DRAFT FOR DISCUSSION

Proposal for

Hydrogeologic Atlas of Green County, Wisconsin

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Submitted to

Green County Land and Water Conservation Committee

February, 2016

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Introduction
Green County, Wisconsin, has some of the most prolific groundwater resources in Wisconsin. Permeable geologic formations that provide and store groundwater are called "aquifers". In Green County, the limestone and sandstone aquifers are thousands of feet thick. This can provide exceptional resilience to drought for public water supply, industrial and livestock use, and irrigated agriculture. The groundwater aquifer in Green County can be thought of as a large, subsurface reservoir naturally full of water.

The County's groundwater resources can be the basis for a strong local economy. With sufficient planning for the location and depths of wells, the groundwater supply can support high water-use industries, such as food and beverage production and processing, irrigated agriculture, and livestock operations.

However, Green County hosts some of the most vulnerable groundwater resources in Wisconsin. In areas where bedrock formations are close to the land surface, overlain by just a few feet of soil, contaminants applied at the land surface readily pollute groundwater. This isn't conjecture— based on data provided UW Stevens Point and summarized in Appendix 1, 70% of 2,662 well water samples collected in the county exceed naturally occurring nitrate concentrations (exceed 2 parts per million, ppm). Sixteen percent of the samples exceed the federal and state health-based nitrate standard, 10 ppm. Groundwater with high nitrate is often associated with other contaminants, such as bacteria or breakdown products of herbicides. In addition to the health risk posed to those who drink this water, poor groundwater quality has implications for County property values; a safe drinking water supply is part of the value of a home.

The purpose of this proposed project is to provide an inventory and analysis of groundwater conditions. The maps and report will provide local officials, residents and agricultural enterprises with a data-driven technical basis for land-use planning and management decisions, and to implement and monitor land use practices.

This study alone will not improve or protect water quality in the County. This project will provide information to help natural resource managers accomplish that challenging task. The products of the study can inform conservation plans and identify areas most in need of oversight to ensure adequate planning and implementation of conservation practices. Ultimately, residents, local officials, businesses, water utilites, agricultural enterprises, and engineering consultants can improve practices that affect groundwater quality and quantity.

The project proposed here was designed following several meetings with the Land and Water Conservation Committee and staff members. County UW Extension staff, GIS Specialist Derrick Frese, and Health Department staff also participated in project planning.

Project scope

This project includes extensive collaboration with staff of the Land & Water Conservation office Green County GIS Specialists. Tasks 1 and 7 would be completed largely by them, as described below.

1. Well database

Basic data on geology and groundwater are available from well construction report databases maintained by the WGNHS and the WDNR. These reports are completed for all water wells drilled in Wisconsin since 1936. They contain information about the well location; depth of well and casing, liner, or screen; geologic materials observed by the driller; and water level and pumping test data. Records from 1936–1989 are available as scanned images, and wells drilled since 1988 are contained in a database of electronic records.

Green County Land and Water Conservation staff have improved this set of records by performing a site inspection of new wells. Mr. Frese has offered to lead an effort to expand this well database by importing well records created prior to the County's exiting data set. He has proposed to use an address matching technique to improve the location accuracy of each record, and to verify that other data fields are imported correctly.

Use of existing well construction records is the most cost effective way to provide data for this project. The success of the project will depend in part on the number and geographic distribution of records in the database. WGNHS GIS staff plan to coordinate directly with Mr. Frese so that his efforts results in data format and accuracy necessary for use by our geologists and hydrogeologists.

The budget for this project does not include cost associated with the County's preparation of the well construction dataset. This is an area identified by the WGNHS, as directed by the Land and Water Conservation Committee, that county staff are qualifed to complete. The WGNHS will consult with Mr. Frese at his discretion, about the GIS methods and results.

