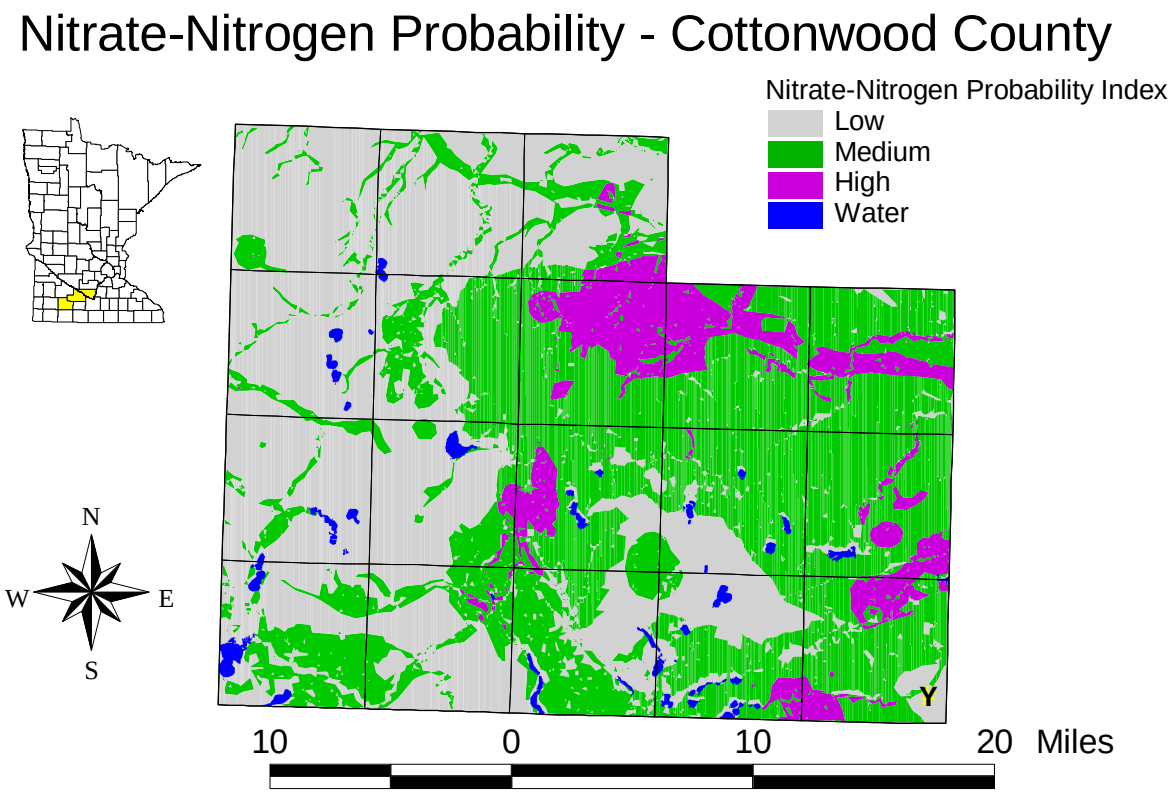
Map 4.1 Brown County probability map with permit locations.



Map 4.2 Nicollet County probability map with permit locations.



Map 4.3 Cottonwood County probability map with permit location.



5.0 Discussion and Conclusions

5.1 Use Permit Decisions

As Table 4.1 shows, only one use permit was approved with conditions added to protect and/or improve water quality. This use permit for a feedlot in Courtland Township was located in an area with little clay above the static water level, shallow depth to the static water level and historically high nitrate water quality results. The

combination of these factors indicated the area is particularly vulnerable to groundwater nitrate contamination. Therefore, the Planning and Zoning Commission chose to add the following conditions to the use permit:

1. Prior to the stocking of the barns, the applicant shall conduct a base line test of the existing nitrate level from the perimeter tile and continue the testing annually for 2 consecutive years, (2004 and 2005). Test results may require additional tests.
2. The applicant shall provide soils tests of the spreading acres within 1 year of the issuance of the conditional use permit. Test results may require amendment of the manure management plan.

These additions to the permit provide a greater degree of environmental safety and reduce the likelihood of an impact to groundwater. The conditions and the water quality concerns were explained to the applicant, and there were no protests to the conditions.

