WASHINGTON COUNTY GROUNDWATER RECHARGE ZONE PRIORITIZATION

Prepared for Washington County Department of Public Health and Environment

Prepared by Aaron DeRusha, Washington Conservation District

December 2021

Contents

1.0 Introduction 1
2.0 Data Overview 1
2.1 Pollution Sensitivity of Near Surface Materials and the Bedrock Surface 2
2.2 Known Groundwater Recharge Zones 3
2.3 Well Protection Areas 4
2.4 Potential for Surface Water and Groundwater Interaction 4
2.5 Supplemental Data 5
3.0 Recharge Zone Prioritization Methodology 5
4.0 Prioritization Results 6
5.0 References 8
6.0 Figures 9

Figures

Figure 1. Groundwater Recharge Area Prioritization Model 9
Figure 2. Pollution Sensitivity of the Near Surface Materials 10
Figure 3. Pollution Sensitivity of the Near Surface Materials Criteria Weight 11
Figure 4. Pollution Sensitivity of the Bedrock Surface 12
Figure 5. Pollution Sensitivity of the Bedrock Surface Criteria Weight 13
Figure 6. Depth to Bedrock 14
Figure 7. Depth to Bedrock Criteria Weight 15
Figure 8. Recharge and Flow Through Lakes and Contributing Subwatersheds 16
Figure 9. Recharge and Flow Through Lakes and Contributing Subwatersheds Criteria Weight 17
Figure 10. Well Protection Areas 18
Figure 11. Well Protection Areas Criteria Weight 19
Figure 12. Surface Water Groundwater Interaction 20
Figure 13. Surface Water Groundwater Interaction Criteria Weight 21
Figure 14. Groundwater Recharge and Discharge Areas 22
Figure 15. Groundwater Recharge Protection Prioritization 23

Figure 16. Groundwater Recharge Protection Prioritization with Supplemental Data 24
Figure 17. Groundwater Recharge Protection Prioritization with Municipalities and Watershed Districts 25

A special thanks to the following who provided consultation and/or additional information for this analysis:

John Clark	Metropolitan Council
Jessica Collin-Pilarski	Washington County Public Health and Environment
John Hanson	Barr Engineering, Valley Branch Watershed District
Jennifer Kostrzewski	Metropolitan Council
John Loomis	South Washington Watershed District
Bob Tipping	Minnesota Department of Health
Ray Wuolo	Barr Engineering

1.0 Introduction

Groundwater is one of the most important natural resources in Washington County. Groundwater accounts for virtually all of the water supply used for drinking water, irrigation, and industrial use in the county (Washington County, 2014). Many of the lakes, streams, and wetlands in the county are dependent upon groundwater to sustain water levels and/or the aquatic life found in them, especially cold water resources like trout streams.

It is vitally important that groundwater is managed for both water quality and water quantity to protect water supplies for human use and the environment, which is identified as the overall goal of the county's 2014-2024 Groundwater Plan. Specifically, this analysis supports Strategies 4.2.4 and 4.2.6 of the Groundwater Plan, which are stated as:

> *"4.2.4: Build on previous groundwater and surface water studies, along with other available data, to inventory and rank groundwater recharge areas (including wetlands, lakes, streams, and fields) in the county. Include contamination potential, and distance to bedrock as part of the ranking criteria."*
>
> *"4.2.6: Collaborate with LGUs , the WCD, and WMOs to identify and preserve regional recharge areas. Encourage WMOs and LGUs to incorporate protection of recharge areas into plan, rule, and ordinance updates."*

Additionally, with regard to land use, the Washington County 2030 Comprehensive Plan states that development will be regulated such that groundwater quality and quantity are protected, with prevention of groundwater pollution as the highest priority. As such, this analysis will focus on prioritization of lands that contribute recharge to the groundwater system that should be protected by zoning, rule, policy, standards, easements, or other measures in order to preserve groundwater quality.

It is important to note that priority recharge areas identified in this analysis do not necessarily mean they are appropriate for focused recharge practices like rain gardens or infiltration basins, which can be used to help maintain recharge rates in developing areas. In some areas, such as those with karst geology or inside Drinking Water Supply Management Areas (DWSMAs), these practices are often prohibited due to their potential to contribute contaminants to the groundwater system. Shallow groundwater may also make focused recharge infeasible. Areas suitable for recharge by focused infiltration practices should be identified by further analysis or by referencing existing studies. Rather, this analysis should be viewed as an identification of lands that should be managed to prevent contamination of recharge water where there is a strong connection to the groundwater system.