2. Depth to bedrock map

This map will show depth to the top of bedrock formations across Green County. Depth to bedrock is a key factor in determining areas where groundwater is most susceptible to surficial contamination because thick deposits of soil, clay or silt can significantly slow down transport of contaminants to the water table. In areas where soil and other unconsolidated material is thin, precipitation and snow melt rapidly infiltrate through fractures and solution openings in the bedrock. A professional geologist makes, or supervises the making of, this type of map.

There is an existing state-wide depth to bedrock map (Appendix 2) which allows comparison of conditions in Green County to other parts of Wisconsin. The state-wide map can serve as a starting point, but it does not have sufficient detail for use in this project. It has 50- and 100-foot contour intervals. A county map would provide a contour interval of 20 feet or less, depending on the available data density. Accuracy would be within about 170 feet, as typical on a 1:100,000 scale map. The statewide map is produced at a scale of 1:1,000,000, with an accuracy of about 1,670 feet.

The WGNHS will use the well database and county soil map as data sources. The WGNHS will also collect new data where necessary to improve resolution of the depth to bedrock map. The budget provides up to three weeks time for new data collection. Appendix 3 describes the equipment and methods that may be used.

3. Water table elevation map

The water table is the top of the saturated zone, where all pore space and fractures are completely filled with groundwater. Under some hydrogeologic conditions, the water table is the same elevation as the water level in a well. Some well records are useful for identifying the water table elevation, but this depends on the depth of the well and casing. A professional hydrogeologist makes, or supervises the making of, this type of map, using well record data and elevations of streams, lakes, and springs. Topographic maps are also used to develop this map.

A water table map is used to identify the direction of shallow groundwater flow. The map allows one to easily understand and communicate which wells, streams, or lakes are hydrogeologically downgradient or upgradient of an area on the land surface. This map illustrates which wells can be affected by near-by spectic systems, landfills, underground gas storage tanks, manure storage facilites and fertilized fields.

A water table map is important in determining where groundwater is most susceptible to surficial contamination. Transport from the land surface to the water table is slower where the depth to groundwater is greater. Where the water table is close to land surface, contaminants can migrate quickly and have little opportunity to degrade in overlying soil or rock.

4. Bedrock type

This map will show the type of uppermost bedrock across Green County. This information is an important part of undertstanding groundwater susceptibility to surficial contamination. Dolomite and limestone are two types of bedrock easily dissolved by groundwater. The process of groundwater dissolving rock to form fractures and dissolution openings, referred to as “Karst” landforms, formed the Cave of the Mounds near Mt. Horeb.

The map of bedrock type is based on information in well records and, where necessary to check or improve upon this interpretation, a professional geologist looks for outcrops or small exposures along streams and roadways. The existing state-wide geologic map (Appendix 2) shows that Green County’s bedrock is similar to other counties to the southwest and northeast. The state-wide map has a scale of 1:1,000,000 with an accuracy of about 1,670 feet. County maps are produced at a scale of 1:100,000 with accuracy on the order of 170 feet. The state-wide map is a good starting point but does not have sufficient detail for use in this project.

5. Groundwater recharge

The spatial distribution of groundwater recharge rates across Green County is of interest to determine how much rainfall and snowmelt infiltrate to the water table in a typical year compared to rainy and dry years. In addition to weather, recharge varies because of differences in land use (for example, row crops compared to forest), soil, and land surface slope. Areas of high recharge tend to be more susceptible to groundwater contamination.

At the WGNHS, GIS staff work with professional hydrogeologists to apply a computer model (referred to as the soil water balance, or SWB) to estimate recharge. Although there is no state-wide recharge map, many counties have worked with the WGNHS to complete this analysis (Washington, Ozaukee, Kenosha. Racine, Milwaukee. Walworth, Waukesha, Menominee, Shawano, Waupaca, Waushara, Chippewa, Dane, Iowa, and Columbia). The method and results are described here: https://wgnhs.uwex.edu/pubs/download_b107/

6. Groundwater contaminant susceptbility map

This map integrates items 2 through 5 into a single map to illustrate the relative susceptibility of groundwater across the County. Those interested in conservation practices to preserve or improve groundwater quality can use this map to prioritize their efforts. A susceptibility map provides a technical basis to determine areas of the county where additional preventative measures, safeguards, or additional monitoring systems are useful.