There were seven other use permit applications located in high probability areas in Nicollet and Brown Counties. These applications were all granted without additional conditions. The reason behind this was twofold. First, the Planning and Zoning Commissions carefully considered each of the factors contributing to the area's overall probability score. Planning officials gave more weight to the factors of percent clay and water quality. Four of the seven areas with high probability scores had 60% or greater clay content above the static water level. Five of the seven areas with high probability had historically low nitrates (0-3 mg/L). Therefore, it was judged by the planning officials that these areas were sufficiently protected by the standard use permit conditions and the geology and geochemistry of the area. This was not necessarily the goal of the project, as it is believed areas with high nitrate probability might require greater drinking water protection. Nevertheless, this is how the Planning and Zoning Commissions chose

to use the information. Second, counties have different standard conditions for use permits. For example, Nicollet County added the conditions of soil and water testing to the use permit in Courtland Township. However, testing of the perimeter tile around hog barns and annual soil testing is required as part of all manure management plans in Brown County. Therefore, though Brown County did not add any additional conditions to use permits, standard conditions for Brown County might already provide more drinking water protection than other counties. This is an important consideration when applying the probability maps to different counties. The procedures and standards of each county are different, thereby affecting the application of the tool.

The nitrate probability maps were applied only once to a Cottonwood County land use permit, as a result of different requirements for obtaining land use permits in the county. However, the one application of the project in Cottonwood County was unique as it was applied to the permit process of a subdivision development. The proposed subdivision was in an area with low probability for nitrate contamination, and was therefore approved with no additional conditions. However, the potential for adding conditions to subdivision proposals based on the probability maps exists. For example, the maps could be used to low probability areas for possible subdivision sites, identify areas to be avoided when siting water supply wells, or determine which water supply wells should be used for evaluating trend analysis of nitrate levels. The maps could also be used to develop recommendations for septic systems or water filtration systems in vulnerable communities.

5.2 Other Applications of Nitrate Probability Maps

5.2.1 Decision Justification

The obvious application of the nitrate probability maps to land use decisions is to determine if additional conditions are needed to protect the local groundwater source. However, another possible application could be to justify the granting of a use permit based on the probability of groundwater nitrate contamination. Local residents concerned with the effects a land use might have on the drinking water supply can be provided the nitrate probability information. In situations where the probability is low, the information could be used to justify granting a use permit and might abate concerns of other residents.

5.2.2 Wellhead Protection

The Wellhead Protection Program is a joint effort between communities and MDH to protect sources of drinking water and provide a safe water supply to residents relying on groundwater. Efforts to protect water quality include determining community water sources, identifying potential pollution sources and managing contaminant sources. Nitrate probability maps could be used to determine which community water sources are susceptible to contamination. This could then be used to manage development in a manner that protects or even improves water quality. MDH has developed a vulnerability ranking system for community water systems based on the probability of nitrate contamination. In Brown, Nicollet and Cottonwood Counties the Red Rock Rural Water System, the St. Peter Regional Treatment Center, the Minnesota Valley Lutheran School near New Ulm, the Immanuel Lutheran School and the cities of Jeffers, Nicollet and

Hanska are considered the most vulnerable community water supplies. Development around these areas and other communities should be managed with respect to the sensitivity of the drinking water supply.

5.2.3 Other Counties

The technical committee discussed the potential for nitrate probability maps to be used as a tool for land use decision making in other counties. The unique aspect of the probability maps for Brown, Nicollet and Cottonwood Counties is the extensive water quality database of over 3600 analyses collected over 16 years. As previously discussed, this data provides valuable geochemical information for the probability maps. At this time, Washington County is the only other county incorporating a water quality database into its probability maps. Nitrate probability maps without a water quality layer could still be a valuable tool for other counties in making land use decisions. The geologic and nitrogen input data available provide good information for the probability of nitrate contamination. The maps and contributing factors are relatively easy to understand and can provide what has been unaccessible information to land use decision makers. A water quality layer could be developed over several years of data collection and added to the probability maps as it becomes available.

5.3 Project Evaluation and Lessons Learned

Upon the conclusion of the project, Planning and Zoning Commission members were asked to complete a survey (Appendix 3) and provide their feedback on the usefulness of the nitrate probability maps as a tool for land use decision making. The

Planning and Zoning Commission for Cottonwood County was not surveyed because of member turnover and lack of application of the project in the county. The number of responses to the survey was low, but most of the feedback from the survey and informal conversations with planning members was positive regarding the project.

One common remark from the feedback was considering groundwater when making planning and zoning decisions represents a new way of thinking. As a result, it might take more time and familiarity with the maps before they are utilized to their full capacity. However, commission members did recognize the importance of protecting groundwater, and indicated that the probability maps were useful tools for doing so. One planning member commented the groundwater probability scoring could help provide justification for granting or denying a permit in the event of a lawsuit.

