Wisconsin Geological
and Natural History Survey
DIVISION OF EXTENSION
UNIVERSITY OF WISCONSIN–MADISON

Evaluation of observation wells used in the Hydrograph Procedure (SPS 385.60(4)) and depth-to-water in parts of Adams, Juneau, Portage, Waushara, Wood, and Marquette counties

July 25, 2025

Susan K. Swanson, G.E. Graham

Wisconsin Geological and Natural History Survey

Division of Extension

University of Wisconsin-Madison

Final Report to the State of Wisconsin

Department of Safety and Professional Services

The University of Wisconsin–Madison Division of Extension provides equal opportunities in employment and programming in compliance with state and federal law.

Contents

Introduction

The Hydrograph Procedure (Wis. Admin. Code § SPS 385.60(4)) is used in Wisconsin to evaluate soil and site conditions for proposed private on-site wastewater treatment systems (POWTS). It applies to sites that are subject to a broad, relatively uniform, regional water table. If there is 5 feet (ft) or more to free water below original grade, the Hydrograph Procedure may be used to estimate the highest predicted groundwater elevation at the site. Historically, this method has been allowed for use in five counties in the Central Sands Region of the state (Adams, Juneau, Portage, Waushara, and Wood) and in a small area in northern Marquette County (Travis Olson, personal communication).

The procedure involves extrapolating water-level conditions from a reference location, or observation well, to estimate the potential high-water level at a proposed POWTS site. Observation wells approved for use with the Hydrograph Procedure should have a multi-year record of water levels that captures both seasonal and long-term fluctuations in the water table. Using the multi-year record, each observation well is assigned a high-water level, referred to as the "assigned high."

When assessing shallow-water conditions at a proposed POWTS site, soil testers are required to measure the water level at both an on-site observation pipe and an approved observation well within a 48-hour window. The difference between the current water level at the observation well and its assigned high is used to determine an equivalent adjustment factor that is applied to account for that much possible water-level rise at the POWTS site being assessed.

The State of Wisconsin Department of Safety and Professional Services (DSPS) suspended use of the Hydrograph Procedure in April 2024 after DSPS program staff observed erratic groundwater levels in the region and areas of groundwater flooding. Wis. Admin. Code § SPS 385.60(4)(f) allows for suspension "when erratic groundwater tables are present due to recent, significant recharge events." In their suspension notice, DSPS resolved that the suspension would remain in effect "until such a time that groundwater levels normalize, and suitable controls are in place to safely allow for the use of the method."

To assist in determining appropriate use of the Hydrograph Procedure, the Wisconsin Geological and Natural History Survey (WGNHS) was contracted to compile existing water-level information for parts of Adams, Juneau, Portage, Waushara, Wood, and Marquette counties and delineate areas where water depths are estimated to be less than 5 ft, 5 to 10 ft, and greater than 10 ft below grade. This report summarizes the methods used to estimate depth-to-water, discusses limitations of the approach, and provides recommendations on the use of the mapped areas. WGNHS was also asked to evaluate the observation wells that have been used by governmental units when applying the Hydrograph Procedure. We did not assess the validity of the Hydrograph Procedure, but we do make recommendations for additional data and analysis needs to support appropriate use of the Hydrograph Procedure in the future.

Hydrogeologic Setting

The Hydrograph Procedure is primarily used in western and southern portions of the Central Sands Region of Wisconsin. This area is characterized by sandy sediments up to 200 feet thick, although buried lenses of fine-grained sediments also exist. The sediments were deposited in outwash plains and glacial lakes during the last ice age, between 100,000 and 20,000 years ago. They form a highly conductive surficial aquifer that is well-connected to lakes, streams, and wetlands in the area. Precipitation and the amount of groundwater recharge are key drivers of groundwater levels in the Central Sands (Hart and others, 2020; DNR, 2021).

Depth to Groundwater

Wis. Admin. Code § SPS 385.60(4) specifies water depth ranges that apply to the use of the Hydrograph Procedure. The procedure may not be used if there is less than 5 ft to free water below original grade. Variations of the procedure may be used when free water at the site is 5 to 10 ft below grade or more than 10 ft below grade. This section describes the data sources and methods used to delineate areas where water depths are estimated to be within these ranges, as well as uncertainties associated with the mapped areas and ways to reduce uncertainty.

Data Sources

Well Construction Reports

The Department of Natural Resources (DNR) has managed digital well construction reports (WCRs) of drilled groundwater wells located to the quarter-quarter section since 1988. The DNR provides these well data to WGNHS, and we house an internal WCR database for post-1988 WCRs (WGNHS, unpub. data, 2024). The WGNHS more precisely geolocates wells in this database on a project-by-project basis. Data on wells drilled in and prior to 1988 are stored as scanned images of well construction reports and typically have no digital depth-to-water data.

Wells in the WGNHS WCR digital database that have not been geolocated plot in the center of the quarter or quarter-quarter section that is recorded on the WCR. As such, the water level recorded on the WCR may not be representative of the depth-to-water at this position, especially in areas of higher topographic relief. Even where wells are geolocated, there are uncertainties in the depth-to-water data. Various equipment with differing levels of precision may be used by drillers to measure the static water level in a newly installed well. Additionally, because the data in the WCR database are collected over time, water levels represent a range of climate conditions and can only provide a generalized view of water-table elevations.

Water Table Maps

Lippelt and Hennings (1981) created water-table maps for Adams, Juneau, Marquette, Portage, Waushara, and Wood counties as part of an irrigable lands inventory for the Golden Sands

Resource Conservation and Development Area in central Wisconsin. The maps were produced at a scale of 1:126,720 and with a 10-foot contour interval. Batten (1989) later mapped the elevation of the water table in Wood County at a larger scale (1:100,000), but with reduced resolution in the water table surface (20-foot contour interval).

Previously only available in a paper format, the Lippelt and Hennings (1981) maps were digitized in late 2024 as part of an ongoing effort at WGNHS to increase accessibility of groundwater data. However, these maps are based on water well data from 1936 to 1979. For Wisconsin's Central climate division (Division 5), where the study area is located, most years during and immediately preceding this period had lower than average precipitation (fig. 1) (Wisconsin State Climate Office, unpub. data, 2024). Moreover, WICCI (2021) reports that annually averaged precipitation has increased by up to 20% from 1950 to 2020 in Division 5. Thus, the Lippelt and Hennings (1981) maps may be more representative of low water-table conditions than long-term average or high water-table conditions.

Hart and others (2020) also compiled data from WCRs and from construction data for high-capacity wells across the Central Sands Lakes Study area. They created regional water-table contours (25-foot contour interval) in ArcGIS using inverse distance weighting. Their analysis was conducted for use in a numerical groundwater flow model. The spatial extent was limited to the Central Sands Lakes Study model boundary and excludes Juneau County.