At the WGNHS, professional hydrogeolgists and GIS staff develop a GIS-based model that combines depth to groundwater, recharge rates, bedrock type and depth to bedrock. The method used to estimate susceptibility is unique to each region of Wisconsin because geologic and hydrogeologic conditions vary regionally. This is why we recommend the County invest in this product rather than use the existing statewide susceptibility map, which is useful for broad comparison to other parts of the state but was not designed for local scale use (Appendix 2). The state-wide map is at a 1:1,000,000 scale. County maps are produced at a scale of 1:100,000 with accuracy on the order of 170 feet.

7. Karst landform map—to be produced by Green County

This map will identify areas of likely closed depressions where surface water runoff drains internally, rather than discharging to a ditch or stream. Closed depressions may indicate sinkholes or fractures that are preferential pathways for fast draingage of surface water. Closed depressions are typically found where dolomite or limestone form the uppermost bedrock.

Staff at the WGNHS have developed a method using LiDAR data and historical aerial photographs to identify areas with close depressions. The method can be used by Mr. Frese, in consultation with WGNHS staff, to make this map. A map identifying closed depressions can be used to alert Land and Water staff to areas of potential Karst. The County Conservationist may wish to consult with land owners to raise awareness of these features, and work to guide surface drainage away from these features.

The budget and publications presented in this proposal do not include production of the map of closed depressions. Production of this is fully within the qualifications of county staff. The WGNHS will consult with Mr. Frese at his discretion to provide input on the GIS approach and results. The WGNHS maintains a database of caves and fissures in Green County that it will provide to Mr. Frese, or any County staff, to include in the closed depression landform map.

Project deliverables

Maps 2- 6 will be published at the end of this project, along with a brief report describing the hydrogeologic setting in Green County and methods used to make the maps. Final draft versions of the maps will be provided to the County about six months earlier, in July 2018.

A report with maps (PDF format) and digital files (maps and data contained in a ArcGIS geodatabase and shapefiles) will be made available electronically in December, 2018. Up to 30 paper copies of the maps and reports will be delivered to the Land And Water Conservation Department. Electronic files will be provided for free from the WGNHS website. Additional printed copies of the materials can be printed and mailed for a nominal fee. All materials will be edited and peer-reviewed in accordance with requirements for publication by the WGNHS. Peer-review is necessary to ensure that a high quality of technical work is maintained throughout the project and in the final publication.

Project schedule

WGNHS staff would be available to begin this work in the summer of 2016, as Mr. Frese completes the well record database. The work to develop items 2 -6 will begin in September 2016, as described in Table 1.

Table 1. Project schedule

Activity	Start	End	Comment
Well database	Spring, 2016	Fall 2016	Green County determines work flow
Map development and field surveys	September, 2016	June, 2018	WGNHS meets with County every 4 to 6 months to review project progress
Review, revise, publish maps and report	July, 2018	December, 2018	County Committee and staff provide review and comment

Notes:

WGNHS can begin work following significant progress towards completing the well database

Map 7 can be completed by Green County independently of the schedule for other work

Estimated Project Cost

The WGNHS will provide $28,093 of in-kind salary for the lead hydrogeologist, which will reduce the cost to Green County from $133,560 to $105,467, as itemized below. The project cost can be billed to the County over three calendar years.