Brown and Nicollet Counties seemed to split on the form of information that was most useful. Brown County appreciated the visual representation provided by the maps, whereas Nicollet County relied more on the written narratives explaining each factor. Planning members did consider each factor separately rather than relying on the overall probability score.

One planning member suggested using the information to develop maps identifying “good” and “bad” areas to locate feedlots. This information could then be made readily available to the public in an effort to avoid locating feedlots in vulnerable areas.

One concern commonly expressed was whether the maps would continue to be used following the project sunset. Because the maps are user friendly and the information is readily available, planning and zoning staff should be able to continue providing the

probability information relatively easily. It is hoped that this information will be used by future county staff and that this approach will be transferred to staff in other counties.

5.4 Future of Groundwater Zoning Project

Another round of county water testing was completed in May of 2004 for the three counties. This data will be incorporated into the existing databases and the probability maps for each county will be updated. Updated nitrate probability maps and information will be turned over to planning and zoning staff for each county where it will continue to be used as a tool for land use decisions.

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Appendix 1 Project summary poster

Groundwater Vulnerability Zoning Pilot Project

Groundwater Nitrate Contamination Probability

What is the Groundwater Project?

The Groundwater Project is a collaborative effort between several Minnesota state and county agencies to map the probability of nitrate-nitrogen contamination of groundwater in Brown, Nicollet and Cottonwood Counties. Elevated nitrate-nitrogen levels have been linked to a serious medical condition called blue baby syndrome. Other studies indicate a link between elevated nitrate and cancer and spontaneous abortions. However, MDH does not support this link without additional data to adequately document a connection. Groundwater is the primary source of drinking water in Brown, Nicollet and Cottonwood Counties. It is essential to protect the quality of this resource.

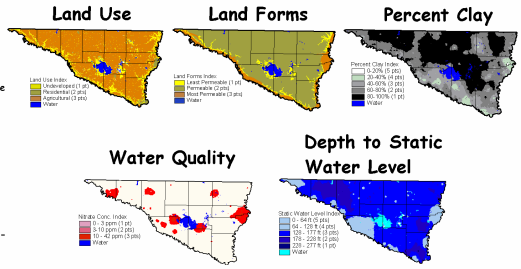
Where does the data come from?

The Nitrate Probability maps are based on extensive data bases.The County Well Indices for the three counties provide data on percent clay above the static water level, depth to bedrock and depth to the static water level. Ten thousand analyses of nearly 3000 wells were performed for nitrate-nitrogen concentration by Brown-Nicollet Environmental Health Services, providing the water quality data base.The land use data base is based on 1988-1990 aerial photography and the land forms data base was provided by the Minnesota Geological Survey.

How are the maps created?

Several factors determine the susceptibility of an area to groundwater nitrate contamination. Geological, geochemical and land use factors can all affect nitrate probability to varying degrees. For these maps, land use, surface permeability (land forms), percent clay above the static water level, depth to bedrock, water quality and depth to static water level were each divided into different categories with each category assigned a different point value. For example, the land use factor is divided into three categories with Undeveloped receiving 1 point, Residential or Commercial receiving 2 points and Agriculture receiving 3 points. Higher point totals represent an increased probability for nitrate contamination. The factors are then layered over each other, and an area's point total determines its nitrate contamination probability. The large three county map above shows the nitrate probability results with purple representing high, green representing medium and gray representing low probability. About 70% of the wells in the three counties with nitrate concentrations above the drinking water standard of 10 ppm are located in the purple areas, but less than 15% of the wells in the purple areas actually have nitrates above 10 ppm. Good water quality, with respect to nitrate, can usually be found by drilling a deeper well.

BNC
Water Quality Board



How are the maps used?

The Nitrate Probability maps are tools used by Planning and Zoning staff to identify areas that have a high likelihood for nitrate-nitrogen groundwater contamination. Sites for permit applications such as subdivisions and dairy or hog operations can be located on the probability maps to determine the risk of groundwater contamination. The maps are not used to deny permits, but rather to identify vulnerable areas so that appropriate conditions can be added to protect water quality.This process also educates permit applicants about the conditions that contribute to nitrate-nitrogen contamination. The maps have been applied to dozens of permit applications as shown on the large Nitrate Probability map. Future uses of the maps might include targeting areas for wellhead protection programs and identifying areas that might be susceptible to other contaminants. A high quality drinking water supply should be everyone's goal, and Nitrate Probability mapping can help us achieve it.