2.0 Data Overview

The data used in this analysis are intended to form a compilation of available information on groundwater in the county to delineate important areas of recharge. Therefore, this analysis references a range of data produced by various studies in the region over a wide range of time.

2.1 Pollution Sensitivity of Near Surface Materials and the Bedrock Surface

Completed by the Minnesota Department of Natural Resources in 2018, Part B of the County Groundwater Atlas describes the hydrogeologic conditions of the county. The atlas provides information on surficial aquifers, buried sand and bedrock aquifers, groundwater chemistry, hydrogeologic cross sections, and pollution sensitivity.

Most applicable to this analysis is the pollution sensitivity information, specifically the pollution sensitivity of the near surface materials and the bedrock surface (Figures 2 and 4). According to the atlas, the pollution sensitivity of the near surface materials is determined by the texture of soils and surficial geologic material to a depth of 10 feet. This method assumes coarse grained materials like sand and gravel will transmit water faster than clays and silts. Sensitivity of the near surface materials is categorized by estimated travel time for the water to infiltrate, ranging from hours to centuries. This data is important to this analysis as it provides an estimate of how long it would take for a contaminant to reach a surficial aquifer.

Table 1. Pollution sensitivity ratings for near surface materials.

Sensitivity	Vertical Travel Time
Karst	Hours to Weeks or more Rapid Conduit Flow
High	Hours to Weeks
Moderate	Weeks
Low	Weeks to Months
Very Low	Months to Years

Similarly, the pollution sensitivity of the bedrock surface provides an estimate of time, ranging from hours to centuries, of how long it would take a contaminant to reach the bedrock surface, and begin moving into deeper bedrock aquifers. Sensitivity of the bedrock surface estimates the travel time for water to move through the cumulative thickness of fine grained sediments overlying the bedrock. For example, bedrock with only a thin layer of silt over it is more sensitive to pollution than bedrock that is overlain by alternating layers of sands, silts, and clays.

Table 2. Pollution sensitivity ratings for the bedrock surface.

Sensitivity	Vertical Travel Time	Cumulative Fine Grained Sediment Thickness (feet)
Very High	Hours to Weeks	0 to 10
High	Weeks to Years	>10 to 20
Moderate	Years to Decades	>20 to 30
Low	Decades to a Century	>30 to 40
Very Low	Centuries	>40

An important factor to note with these layers is the methods used to determine pollution sensitivity assumes water travels vertically to an aquifer, and horizontal flow is not considered (Berg, 2018). Significant horizontal flow occurs in much of the county, and while predicting flow paths for specific points, such as a well, is possible through additional analysis it would be impossible to determine all flow paths to all points of an aquifer.

Depth to the bedrock surface was also considered (Figure 6). Areas with shallow bedrock are considered to be more susceptible to pollution entering bedrock aquifers than areas where significant sediment deposits overlie the bedrock.

2.2 Known Groundwater Recharge Zones

Two studies, Integrating Groundwater and Surface Water Management- Northern Washington County and Integrating Groundwater and Surface Water Management- Southern Washington County were completed in 2002 and 2005, respectively. These studies provide a wealth of information on groundwater resources in the county, including descriptions of geology, climate, land use, sample chemistry, water levels, and inventories of groundwater dependent resources.

The studies used sample chemistry results, water level data, and other metrics to classify lakes with regard to their role in the groundwater system. To simplify, lakes were categorized as being recharge, flow through, discharge, or perched with respect to groundwater (Figure 8). Recharge lakes contribute surface water directly to the groundwater system, whereas discharge lakes receive water from the groundwater system. Flow through lakes exhibit water being recharged to the groundwater system in some areas of the lake bed, while other areas receive groundwater discharge. Perched lakes were considered mostly separated from the groundwater system, often due to underlying fine grained materials like silts and clays. Most important to this analysis are the recharge and flow through lakes, which provide direct conduits for contaminants to move into the groundwater system. Consultation with watershed district staff determined where additional focused recharge areas to be included, such as the CDP-85 infiltration area in South Washington Watershed District.