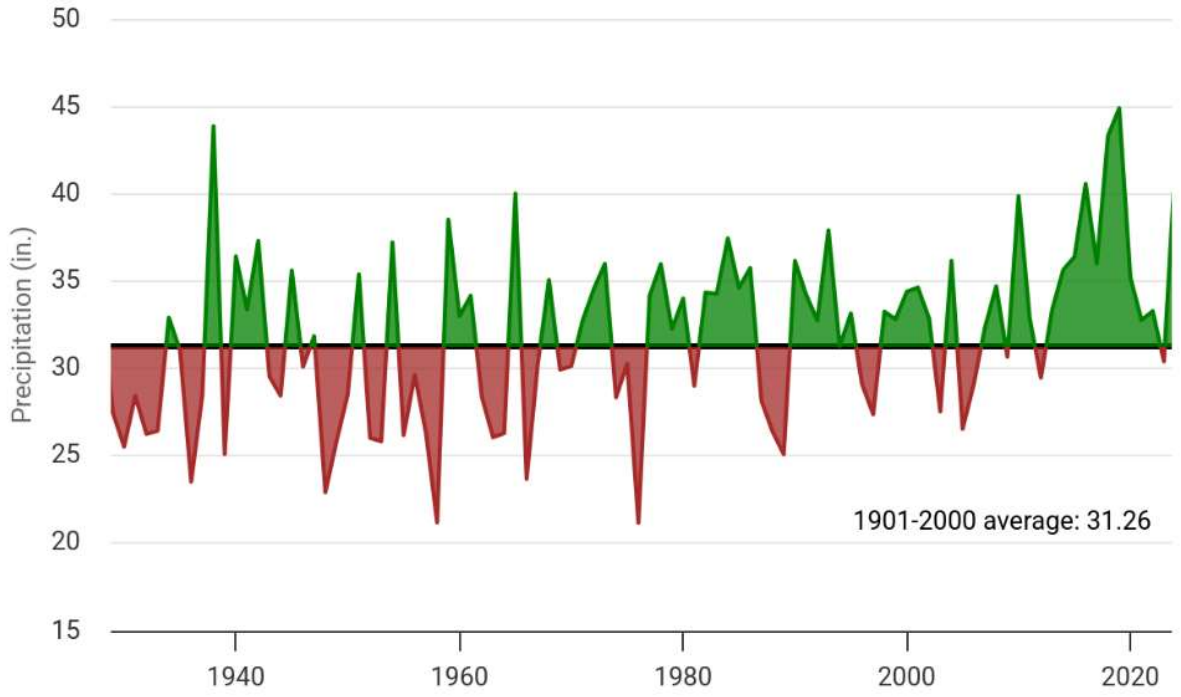


Figure 1. *Wisconsin's Central climate division (Division 5) annual average precipitation in inches from 1930 to 2024 (Wisconsin State Climatology Office, unpub. data, 2024).*

Methods

The Lippelt and Hennings (1981) maps may be more representative of low water-table conditions, and tens of thousands of new wells have been installed in the study area since the late 1970s. Therefore, our depth-to-water analysis used more recent well data that are available in the WGNHS WCR database (WGNHS, unpub. data, 2024). Nearly 31,000 well records are digitally compiled for Adams, Juneau, northern Marquette, Portage, Waushara, and Wood counties. Wells in Marquette County are included in this total and in our analysis due to the county's adjacency to Adams and Waushara counties and because the Hydrograph Procedure was historically used in a small area of northern Marquette County (Travis Olson, personal communication). For most pre-1988 wells, the database contains scanned images of WCRs, but construction characteristics, including water level, are not digitally tabulated. Therefore, the mapped depth-to-water areas presented in this report use data for wells primarily constructed in 1988 or later. Future analysis could incorporate pre-1988 well water levels; however, tabulation of these well data was beyond the scope of the project.

Adams, Marquette, Portage, and Waushara counties have geolocated wells that have positional accuracies ranging from 3 to 750 ft. Wells in Juneau and Wood counties are roughly located to the centroid of a quarter or quarter-quarter section. As such, locations may be off by as much as 1,320 ft. Further well geolocation was beyond the scope of the project.

Well Screen Depth

To ensure that appropriate wells were included in the analysis, we first removed wells with no reported depth-to-water measurement. Wells were then sorted by screen depth. Wells screened at shallower depths are more likely to represent water-table conditions. To select for shallow wells, but also maximize the number of wells, we tested for differences in mean water level among three well screen depth categories (table 1).

Table 1. Number of wells in the study area and numbers of wells sorted by screen depth.

County	Total number of wells with reported water levels	Depth to the top of well screen (ft)		
		≤ 100, but > 75	≤ 75, but > 50	≤ 50
Adams	6,167	565	2,784	1,913
Portage	5,596	838	1,001	2,097
Waushara	5,579	1,383	1,241	388
Wood	7,131	210	1,063	5,765
Juneau	4,910	335	1,289	2,993
Marquette	1,295	304	260	94
Sum	30,678	3,635	7,638	13,250
% of total number of wells		12%	25%	43%

An analysis-of-variance (ANOVA) test showed that the mean water levels differ among the three screen depth categories of 50 ft or less, greater than 50 ft but 75 ft or less, and greater than 75 ft but 100 ft or less in depth ($p<0.001$). A Tukey-Kramer Honestly Significant Difference (HSD) test showed that all means differ from one another, but that the mean water levels for wells that are 50 ft or less and those that are greater than 50 ft, but 75 ft or less differ the least. Therefore, we chose to utilize wells screened at depths of 75 ft or less, which includes 68% of the total number of wells with reported water levels (fig. 2).

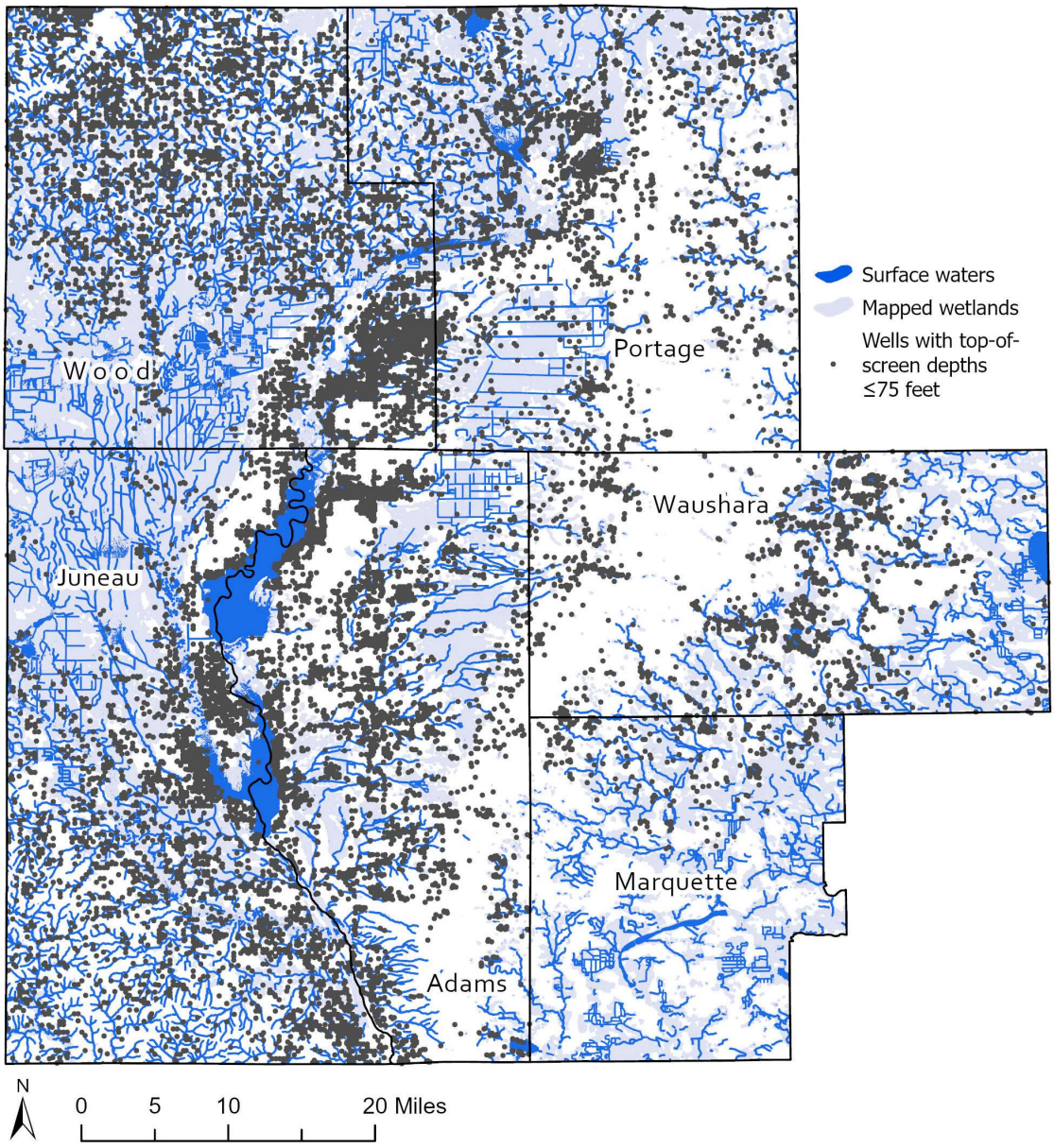


Figure 2. *Distribution of supporting data for shallow groundwater mapping, showing the positions of 20,888 wells with screens shallower than or equal to 75 feet, surface waters from the National Hydrography Dataset, and wetlands from the Wisconsin Wetlands Inventory (accessed May 2025).*

Seasonality

Wells installed during groundwater recharge periods may be more likely to represent high water-table conditions. Groundwater recharge in central and southern Wisconsin typically occurs during periods of snowmelt, high precipitation, and low evapotranspiration. To evaluate whether water levels in the WGNHS WCR database differ between wetter versus drier periods, wells were sorted by installation month, where February through May represent months when recharge is more likely to occur, and all other months represent times when recharge is less likely to occur. A Student's T-test (α=0.05) suggests a slight difference between mean water levels in wetter versus drier periods. However, using wells installed in February through May would substantially reduce the number of available wells (from 20,888 to only 6,732). Therefore, wells installed in all months were used in this analysis.