Project funding provided by the Minnesota Pollution Control Agency through the Federal 319 Program

For more information call 507-934-4140

Appendix 2 Example of narrative provided to planning and zoning commissions.

Narrative of Mapping Results for Landowner's Conditional Use Permit

Applicant's name
Location: NE4 of the NW4
28-110-29
Courtland Township

Aerial Photo Map: Indicates approximate location of proposed barns.

Land Use Map: Proposed site is located in agricultural area resulting in a score of 3 points for the Land Use index.

Percent Clay Map: Percent clay is an index of the permeability of the sub-surface geology. Areas with high percent clay are less susceptible to groundwater nitrate contamination. Proposed site is located in an area with 80-100% clay above the static water level. Therefore, the proposed site receives 1 point for the Percent Clay index.

Landforms Map: Landforms is an index of the permeability of the surface geology of a location. Areas with low surface permeability are less susceptible to groundwater nitrate contamination. The proposed site is in an area of low surface permeability. Therefore, the proposed site receives 1 point for the Landforms index.

Depth to Static Water Level Map: Depth to static water level is an index of the depth to the top of the water column in a well. Greater depth to the static water level means a lower probability for groundwater nitrate contamination. The proposed site is located in an area with static water levels ranging between 178-228 feet. Therefore, the proposed site receives a score of 2 points for the Depth to Static Water Level index.

Nitrate Testing Map: Nitrate testing is an index of the water quality of a location based on actual well test results. The proposed site is located in an area with nitrate well test results in the range of 0-3 mg/L. Therefore, the proposed site receives a score of 1 point for the Nitrate Testing index.

Nitrate Probability Map: Nitrate probability is an index of the overall probability of groundwater nitrate contamination. High total scores indicate a high probability for groundwater contamination. The proposed site has a total score of 8 points. Therefore, the location has a low probability for groundwater nitrate contamination.

Appendix 3 Planning and Zoning Commission Survey

1. Was the purpose of the Groundwater Vulnerability Project clear? What improvements could have been made to the background information provided?
2. Were materials provided for individual zoning decisions easily understandable? Please give your comments on the vulnerability maps and narratives provided for each case. Did you rely more on the maps, narratives or overall score? Please explain.
3. Do you think the groundwater vulnerability scoring is a valuable tool? Is it worth continuing under the direction of the County Planning and Zoning staff?
4. Were any of your zoning decisions influenced by the groundwater vulnerability scores? Did you feel the vulnerability information helped to justify any of your zoning decisions? Please explain.
5. Can you envision other uses for the groundwater information (establishing wellhead protections areas, identifying areas vulnerable to other contaminants, etc.)?
6. One of the major goals of the project was to develop a groundwater protection tool. How effective do you think the vulnerability maps are as a tool for groundwater protection? What improvements would you like to see made?
7. Other Comments.

Appendix 4 Budget

Ground Water Vulnerability

Jan-April 2004	Cash				InKind			
	Budget	Quarterly Expense	YTD Expense	Balance	Budget	Expend 2003	YTD Expenses	Balance
Program Element 1								
1 - Database, maps, locations								
Labor	7080.00		7431.25	-351.25	1750.00		10750.00	-9000.00
2 - Criteria & Data inputs								
Labor	980.00		981.25	-1.25	1750.00		1677.50	72.50
3 - Educational Materials								
Labor	3320.00		2818.75	501.25	4500.00		4618.75	-118.75
4 - Final Workplan								
Labor					1000.00		2987.50	-1987.50
5 - Vuln Maps & Interpretations								
Labor	425.00		593.75	-168.75	4500.00		6731.25	-2231.25
6 - TIP Training & Prel. work								
Labor	2205.00		1118.75	1086.25	2000.00			2000.00
7 - Township Maps								
Labor	500.00			500.00	1500.00		1500.00	0.00
8 - Work with Counties								
Labor	1450.00		1462.50	-12.50	1000.00		2037.50	-1037.50

9 - Develop Procedures								
Labor	800.00		412.50	387.50	1000.00			1000.00
Overall Costs								
Travel	700.00		626.64	73.36				
Equipment	3650.00		3649.47	0.53	3000.00		3000.00	0.00
Supplies	3800.00		3823.97	-23.97				
Fiscal Management	2850.00		5699.90	-2849.90				
Phone/Internet	205.00		205.00	0.00				
Utitilites	115.00		114.58	0.42				
Insurance	50.00		50.00	0.00				
Rent					300.00		300.00	0.00
Subtotal Program Element 1	**$28,130.00**	**$0.00**	**$28,988.31**	**($858.31)**	**$22,300.00**	**$0.00**	**$33,602.50**	**($11,302.50)**
Program Element 2								
1 - Consult with Counties								
Labor	3000.00		1687.50	1312.50	3000.00		1987.50	1012.50
2 - Produce Materials								
Labor	7000.00		8521.75	-1521.75	1000.00		11387.50	-10387.50
3 - Explain Materials								
Labor	3000.00		1168.75	1831.25	8000.00		9300.00	-1300.00
4 - Assist with Cases								
Labor	3000.00	575.00	3693.75	-693.75	15000.00			15000.00