Also considered are subwatersheds that are likely to contribute overland flow to these lakes and basins (Figure 8). Contaminants on the land surface collected by runoff that enters these lakes are more likely to enter the groundwater system. Therefore, protection of these subwatersheds should be considered. Subwatershed data was obtained from individual watershed districts where recharge and flow through lakes occur. Typically these datasets are developed from LIDAR elevation data, and hydrocorrected to account for flow paths of culverts and stormwater pipes. Landlocked subwatersheds were removed wherever possible based on data available from the watershed districts.

Finally, the studies classified all areas of the county as being either recharge or discharge zones (Figure 14). The majority of the county area is considered a recharge zone, as a portion of precipitation that falls on the land surface will infiltrate to an aquifer in most cases. Notable groundwater discharge zones occur along the St. Croix River where springs and seeps are found, around groundwater dependent resources like Brown's Creek, Valley Creek, and Carnelian Creek, and wetlands in the northwest portion of the county. This analysis was limited to the county area defined as a recharge zone.

2.3 Well Protection Areas

Drinking Water Supply Management Areas (DWSMAs) and Emergency Response Areas (ERAs) were included in this analysis, available from the Minnesota Department of Health (Figure 10). Simply, DWSMAs define the 10 year capture zone for a water supply well, while the ERAs define the one year capture zone. Recharge areas that are in a DWSMA or ERA should be considered for protection as contaminants entering the groundwater system are likely to impact public water supplies. DWSMAs and ERAs are also subject to regulations regarding use of infiltration practices. For example, infiltration practices are generally prohibited unless a higher level of engineering finds them acceptable, according to the Minnesota Pollution Control Agency. DWSMA vulnerability rating data are available as well, but were not used in this analysis since they are generally comparable to the pollution sensitivity ratings of the near surface materials.

2.4 Potential for Surface Water and Groundwater Interaction

Understanding where connections between surface water and groundwater are likely to occur is also important to this analysis. The Metropolitan Council completed the study, Interactions of Groundwater and Surface Water Resources, Phase 1, in 2020. The study compares the calculated travel time of water to move through subsurface materials based on texture and conductivity, and groundwater chemistry samples to determine if there is a high, low, or indeterminate potential for hydraulic connection between surface waters and groundwater of the metro region (Figure 12). Groundwater chemistry samples can help estimate age of groundwater if anthropogenic compounds are present or not. For example, elevated levels of tritium from atmospheric nuclear bomb testing in the 1960s can indicate groundwater is less than 60 years old. Nitrate, chloride, and chloride/bromide ratios were also used to estimate if human impacted surface waters have entered the groundwater system.

Agreement or disagreement between the methods can indicate the potential for hydraulic connection. For instance, if the calculated water travel time based on hydrogeologic properties of sediments is short and chemistry shows groundwater is young, the methods agree and there is a high potential for hydraulic connection between surface water and groundwater. Conversely, if the travel time is long and samples indicate vintage groundwater, there is low potential. If the methods disagree the connection is indeterminate, meaning there may be complex groundwater flow paths that are not able to be detected by the analysis.

This analysis considers the areas with high and indeterminate potential for surface and groundwater interaction most important. These areas indicate there is a higher likelihood of contaminants reaching the groundwater system than those with low potential.

2.5 Supplemental Data

In order to provide additional information when considering lands to be managed to protect recharge, the following layers are included as overlays on the final map in Figure 16.

Bedrock faults: Fault lines can be important conduits for recharge water and have significant influence on groundwater flow paths (Berg, 2018). Lands adjacent to these faults may be a higher priority for protection.

Decorah Shale and Platteville-Glenwood Formation confining units: These layers of low permeability bedrock act as a seal over the porous Prairie du Chien Group and Jordan Sandstone aquifers in the southwestern part of the county (Tipping, 2012). Recharge to deeper aquifers is likely reduced where these layers are present.

Impervious surfaces: Areas that have greater than 75% impervious cover (parking lots, buildings, roadways, etc.) as described by the Minnesota Land Cover Classification System, updated for Washington County in 2017, likely have reduced recharge rates to shallow aquifers. However, these areas were not be removed from the recharge analysis as many of them have stormwater management features that do provide recharge.

Lakes and Streams: Proximity of lakes and streams may influence prioritization decisions. In many cases, the residence time of groundwater before discharging to some water bodies, like the St. Croix River or Valley Creek, will be less than that of groundwater being recharged in aquifers far away from a discharge area. Therefore, recharge zones with long groundwater residence times away from discharge zones may be a higher protection priority.