Itemized project costs:

Sponsor: **Green County**
Project Title: **Hydrogeologic Atlas of Green County**
Project Period: Begin: **09/01/16**
End: **12/30/18**

	Year 1	Year 2	Year 3	Cumulative
Salaries & Wages	$29,881	$17,291	$6518	$53,690
Fringe Benefits	$10,844	$5,865	$3239	$18,697
Supplies	$500	$600	$300	$1,400
Travel	$408	$408	$204	$1,020
Tuition remission	$12,000	$6,000	$0	$18,000
Direct Costs	$53,633	$29,544	$9,630	$92,807
Modified Total Direct Costs (MTDC)	$41,633	$24,164	$10,261	$74,807
Indirect Costs (15.00% of MTDC)	$6,245	$3,531	$1,444	$11,221
Total Costs	$59, 878	$33,789	$11,800	**$105,467**

Note:
Tuition remission is required when hiring a graduate student assistant. Such assistants hold a bachelor's degree in geology and are pursuing graduate studies in hydrogeology, geology or engineering.

Travel costs from Madison to Green County are estimated for 20 days of field work and project meetings.

Appendix 1
Nitrate-impacted private water wells in Wisconsin

The Center for Watershed Science and Education, at UW Stevens Point, provides public access to data on water quality at private, residential water wells in Wisconsin:
http://www.uwsp.edu/cnr-ap/watershed/Pages/WellWaterViewer.aspx
These data reflect voluntarily submitted well water samples from homeowners and other well water data collected by state agencies. Samples were collected over 25 years, and water quality can change over time. However, many recent studies indicate that nitrate concentrations in groundwater in Wisconsin are not declining. Green County has sponsored well water sampling programs, and this has resulted in a large number of data in the County, as shown in these figures.

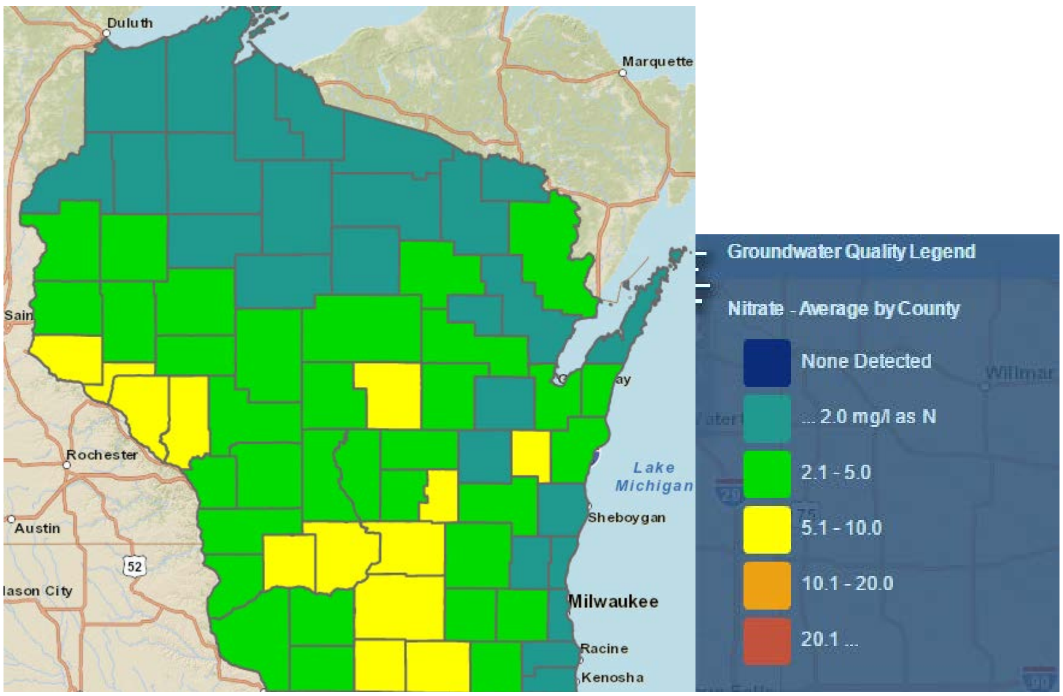


Figure 1-1. Average nitrate concentration in well water in Wisconsin's counties.