Overall Costs								
Travel	900.00		331.44	568.56				
Equipment	3000.00		3002.75	-2.75	1000.00		1000.00	0.00
Supplies	1500.00		2319.35	-819.35				
Fiscal Management	6450.00		5270.45	1179.55				
Prof/Technical	500.00		290.00	210.00				
Phone/Internet	420.00		447.71	-27.71				
Utitilites	300.00		265.99	34.01				
Insurance	200.00			200.00				
Rent					1200.00		1200.00	0.00
Total Program Element 2	**$29,270.00**	**$575.00**	**$26,999.44**	**$2,270.56**	**$29,200.00**	**$0.00**	**$24,875.00**	**$4,325.00**
Program Element 3								
1 - Survey & Interview								
Labor	1370.00	475.00	1125.00	245.00	2250.00			2250.00
2 - Examine Decisions								
Labor	1000.00		456.25	543.75	2250.00			2250.00
3 - Determine next steps								
Labor	500.00		1231.25	-731.25	1000.00		687.50	312.50
4 - Determine other Areas								
Labor	500.00			500.00	500.00			500.00
5 - Present Overviews								
Labor	2000.00		1987.50	12.50	500.00		1750.00	-1250.00

6 - Final Report								
Labor	2000.00		2812.50	-812.50	1200.00	131.25	1611.25	-411.25
Overall Costs								
Travel	2000.00		1648.47	351.53				
Supplies	1000.00		2615.35	-1615.35				
Fiscal Management	6250.00		4641.62	1608.38				
Prof/Technical	460.00		1440.00	-980.00				
Phone/Internet	200.00		350.01	-150.01				
Utitilites	220.00		345.13	-125.13				
Insurance	100.00		910.59	-810.59				
Equipment					500.00	250.00	750.00	-250.00
Rent					500.00	250.00	750.00	-250.00
Total Program Element 3	**$17,600.00**	**$475.00**	**$19,563.67**	**($1,963.67)**	**$8,700.00**	**$631.25**	**$5,548.75**	**$3,151.25**
Program Element 1	28130.00	0.00	28988.31	-858.31	22300.00		33602.50	-11302.50
Program Element 2	29270.00	575.00	26999.44	2270.56	29200.00		24875.00	4325.00
Program Element 3	17600.00	475.00	19563.67	-1963.67	8700.00	631.25	5548.75	3151.25
Totals	**$75,000.00**	**$1,050.00**	**$75,551.42**	**($551.42)**	**60200.00**	**631.25**	**$64,026.25**	**-3826.25**

MDH Funding	$15,000.00
PCA Funding	$60,000.00

	Labor	Travel	Equipment	Supplies	Fiscal	Phone	Utilies	Insurance	Prof.Tech	
Program Element 1		73.36	0.53	-23.97	-2849.90	0.00	0.42	0.00		
1 - Database, maps, locations	-351.25									
2 - Criteria & Data inputs	-1.25									
3 - Ed materials	501.25									
4 - Final Workplan	0.00									
5 - Vuln. maps & Interpretation	-168.75									
6 - TIPS Training - Prel. work	1086.25									
7 - Township Maps	500.00									
8 - Work with counties	-12.50									
9 - Develop Procedures	387.50									
Program Element 2		568.56	-2.75	-819.35	1179.55	-27.71	34.01	200.00	210.00	
1 - Consult with Co.	1312.50									
2 - Produce Materials	-1521.75									
3 - Explain materials	1831.25									
4 - Assist with Cases	-693.75									
Program Element 3		351.53	0.00	-1615.35	1608.38	-150.01	-125.13	-810.59	-980.00	
1 - Survey & Interview	245.00									
2 - Examine Decisions	543.75									
3 - Determine next step	-731.25									
4 - Determin other areas	500.00									
5 - Present Overviews	12.50									
6 - Final Report	-812.50									
	2627.00	**993.45**	**-2.22**	**-2458.67**	**-61.97**	**-177.72**	**-90.70**	**-610.59**	**-770.00**	**-551.42**