3.0 Recharge Zone Prioritization Methodology

Using the sources of data described above, a weighted overlay model was developed to complete this analysis (Figure 1). Careful consideration were given to each data source after consultation with county, watershed, and state agency staff.

Each of the datasets were converted to raster formats, and reclassified to assign relative weights of importance to classes of values within each layer with respect to their influence on groundwater recharge (Figures 3-13). The layers were then overlayed, and the weights summed to produce a final score. To simplify interpretation of the output, prioritization scores were divided into five classes from Very Low to Very High.

The weights assigned to each layer can be seen below in Table 3, and the prioritization model can be seen in Figure 1. Individual layers and their corresponding criteria weights can be seen in Figures 2 through 14.

Table 3. Criteria weights for groundwater recharge protection prioritization.

Layer	Criteria Weight	Layer	Criteria Weight
Sensitivity of the Near Surface Materials		**Recharge and Flow Through Lakes**	
Karst	3	Recharge	3
High	2	Flow Through	2
Moderate	1		
Low and Very Low	0		
Sensitivity of the Bedrock Surface		**Recharge and Flow Through Lake Subwatersheds**	
Very High	3	Recharge	2
High	2	Flow Through	1
Moderate	1		
Low and Very Low	0		
Depth to Bedrock (feet)		**Potential for Surface and Groundwater Interaction**	
1 to 50	2	High	2
51 to 100	1	Indeterminate	1
>100	0	Low	0
Well Protection Areas			
Emergency Response Area	3		
DWSMA	1		

4.0 Prioritization Results

The final groundwater recharge zone prioritization map can be found in Figure 15. In order to better inform groundwater recharge management decisions, the supplemental information described above is displayed over the prioritization scores in Figure 16. An overlay of municipalities and watershed management organizations on the prioritized areas is available in Figure 17.

The results of this prioritization show that much of the recharge area most important to protect to prevent groundwater contamination occur in the southern half of the county, especially in Cottage Grove, Woodbury, Afton, and Denmark Township. Karst geology, shallow, sensitive bedrock, and sensitive near surface materials are the primary drivers for the prioritization of this area. A table of the prioritized recharge areas broken out by municipality can be seen in Table 4.

Table 4. Groundwater recharge protection prioritization areas by municipality.