Mapping Depth-to-Water

Using the water levels recorded on WCRs for wells screened at depths of 75 ft or shallower, three zones were mapped: 1) areas where the estimated depth-to-water exceeds 10 ft; 2) areas where the estimated depth-to-water exceeds 5 ft; and 3) areas where the estimated depth-to-water is less than 5 ft (fig. 3, dataset 1). The zones were hand-drawn using the well data and by referencing surface-water features (streams, lakes) from the National Hydrologic Dataset and wetlands from the WDNR Wisconsin Wetland Inventory (fig. 2). The Quaternary Geology of Wisconsin map (Rawling and others, 2025) and topography from Lidar were also used as guides.

We have higher confidence in the areas where the approximate depth-to-water is mapped as ≥ 10 ft. The density of wells is higher in these zones, and nearly all wells (98%) have water levels that are ≥ 10 ft below grade. Exceptions include limited areas within about 300 ft of a surface-water feature or within or near the margin of a floodplain. The prevalence of surface waters and wetlands in these zones is generally lower, which also suggests a deeper water table. We have moderate confidence in zones where the approximate depth-to-water is mapped as < 5 ft. The density of wells is lower in these zones and there is more variation in the WCR depth-to-water data. However, the prevalence of surface waters and wetlands is high, which suggests very shallow groundwater. Areas that lie between the two zones described above should correspond to zones where the depth-to-water is 5 to 10 ft below grade. However, we have lower confidence in estimated water depths in these areas because there is wide variation in the WCR depth-to-water data. Therefore, these zones are more appropriately characterized as areas where the approximate depth-to-water is ≥ 5 ft (fig. 3). Individual maps for Adams, Juneau, Portage, Waushara, and Wood counties are provided in Appendix A.

To evaluate the three mapped water-depth zones we (i) performed limited field checking during a period of seasonally high water-table conditions and (ii) compared the mapped areas to existing water-table maps (Lippelt and Hennings, 1981) that are assumed to represent low water-table conditions. DSPS personnel accompanied WGNHS hydrogeologist G. Graham in the field in March 2025. They visited areas that experienced prolonged groundwater flooding in recent years. Additionally, areas with standing water and areas that had experienced tree die-

off due to past flooding were documented. All these areas were compared to the mapped depth-to-water zones, and zone boundaries were adjusted as necessary.

We applied the Topo to Raster Spatial Analyst Tool in Esri ArcGIS Pro 3.4.2 to the digitized Lippelt and Hennings (1981) water-table contours to produce a continuous water-table surface raster. A depth-to-water map was constructed by subtracting the water-table surface from the U.S. Geological Survey (USGS) 2017 National Elevation Dataset (NED) digital elevation model. Comparing this surface to the hand-drawn zones, broad patterns in water depth are similar, but water levels appear to be deeper in figure 4a and shallower in figure 4b, which aligns with the observed increase in precipitation in the region over the last ~75 years (WICCI, 2021).

Limitations and Guide to Use

The accuracy of the mapped depth-to-water zones in figure 3 is directly related to the availability and quality of the WCR data in any given area of the region. There is greater certainty in areas with higher densities of wells and surface-water features, such as in east-central Juneau and northwestern Adams counties. There is lower certainty in areas with few wells and surface-water features. The occurrence of wetlands strengthen confidence in shallow-water designations where well records are limited (fig. 2).

There is also greater certainty in Adams, Portage, Waushara, and northern Marquette counties because wells in these areas have been geolocated. However, the spatial accuracy of the mapped zones is still no less than about 750 feet or roughly 1/8 mile. There is lower certainty in Juneau and Wood counties because individual wells are only located to the quarter or quarter-quarter section. Therefore, the spatial accuracy of the mapped zones in these areas is no less than about 1,320 feet or roughly 1/4 mile.

Additionally, because the data in the WCR database are collected over time, water levels represent a range of climate conditions and can provide only a generalized view of water-table elevations. Well records represent one point in time and where there are fewer wells, the documented conditions are less likely to reflect a long-term average or the possible range in local conditions. Even where wells are spatially dense, they might still represent only a narrow window of time.

Due to the limitations in availability and quality of the WCR data, the mapped zones in figure 3 should be used as a general guide to depth-to-water in combination with other factors that may also indicate periodic shallow water-table conditions, such as areas of tree die-off due to flooding near a proposed POWTS site, or site-specific soils data and conditions.