Nitrate (mg/l as N) for Green County

Range	Number	Percent	Summary
None Detected	194	7%	Minimum: No Detect
... 2.0	622	23%	
2.1 - 5.0	724	27%	Median: 4.1
5.1 - 10.0	694	26%	Average: 5.61288
10.1 - 20.0	364	14%	
20.1 ...	64	2%	Maximum: 69.9
Total	2662		
> 10mg/l N	428	16%	Exceeds Health Standard

Figure 1-2. There are 2,662 samples collected in Green County.

Appendix 2
Published statewide maps

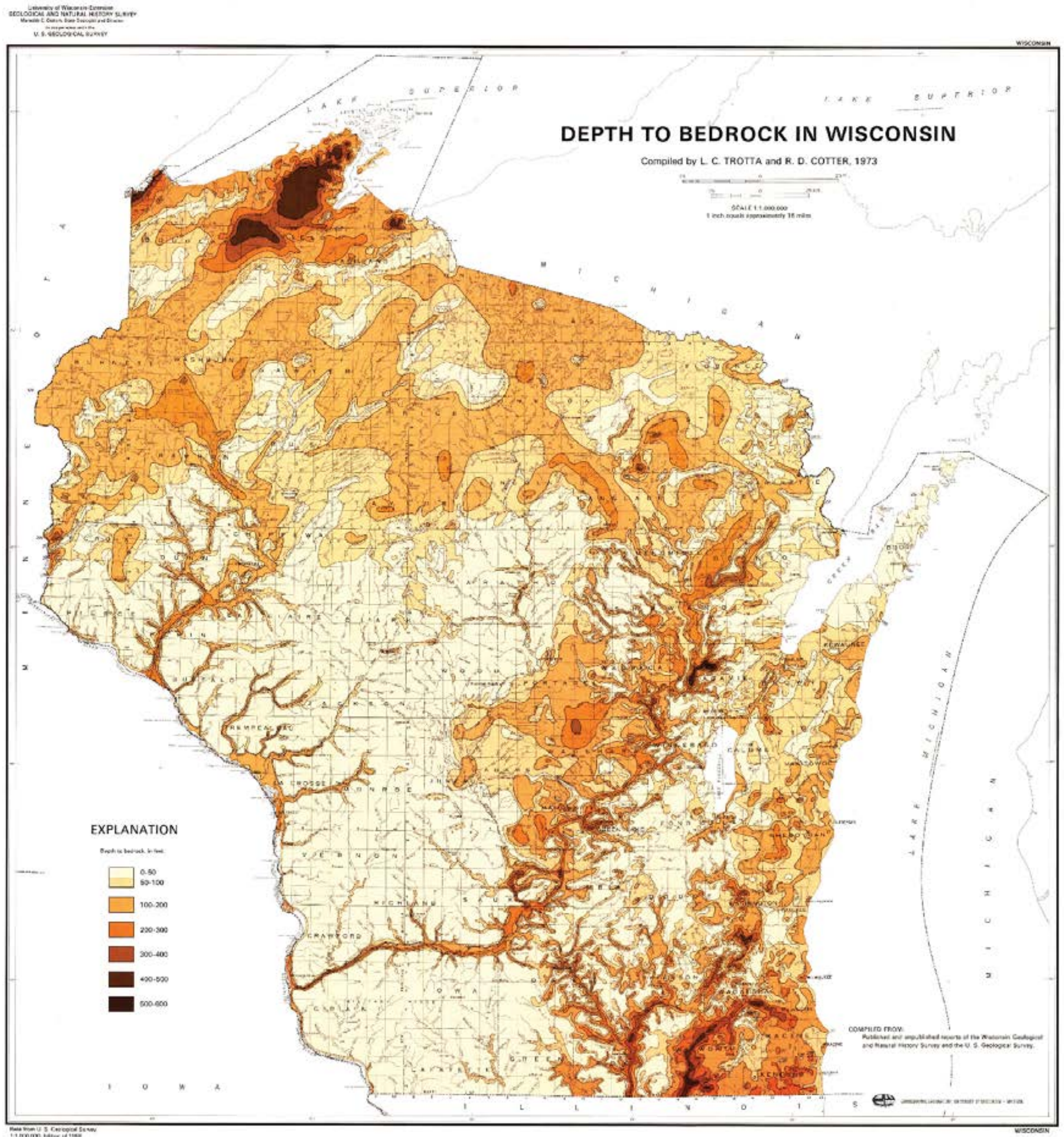


Figure 2-1. Map of depth to bedrock in Wisconsin, contour intervals are 0- 50 feet, 50-100 feet, and 100 foot-intervals at greater depths.