	0 Very Low		1-3 Low		4-6 Moderate		7-9 High		10-16 Very High	
	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent
Afton	0	0.00%	608	0.27%	2,093	0.94%	7,703	3.47%	5,178	2.33%
Bayport	0	0.00%	21	0.01%	201	0.09%	254	0.11%	123	0.06%
Baytown	1	0.00%	1,109	0.50%	2,100	0.95%	1,609	0.72%	461	0.21%
Birchwood Village	0	0.00%	0	0.00%	56	0.03%	120	0.05%	38	0.02%
Cottage Grove	39	0.02%	420	0.19%	2,895	1.30%	8,739	3.94%	9,210	4.15%
Dellwood	0	0.00%	1,052	0.47%	500	0.23%	48	0.02%	0	0.00%
Denmark	2	0.00%	189	0.08%	678	0.31%	6,225	2.80%	10,667	4.81%
Forest Lake	36	0.02%	4,084	1.84%	354	0.16%	12	0.01%	0	0.00%
Grant	0	0.00%	9,665	4.35%	5,366	2.42%	1,194	0.54%	86	0.04%
Grey Cloud	3	0.00%	118	0.05%	210	0.09%	708	0.32%	204	0.09%
Hastings	0	0.00%	51	0.02%	32	0.01%	10	0.00%	0	0.00%
Hugo	56	0.03%	10,486	4.72%	5,304	2.39%	751	0.34%	73	0.03%
Lake Elmo	0	0.00%	2,198	0.99%	7,797	3.51%	4,081	1.84%	1,063	0.48%
Lake St. Croix Beach	0	0.00%	4	0.00%	80	0.04%	268	0.12%	0	0.00%
Lakeland	0	0.00%	63	0.03%	567	0.26%	570	0.26%	25	0.01%
Lakeland Shores	0	0.00%	20	0.01%	161	0.07%	1	0.00%	0	0.00%
Landfall	0	0.00%	0	0.00%	0	0.00%	29	0.01%	24	0.01%
Mahtomedi	0	0.00%	165	0.07%	1,315	0.59%	700	0.32%	211	0.09%
Marine on St. Croix	0	0.00%	176	0.08%	614	0.28%	632	0.28%	56	0.03%
May Township	0	0.00%	9,365	4.22%	7,803	3.52%	3,363	1.52%	260	0.12%
Newport	0	0.00%	23	0.01%	395	0.18%	625	0.28%	986	0.44%
Oak Park Heights	0	0.00%	139	0.06%	626	0.28%	521	0.23%	297	0.13%
Oakdale	0	0.00%	355	0.16%	4,756	2.14%	1,500	0.68%	583	0.26%
Pine Springs	0	0.00%	198	0.09%	339	0.15%	41	0.02%	1	0.00%
Scandia	0	0.00%	14,192	6.39%	6,233	2.81%	1,392	0.63%	365	0.16%
St. Paul Park	36	0.02%	16	0.01%	24	0.01%	782	0.35%	1,101	0.50%
St. Mary's Point	0	0.00%	21	0.01%	204	0.09%	8	0.00%	0	0.00%
Stillwater Township	0	0.00%	2,983	1.34%	3,092	1.39%	1,191	0.54%	200	0.09%
Stillwater	0	0.00%	984	0.44%	1,890	0.85%	1,265	0.57%	969	0.44%
West Lakeland	0	0.00%	305	0.14%	2,165	0.98%	3,712	1.67%	1,732	0.78%
White Bear	0	0.00%	0	0.00%	0	0.00%	35	0.02%	9	0.00%
Willernie	0	0.00%	10	0.00%	74	0.03%	0	0.00%	0	0.00%
Woodbury	0	0.00%	636	0.29%	6,036	2.72%	7,921	3.57%	8,243	3.71%
Total	173	0.08%	59,657	26.88%	63,958	28.81%	56,009	25.23%	42,164	19.00%

Percentages are of the total county area classified as recharge. Excludes all discharge areas.

To reiterate, the lands prioritized in this analysis should be viewed as those that would be most beneficial to protect by zoning, rule, policy, standards, easements, or other measures to prevent contamination of groundwater. Siting for implementation of focused recharge practices, such as regional infiltration areas, should be determined through other analyses or by referencing other studies, such as Metropolitan Council's Regional Groundwater Recharge and Stormwater Capture and Reuse Study (2016). Methods such as those used in the Groundwater/Surface Water Interaction Study (Barr, 2015) could also be used to identify sites for focused recharge practices.

5.0 References

Barr Engineering Company, Washington County and Washington Conservation District. 2005. Integrating Surface Water and Groundwater Management – Southern Washington County. https://www.co.washington.mn.us/DocumentCenter/View/730/Integrating-Groundwater-and-Surface-Water-Management?bidId

Barr Engineering Company. 2015. Groundwater/Surface Water Interaction Study. Prepared for Ramsey Washington Metro Watershed District.

Bauer, Emily J. 2016. Geologic atlas of Washington County, Minnesota (Part A): Minnesota Geological Survey. County Atlas Series C-39, Plates 1-6.

Berg, J.A. 2018. Geologic atlas of Washington County, Minnesota (Part B): Minnesota Department of Natural Resources. County Atlas Series C-39, Report and Plates 7-9.

Emmons and Olivier Resources, Inc. (EOR). 2003. Integrating Surface Water and Groundwater Management – Northern Washington County. https://www.co.washington.mn.us/DocumentCenter/View/733/Integrating-Groundwater-and-Surface-Water-Management---North-Washington-County?bidId

Metropolitan Council. 2016. Regional Groundwater Recharge and Stormwater Capture and Reuse Study: North and East Metro Study Area. Prepared by HDR. Metropolitan Council: St. Paul, MN. https://metrocouncil.org/Wastewater-Water/Publications-And-Resources/WATER-SUPPLY-PLANNING/OTHER/Regional-Groundwater-2016.aspx

Metropolitan Council. 2020. Interactions of Groundwater and Surface Water Resources. Phase 1: Potential hydraulic connections between bedrock aquifers and surface water in the Twin Cities Metropolitan Region. Metropolitan Council Environmental Services: Water Supply Planning, St. Paul, MN. https://metrocouncil.org/Wastewater-Water/Publications-And-Resources/WATER-SUPPLY-PLANNING/GROUNDWATER-SURFACE-WATER/Interactions-of-Groundwater-and-Surface-Water-Reso.aspx