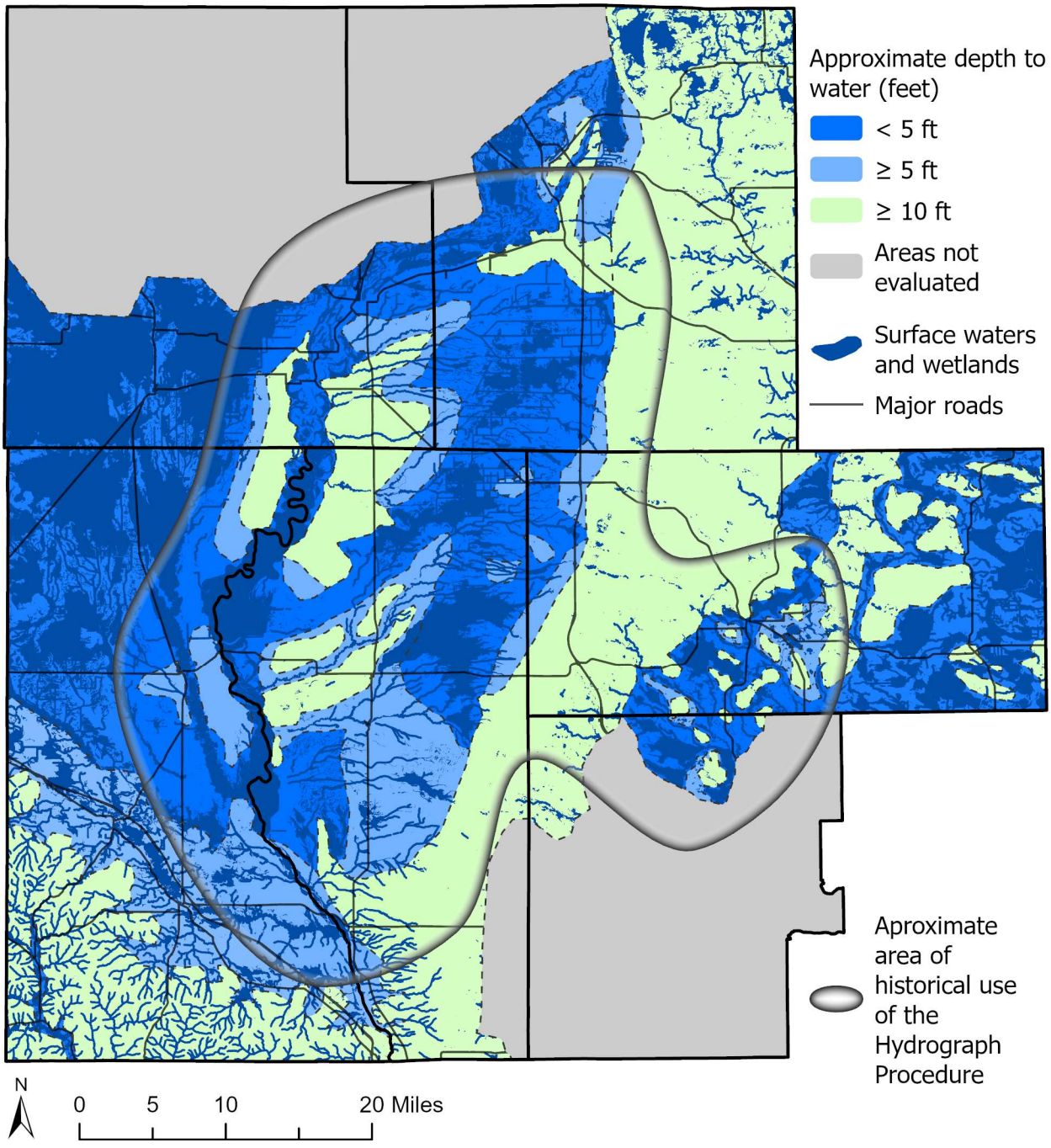


Figure 3. *Areas where water depths are estimated to be less than 5 ft, greater than or equal to 5 ft, and greater than or equal to 10 ft below grade. Zones use data for wells primarily constructed in 1988 or later. Approximate area of historical use of the Hydrograph Procedure based on personal communication with DSPS personnel (January 2025).*

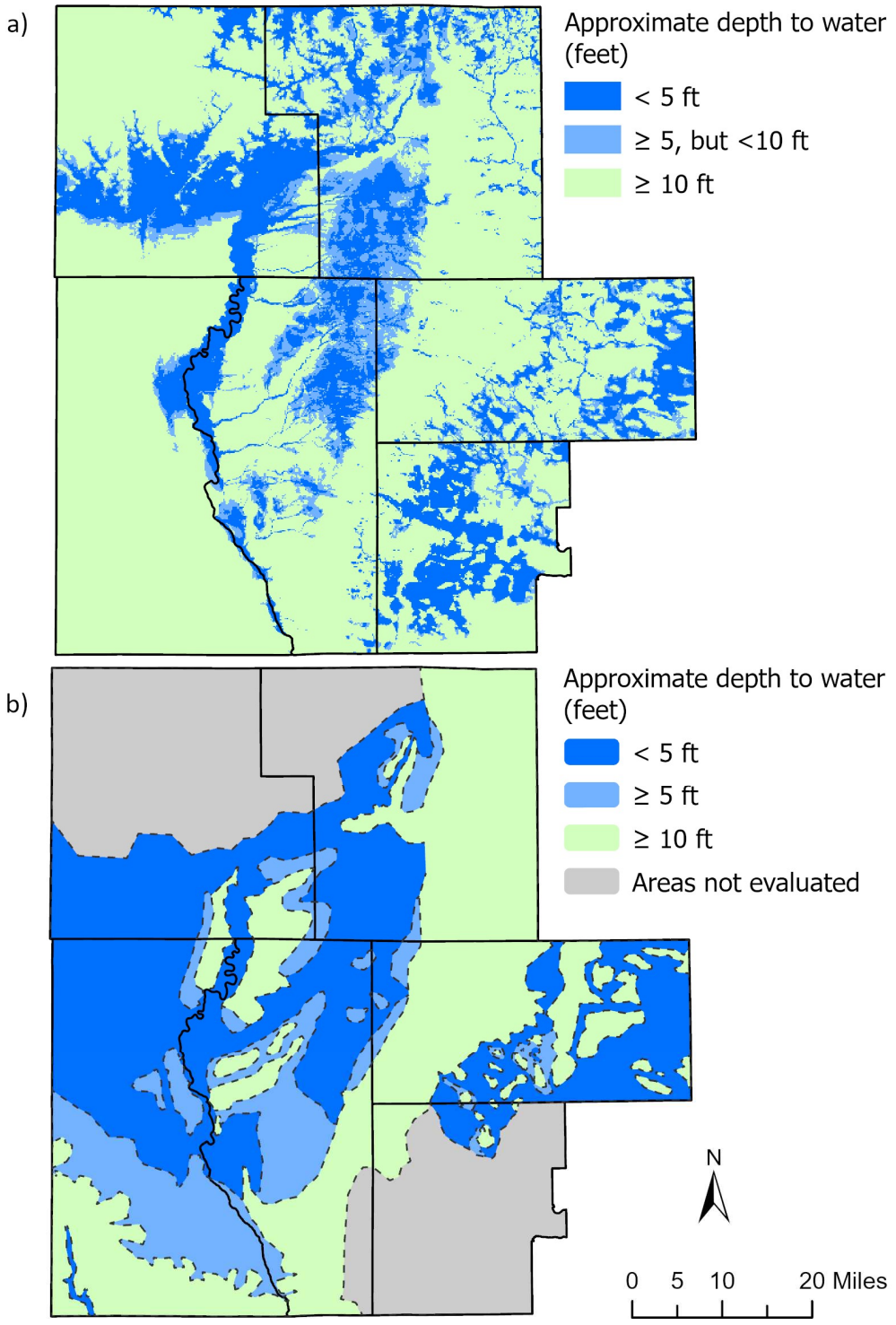


Figure 4. *Comparison of estimated depth-to-water surfaces constructed using a) data for wells installed between 1936 and 1979 (Lippelt and Hennings, 1981) and the USGS 2017 NED and b) data for wells constructed in 1988 or later.*

Recommendations for Future Analysis

Geolocation of wells in Wood and Juneau counties is recommended to enhance the spatial accuracy of depths-to-water in those areas. Updated water-table mapping in regions where the Hydrograph Procedure is applied is also recommended, as existing maps are based on data from historically dry periods (1936–1979) and likely reflect low to average water-table conditions. These older maps are less useful for the Hydrograph Procedure, which relies on estimates of average and high-water levels. Incorporating newly available data sources, such as high-resolution LiDAR, updated National Hydrography Dataset (NHD) layers, wetlands inventories, and well construction reports submitted since 1979, would provide a more complete and current view of the water table and groundwater flow directions. The large number of wells drilled since the 1970s has expanded the available dataset for mapping. Since 1988, state law has required well drillers to submit Well Construction Reports (WCRs) for most types of wells, further improving data availability and reliability.

Observation Wells

Existing Conditions

DSPS personnel provided existing documentation for observation wells most recently in use by governmental units in Adams, Juneau, Portage, Waushara, and Wood counties. We supplemented these data with information from WCRs, where available, and compiled the information into a spreadsheet (dataset 2). The dataset and the following summary describe the status and condition of the observation wells, including their geographic distribution, construction characteristics, and the quality of available water-level records. The summary reflects both the compiled data and limited field visits conducted in March 2025.

Distribution of wells and monitoring history

Figure 5 shows the geographic distribution of observation wells that were in use prior to the suspension of the Hydrograph Procedure by DSPS in April 2024. When the Hydrograph Procedure was implemented in 1988, seven observation wells were approved across Adams, Wood, Portage, and Waushara counties. Six of these wells remain operational today. Except for the Eikhorn well, all original wells are part of the National Groundwater Monitoring Network (NGWMN) and have consistent, long-term water level records spanning several decades.

In the mid-2000s, nine observation wells in Juneau County were approved for use with the Hydrograph Procedure. These wells were originally installed around 1990 as observation pipes to support on-site water-level evaluations for septic system permitting. They were retained for periodic monitoring and later adopted into the Hydrograph Procedure as observation wells based on monitored water levels collected in 1990-2000. Six wells were installed in Adams County in 2010 with the intention of future use as observation wells under the Hydrograph Procedure. Since 2022, Adams County has equipped these wells with pressure transducers and

remote data loggers, enabling daily water-level monitoring. The data are transmitted to an online archive that is accessed and maintained by the county.