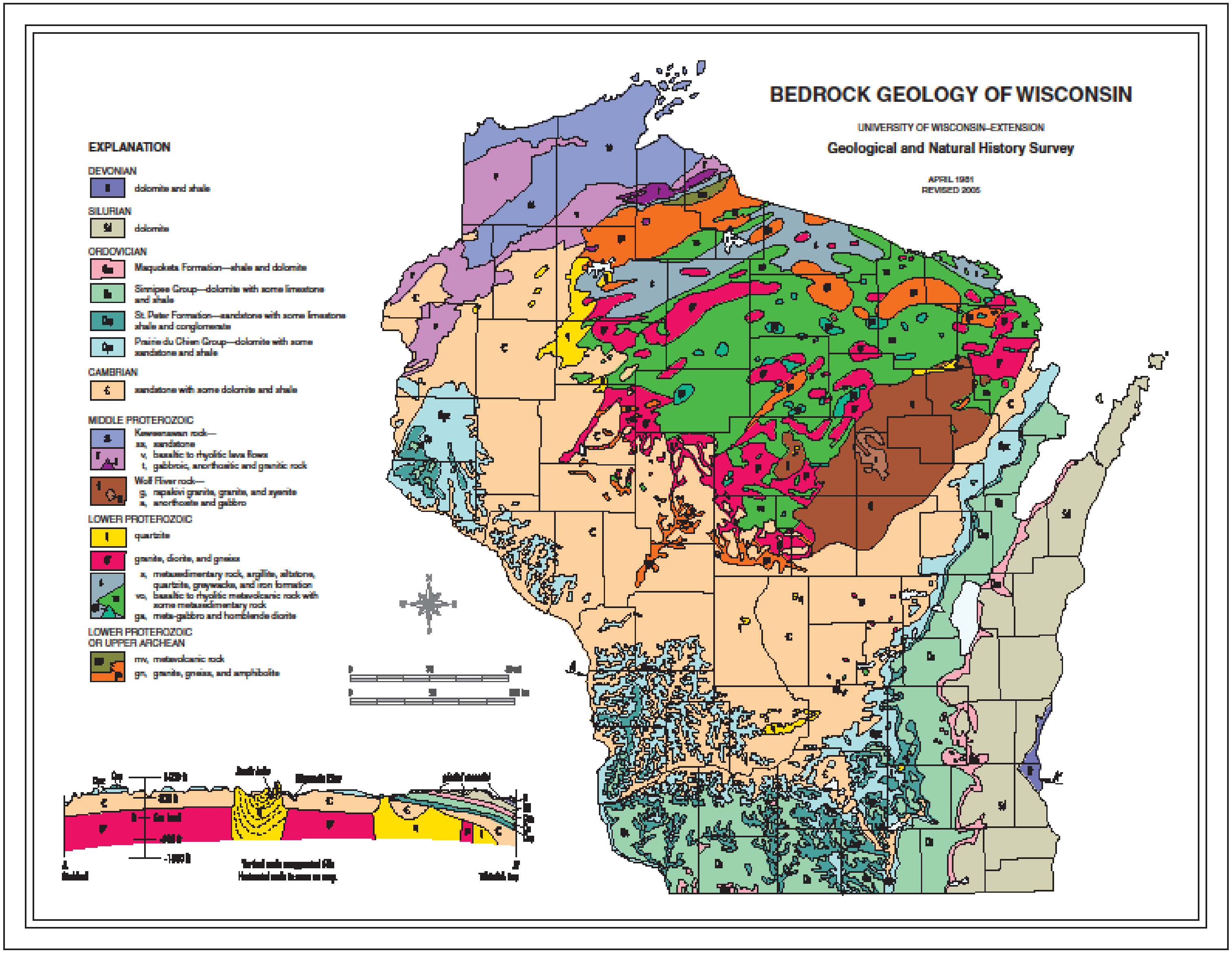