Tipping, Robert. 2012. Characterizing Groundwater Flow in the Twin Cities Metropolitan Area, Minnesota: A Chemical and Hydrostratigraphic Approach.; http://conservancy.umn.edu/bitstream/132004/1/Tipping_umn_0130E_12804.pdf

Washington County. 2010. Washington County 2030 Comprehensive Plan. Adopted by Board of Commissioners September 7, 2010. https://www.co.washington.mn.us/DocumentCenter/View/21955/Washington-County-2040-Comprehensive-Plan-?bidId=

Washington County. 2014. Washington County Groundwater Plan 2014-2024. https://www.co.washington.mn.us/DocumentCenter/View/794/Groundwater-Plan-2014-2024?bidId

6.0 Figures

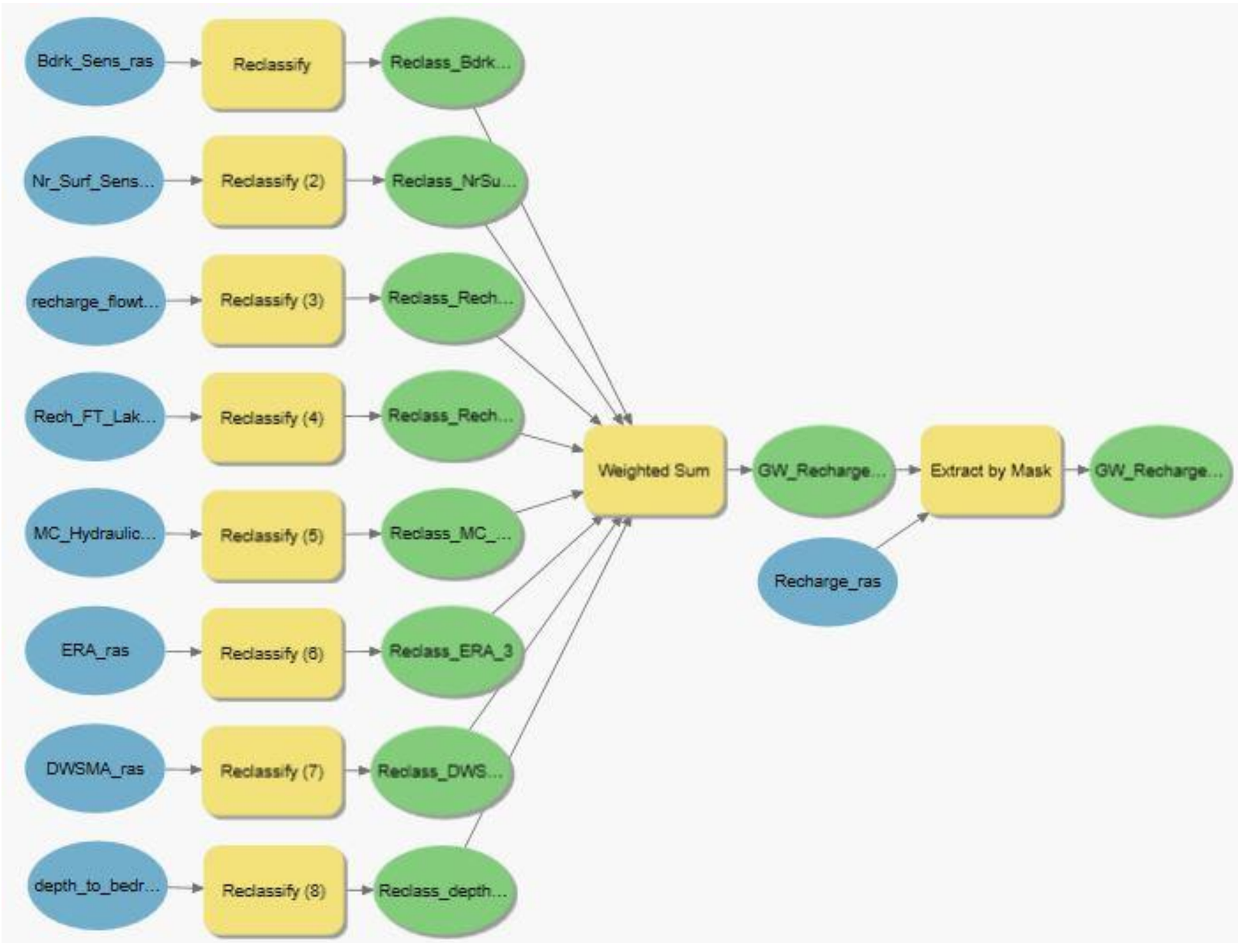


Figure 1. Groundwater Recharge Area Prioritization Model

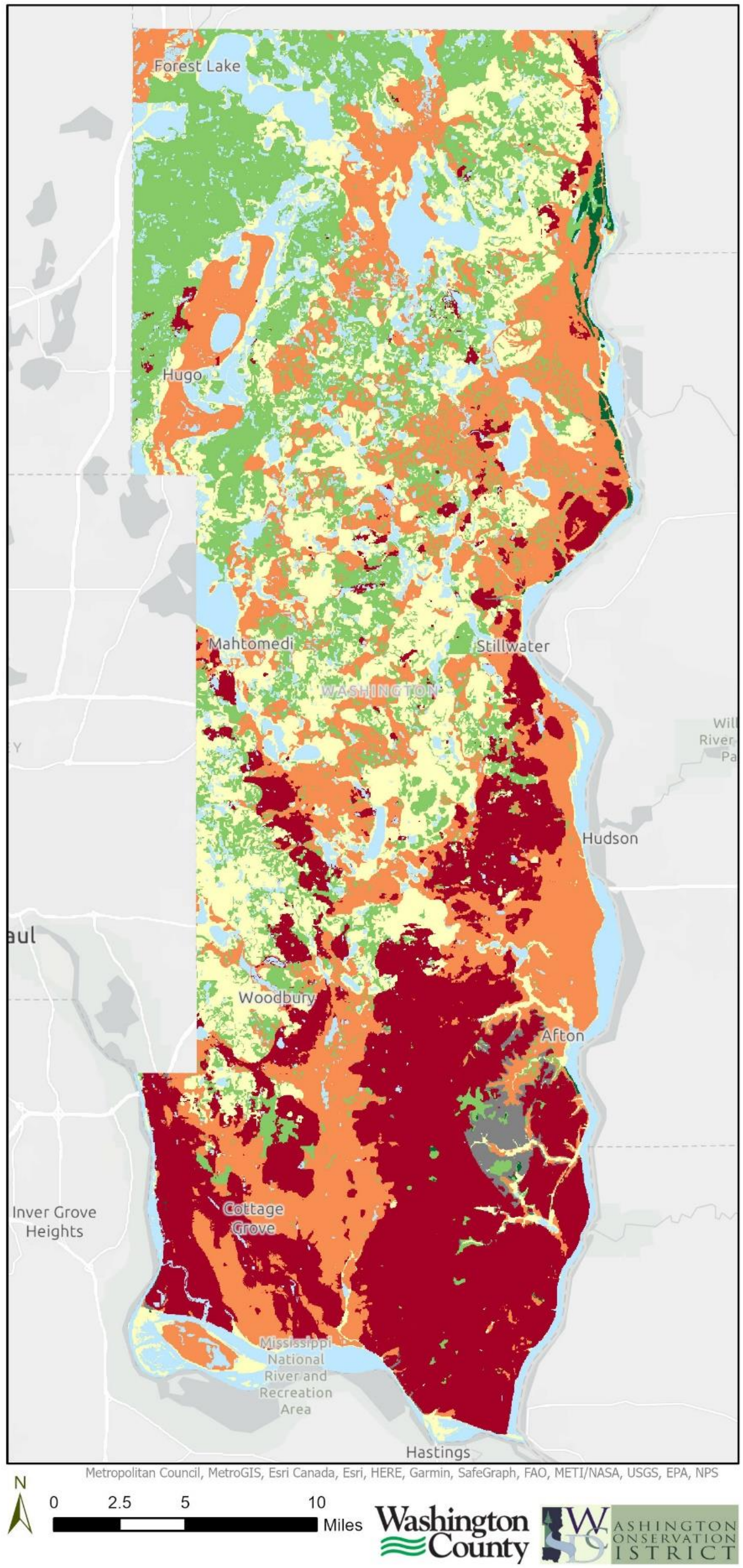


Figure 2. Pollution Sensitivity of the Near Surface Materials