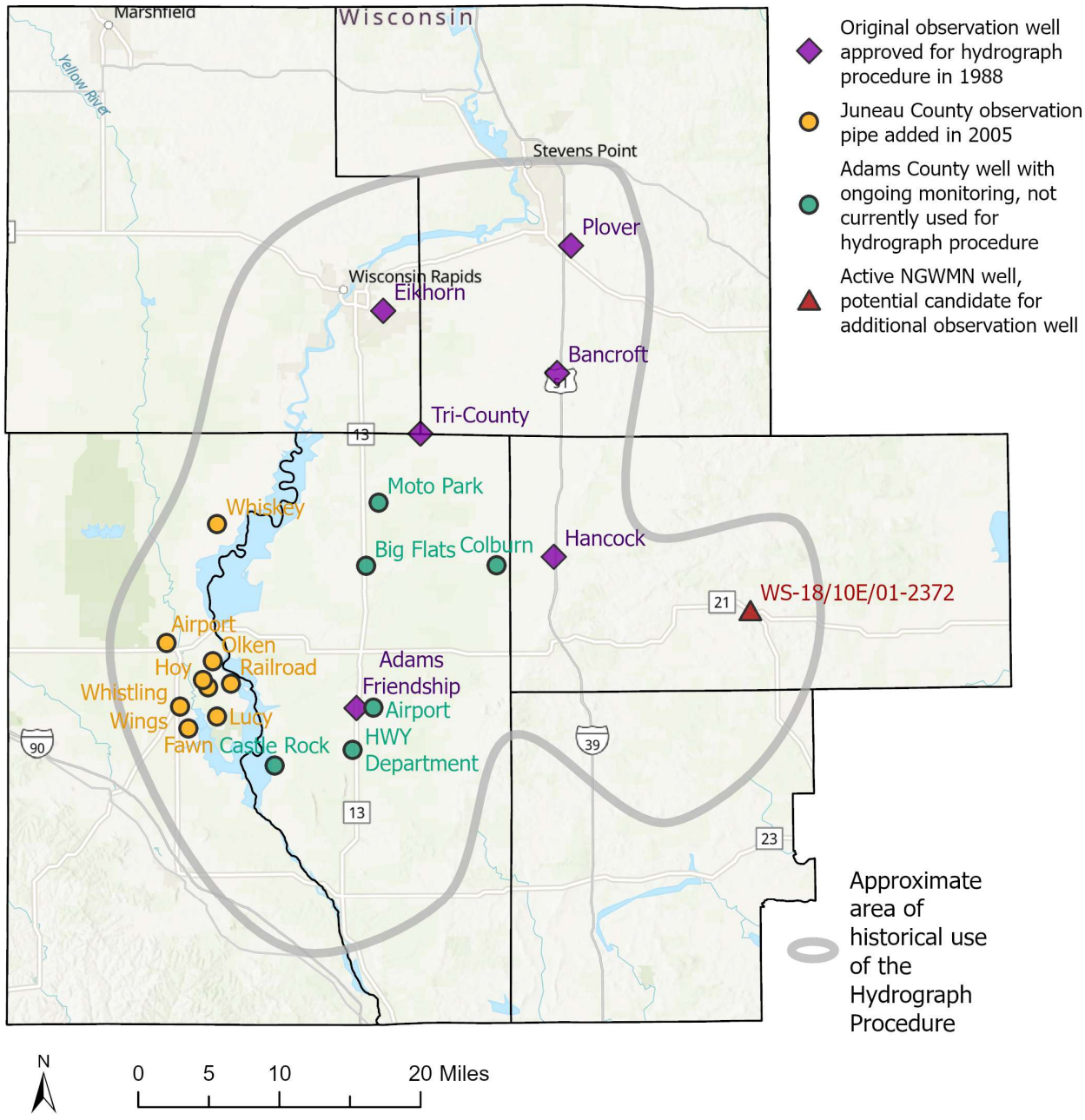


Figure 5. *Locations of approved and future potential observation wells. The well symbols indicate the status or date of approval of each well for use with the procedure. Approximate area of historical use of the Hydrograph Procedure based on personal communication with DSPS personnel (January 2025).*

Well Construction

All the observation wells are shallow wells (< 30 ft deep) completed in the sand and gravel aquifer. Formal well construction reports are available for only three of the 22 observation wells. While many construction details were obtained from other sources (DSPS, WGNHS, and USGS records), key information typically included in a WCR is missing for several wells. This includes total well depth, the presence or absence of a well screen (versus an open-bottom design), and the screen's depth and length.

Monitoring wells should be constructed with screened intervals that are deep enough to intersect the water table even during low-water periods. However, at least two of the observation wells were found to be dry during site visits in March 2025, indicating that the wells are not constructed to sufficient depths to reliably measure the water table or capture the full range of water-level conditions at the site.

Water level records available for estimating high-water conditions

Six observation wells have reliable water-level records that capture local seasonal and annual fluctuations. This group includes all five wells that are part of the NGWMN (Adams Friendship, Bancroft, Hancock, Plover, Tri-County) and one observation well in Juneau County (Hoy). These wells have records characterized by frequent or continuous measurements spanning multiple years.

Twelve of the observation wells have sparse or irregular measurement records, particularly during high water periods, that do not adequately capture high-water conditions or the full range of seasonal and annual variability. This group includes the nine remaining observation wells in Juneau County (those other than Hoy), and at least three of the Adams County wells currently equipped with pressure transducers (HWY Department, Airport, and Big Flats). The pressure transducers installed in these wells are not capable of capturing the full range of water levels, either because the high is out of vertical range of sensor detection or because seasonal low water falls below the depth at which the transducer is installed. We were unable to view records from four of the wells (Colbourn, Castle Rock, Moto Park, and Eikhorn).

The assigned highs associated with observation well records also vary in quality or reliability. Seven observation wells have assigned high-water levels that are lower than the highest levels observed at those wells. Eight of the wells have been assigned multiple highs over time.

Observation Well Recommendations

Construction

To support consistent application of the Hydrograph Procedure, observation wells should follow standardized practices for construction, monitoring, and placement. Wells should be constructed in accordance with Wisconsin groundwater monitoring well requirements (Ch. NR 141) and have screen lengths capable of measuring expected seasonal and annual water-table

conditions. Complete well construction documentation, including depth and screen details, should be recorded and archived in accordance with NR 141.

Monitoring

The use of pressure transducers and data loggers are recommended where feasible. Transducers should be rated to accommodate the expected range of water-level fluctuations at each site. Periodic manual water-level measurements should still be collected to verify accuracy and detect and correct for instrument drift. If pressure transducers and data loggers are not feasible, water-level records should contain at least monthly measurements.

A minimum of two years of water-level monitoring (or longer during drought conditions) is recommended before assigning a high-water level to a new observation well or for an existing observation well lacking a long-term record. Ongoing data collection and an annual assessment of the assigned high should be performed to confirm that the assigned high is appropriate and that the well remains in good condition. All data should be archived in a centralized repository to support long-term trend analysis.

Consistency in data collection protocols is also important. Water levels should be measured relative to a fixed, and clearly defined, reference point on each well casing to ensure comparability between technicians and over time. Ideally, the reference point should be surveyed to a vertical datum (established benchmark or local datum) to convert water depth to water elevation. If a well is repaired or replaced, specifications on reference point elevation and stick-up height must be updated.

Currently, there is no formal procedure for reviewing or updating assigned highs as new data become available. Review of newly assigned highs would help ensure that high-water estimates remain accurate and reflect longer term groundwater conditions.

Placement

Wells should be distributed across the geographic area where the Hydrograph Procedure is applied. The addition of a well in Waushara County should be considered to improve coverage in the eastern extent of the area in which the Hydrograph Procedure has historically been applied (WS-18/10E/01-2372 in fig. 5). This existing shallow sand and gravel well is part of the NGWMN and has a water-level record dating back to 2021. WGNHS can provide further consultation to counties regarding siting and construction of new observation wells to enhance data quality or spatial coverage.