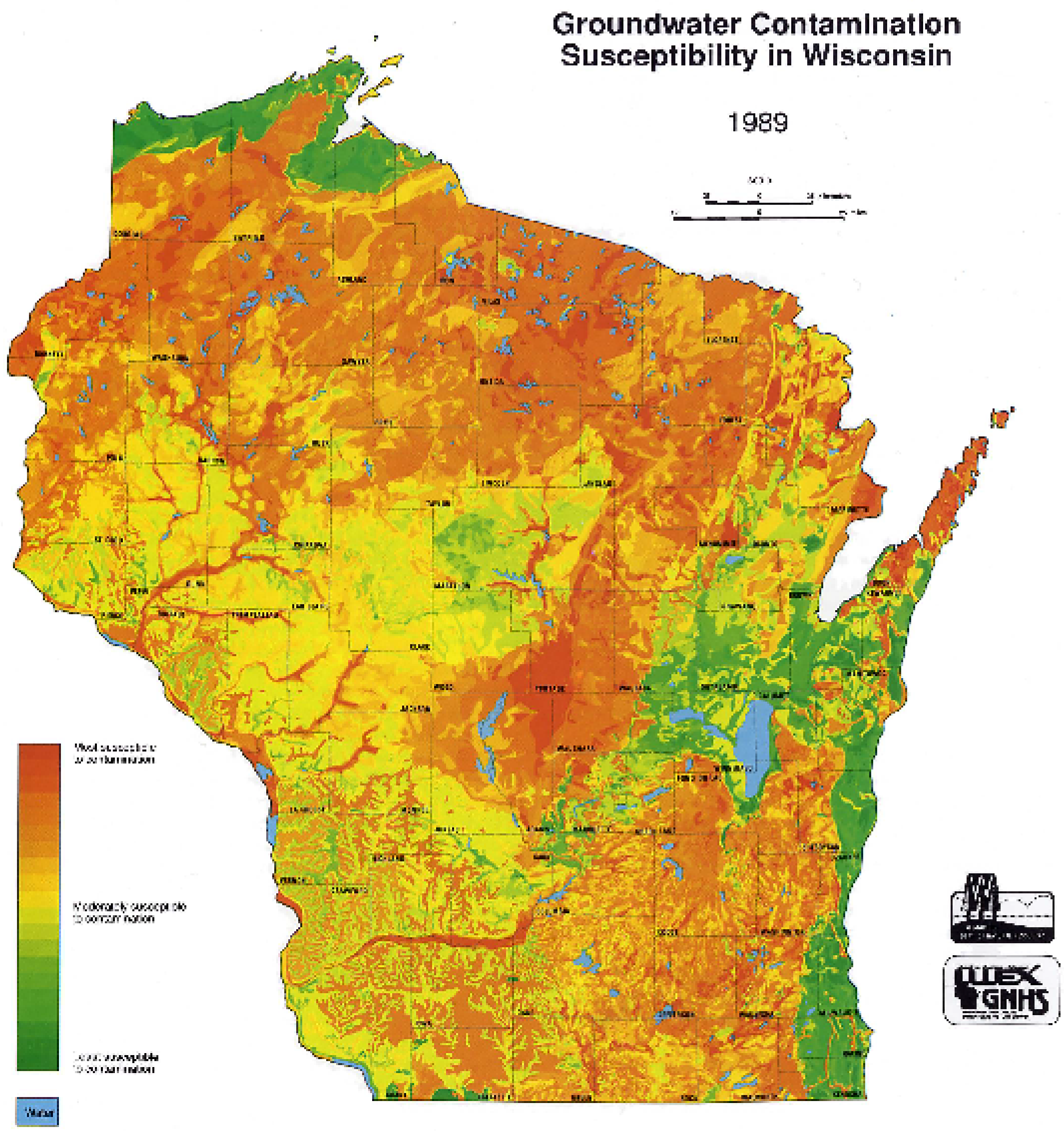