Once long-term, high-quality records are available for observation wells, cross-comparisons among wells may reveal similarities or differences in water-level trends across the region, thus informing extrapolation distances for individual wells, as well as additions to or removals from the observation well network. This type of analysis may be possible using water-level records for the existing NGWMN wells but was beyond the scope of this project.

Summary of Recommendations

To support appropriate use of the Hydrograph Procedure in the future,

- Well geolocation in Wood and Juneau counties is recommended to enhance the spatial accuracy of depths-to-water in those areas.
- Updated water-table mapping in regions where the Hydrograph Procedure is applied is recommended.
- Observation wells should be constructed in accordance with Wisconsin groundwater monitoring well requirements (Ch. NR 141) and have screen lengths capable of measuring expected seasonal and annual water-table conditions.
- Pressure transducers that are rated to accommodate the expected range of water-level fluctuations and data loggers should be used to monitor and record water levels at observation wells, but periodic manual water-level measurements should still be collected to verify accuracy and detect and correct for instrument drift.
- Water levels at observation wells should be measured relative to a fixed, and clearly defined, reference point on each well casing to ensure comparability between technicians and over time.
- A minimum of two years of water-level monitoring (or longer during drought conditions) is recommended before assigning a high-water level to a new observation well or for an existing observation well lacking a long-term record.

Supplemental material

Supplemental material in this report includes a file geodatabase with a polygon feature class of the mapped zones shown in figure 3 (dataset 1) and spreadsheets with compiled information on the status and condition of the observation wells that were in use prior to the suspension of the Hydrograph Procedure by DSPS in April 2024 (dataset 2).

Dataset 1: Areas where water depths are estimated to be less than 5 feet, greater than 5 feet, and greater than 10 feet below grade in areas where the Hydrograph Procedure is applied.

A file geodatabase (.gdb format) that includes a polygon feature class with mapped zones where water depths are estimated to be less than 5 feet, greater than 5 feet, and greater than 10 feet below grade.

Dataset 2: Status and condition of observation wells.

Two spreadsheets (.csv format). The first spreadsheet (dataset_2_observation_wells.csv) includes observation well location and construction data, as well as information on the quality of available water-level records. The second spreadsheet (dataset_2_headers.csv) includes header definitions used in the observation well spreadsheet.

References

Batten, W.G., 1989, Hydrogeology of Wood County, Wisconsin: Wisconsin Geological and Natural History Survey Information Circular 60, 27 p.

Hart, D., Greve, R., Parsen, M., Rawling, J.E., Mauel, S., Chase, P., 2020, Appendix A - Central Sands Lakes Study Technical Report: Data Collection and Hydrostratigraphy, In Central Sands Lakes Study Report: Findings and Recommendations: Wisconsin Department of Natural Resources, 104 p.

Lippelt, I.D., Hennings, R.G., 1981, Irrigable Lands Inventory - Phase I Groundwater and Related Information: Wisconsin Geological and Natural History Survey MP81-1, 13 p., 11 plates.

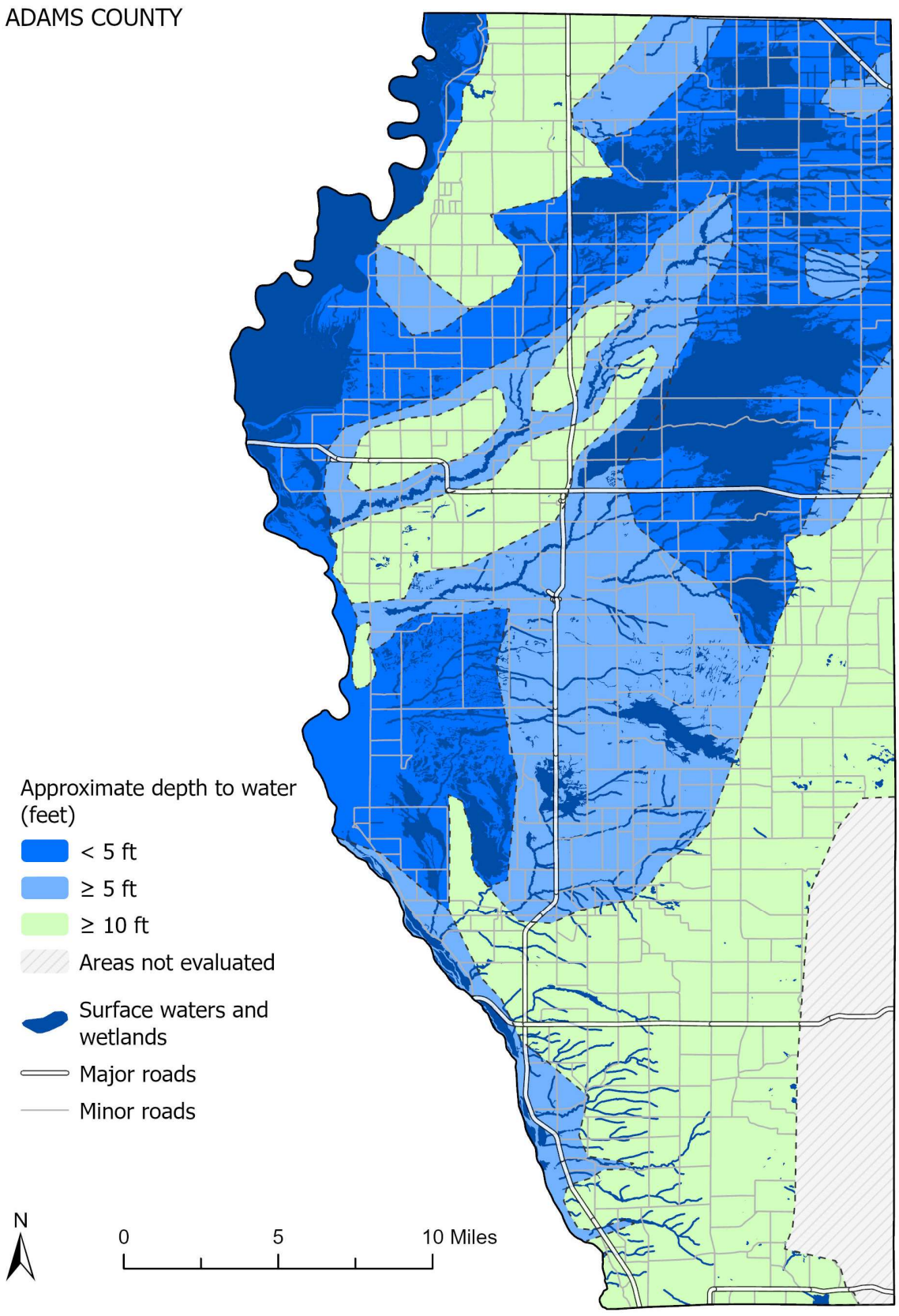
Rawling, J.E., III, Carson, E.C., Attig, J.W., Mickelson, D.M., Mode, W.M., Johnson, M.D., and Syverson, K.M., 2025, Quaternary Geology of Wisconsin: Wisconsin Geological and Natural History Survey Map 512, 1 pl., scale 1:500,000, https://doi.org/10.54915/xqpw9883.

Wisconsin Initiative on Climate Change Impacts (WICCI), 2021, Wisconsin's changing climate: Impacts and solutions for a warmer climate: Nelson Institute for Environmental Studies, University of Wisconsin-Madison and the Wisconsin Department of Natural Resources, Madison, Wisconsin, 99 p.

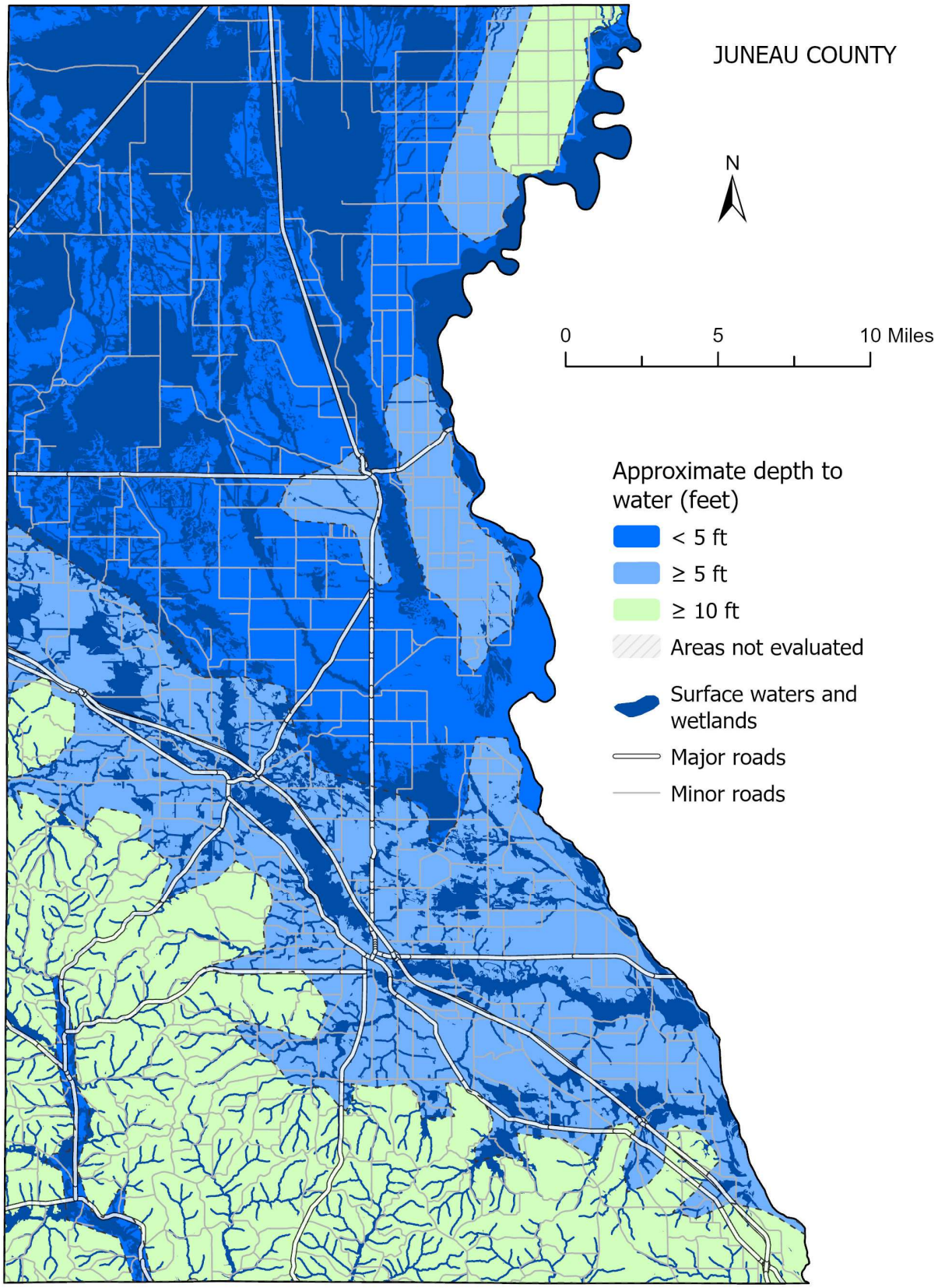
Wisconsin Department of Natural Resources (DNR), 2021, Central Sands Lakes Study Report: Findings and Recommendations: Wisconsin Department of Natural Resources, 32 p.

Appendix A

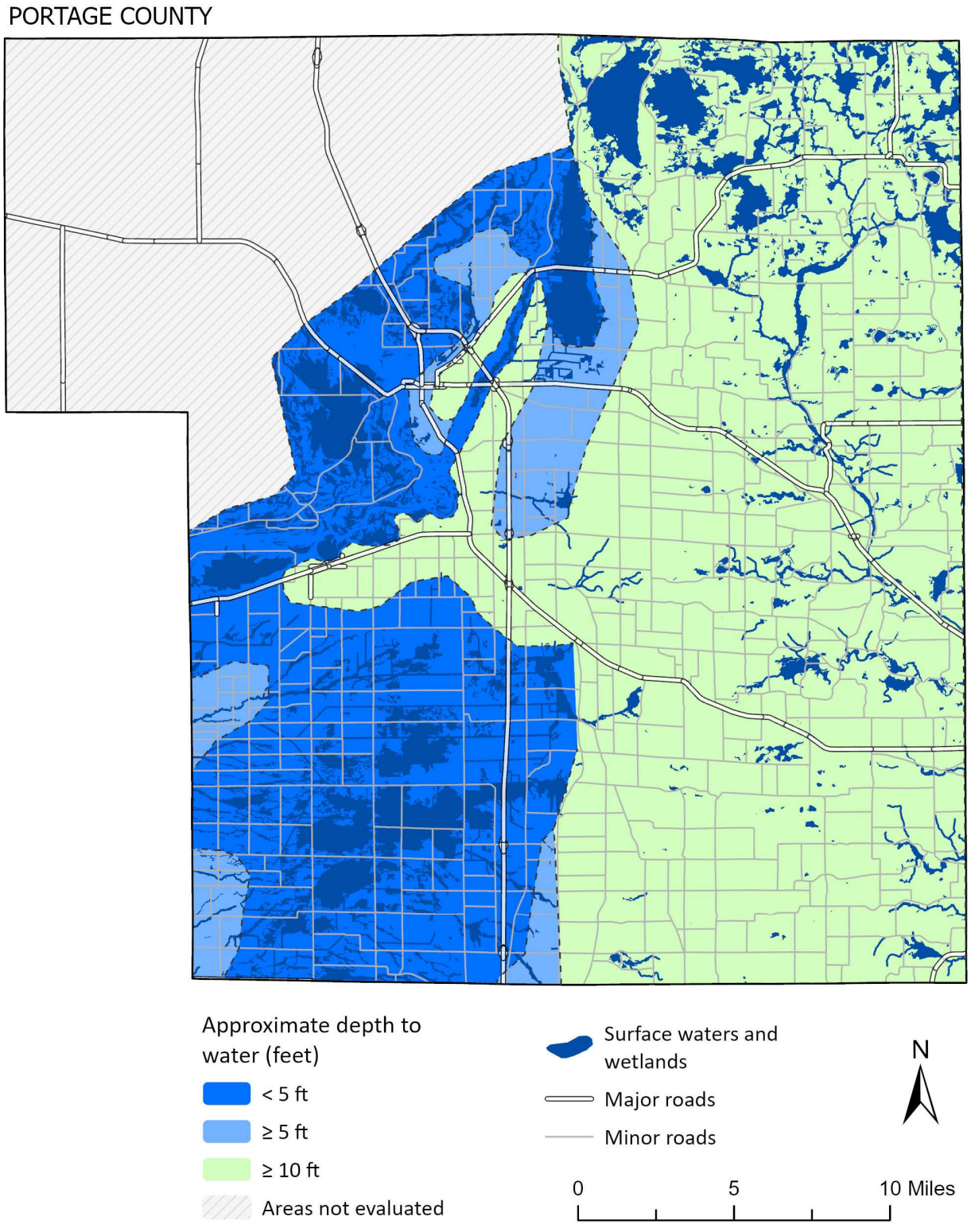
Five maps: Areas where water depths are estimated to be less than 5 ft, greater than or equal to 5 ft, and greater than or equal to 10 ft below grade in Adams, Juneau, Portage, Waushara, and Wood counties.