Figure 2-2. Bedrock type across Wisconsin, mapped at 1 to 1,000,000 scale.



This map of groundwater contamination susceptibility in Wisconsin was reduced from an original 1:1,000,000-scale map. This page-size map has been published for general information and educational purposes only and should not be used for making planning or management decisions.

This map does not show areas that **will be contaminated**, or areas that **cannot be contaminated**. Whether an area will have groundwater contamination depends on the likelihood of contaminant release, the type of contaminants released, and the sensitivity of the area to contamination. In turn, the likelihood of contaminant release depends on the type and intensity of land use and contaminant sources in an area. This map highlights areas sensitive to contamination and shows them in a generalized way. It does not consider the individual characteristics of specific contaminants or the subsurface release of contaminants; that is, it only considers the ability of water to move from the land surface to the water table.

Figure 2-3. Statewide groundwater susceptibility map useful to compare conditions across Wisconsin, mapped at 1 to 1,000,000 scale.

Appendix 3

Measuring the depth to bedrock formations

In areas where there is insufficient water well data, geophysical methods can be used to estimate the depth to bedrock. These methods are less expensive and faster than drilling or auguring boreholes.

The Horizontal-to-Vertical Spectral Ratio Passive Seismic Method (HVSR or Passive Seismic) (Figure 1) records the timing of vibrations bouncing from the land surface through near subsurface geologic materials. Ambient ground vibrations occur due to movement of objects at the ground surface penetrating down into the earth, such as the roots of a tree vibrating as the tree blows in the wind. Data collection at each location takes up to 20 minutes, depending on ambient ground vibrations and the type of underlying sediment. A Minnesota Geological Survey report describes this method in detail: http://conservancy.umn.edu/handle/11299/162792

Ground Penetrating Radar (GPR) is another method useful for estimating depth to bedrock. GPR images the subsurface, and consists of an antenna, transmitter and recorder. The GPR is towed behind a slowly-moving truck or dragged overland by foot. Ambient ground vibrations occur due to movement of objects at the ground surface penetrating down into the earth, such as the roots of a tree vibrating as the tree blows in the wind. The GPR records these waves as they bounce off underlying sediments and rock. A 80 MHz antenna can be towed by truck or pulled by foot on lightly travelled dirt roads, open fields, or grasslands. A smaller 500 MHz antenna is pulled by foot and can be used close to buildings or in fields between rows of corn.

These methods are used only in after obtaining permission from landowners.

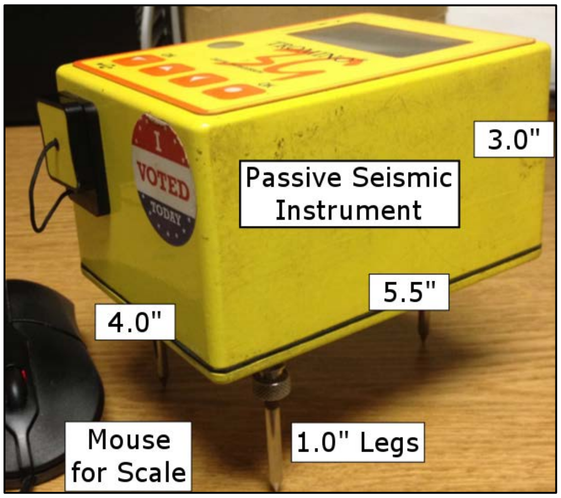


Figure 3-1. The Passive Seismic instrument shown in the field (left) and up close (right). The three 1-inch metal legs are inserted into the ground to record ambient ground vibrations. A computer mouse is shown for scale next to the instrument.