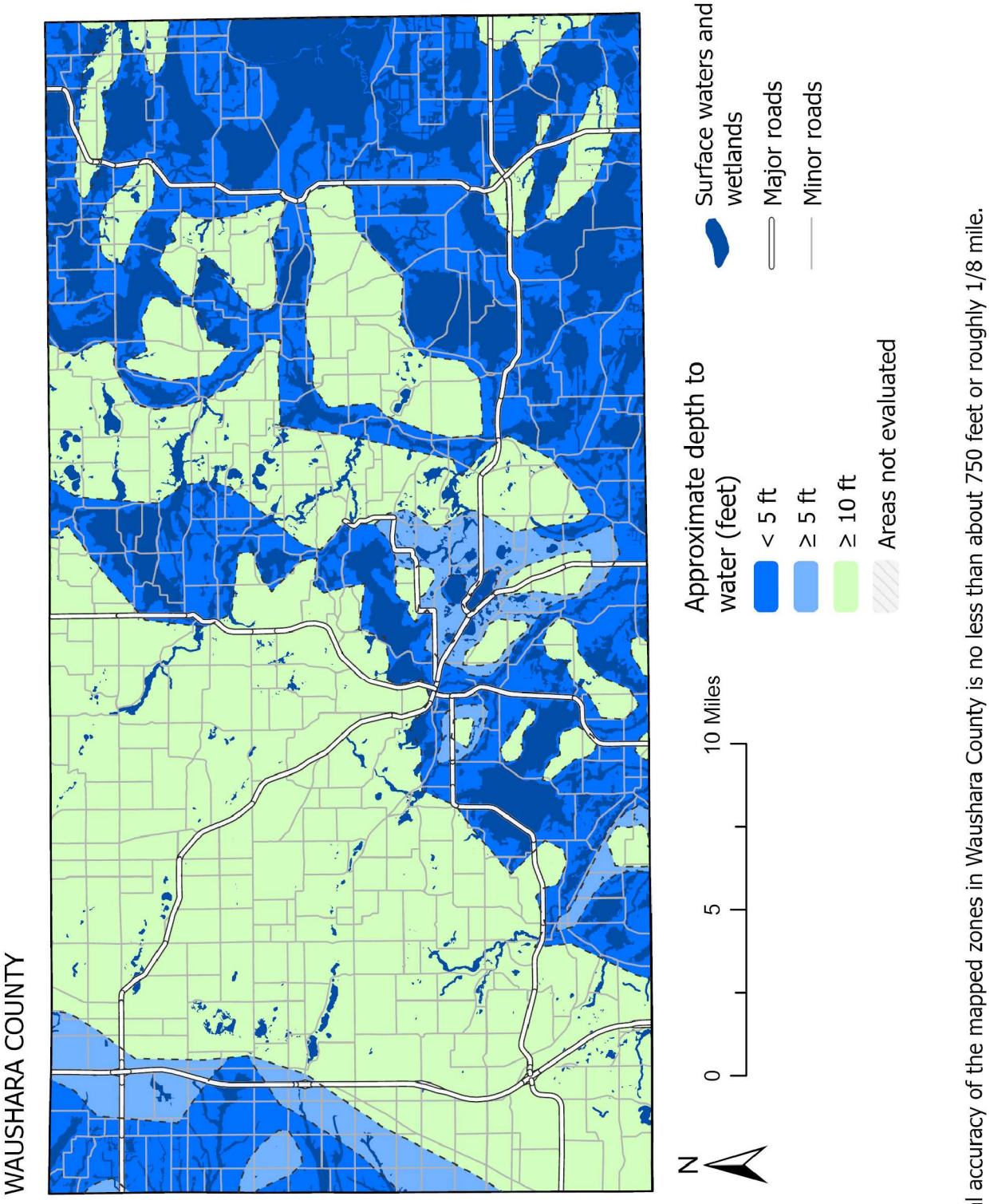
The spatial accuracy of the mapped zones in Adams County is no less than about 750 feet or roughly 1/8 mile.



The spatial accuracy of the mapped zones in Juneau County is no less than about 1,320 feet or roughly 1/4 mile.

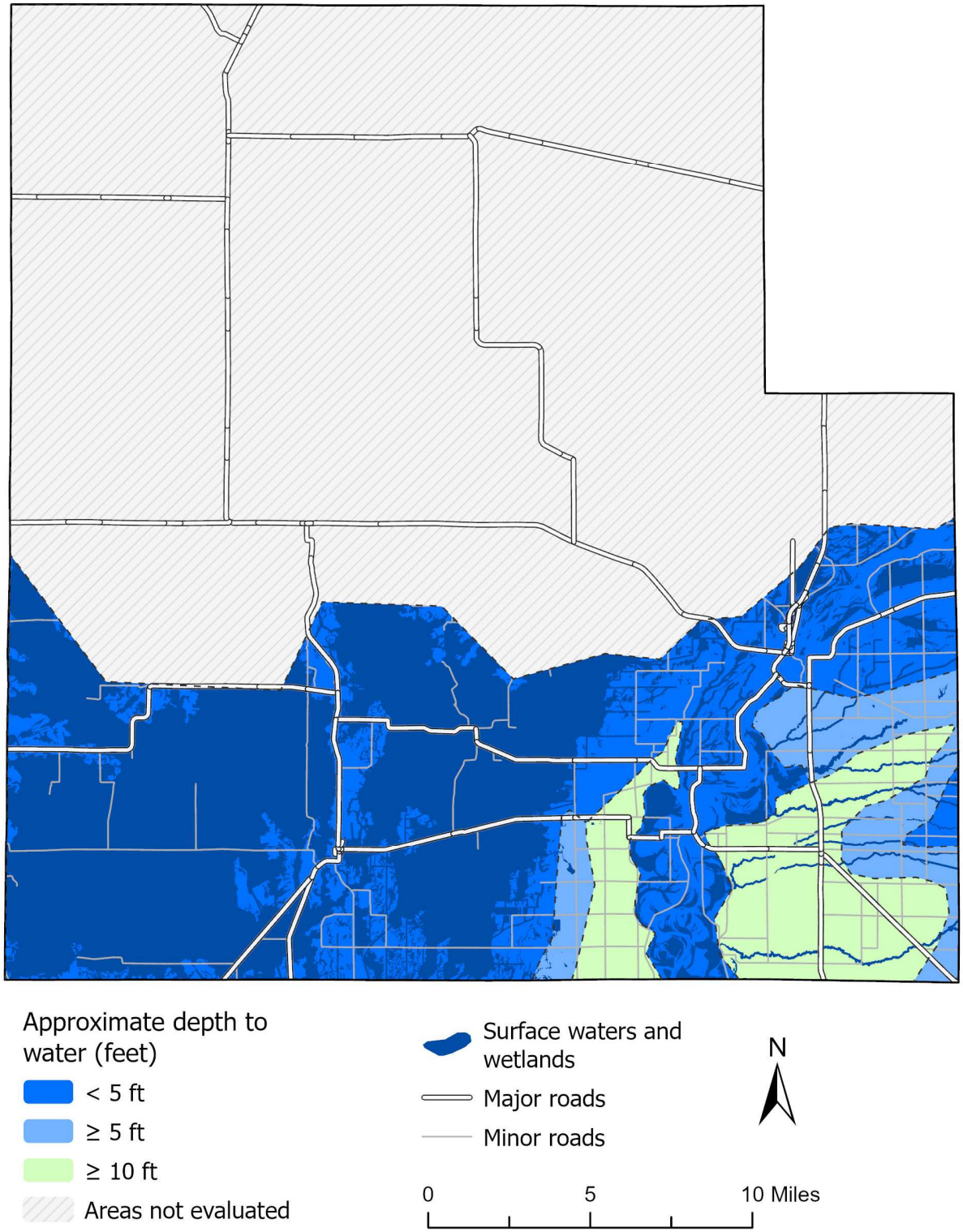


The spatial accuracy of the mapped zones in Portage County is no less than about 750 feet or roughly 1/8 mile.



The spatial accuracy of the mapped zones in Waushara County is no less than about 750 feet or roughly 1/8 mile.

WOOD COUNTY



The spatial accuracy of the mapped zones in Wood County is no less than about 1,320 feet or roughly 1/4 mile.