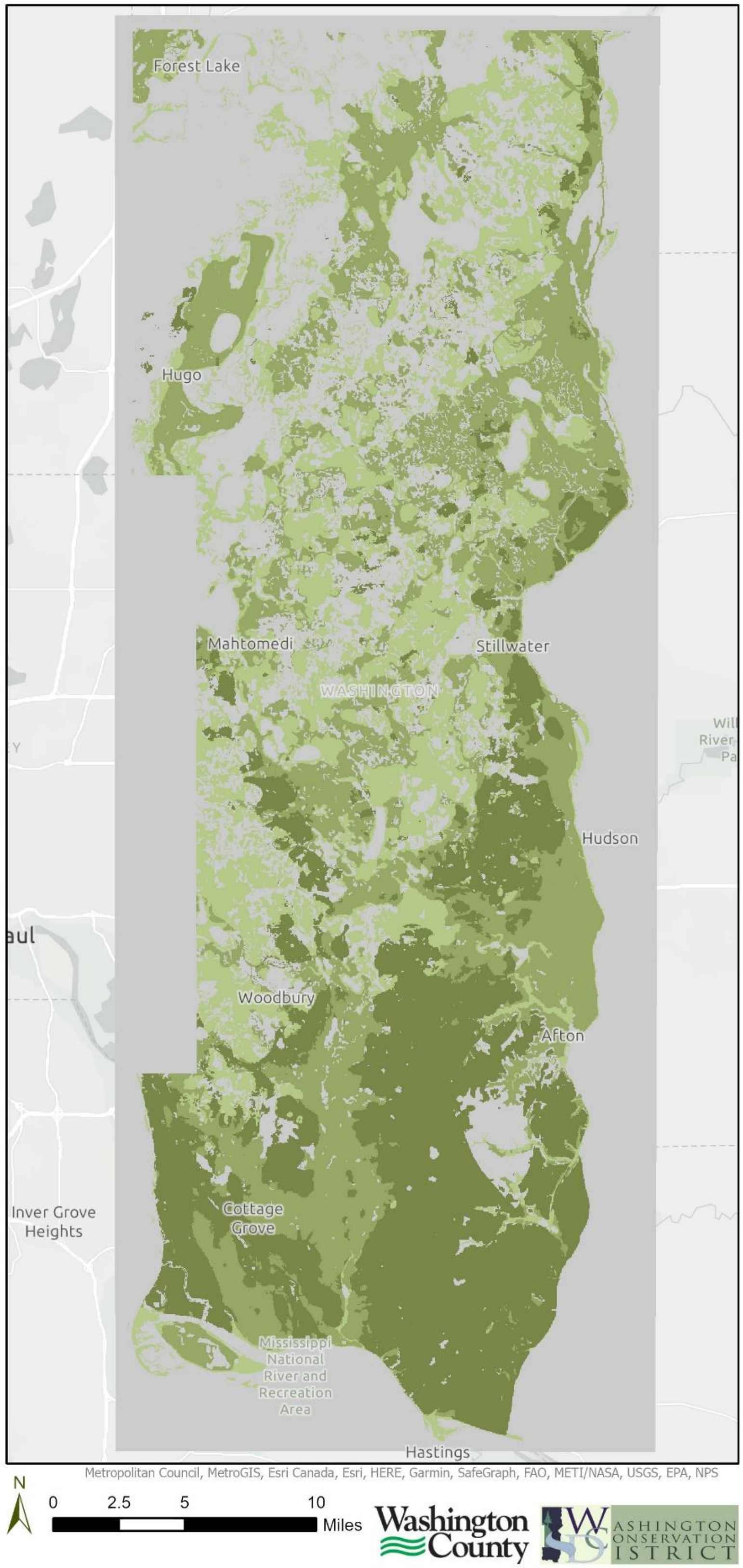
Sensitivity Rating
- Karst
- High
- Moderate
- Low
- Very Low
- Water
- Bedrock at Surface

Data Sources:
Minnesota Department of Natural Resources

Figure 3. Pollution Sensitivity of the Near Surface Materials Criteria Weight

Sensitivity Criteria Weight

- 0
- 1
- 2
- 3



Data Sources:
Minnesota Department of Natural Resources

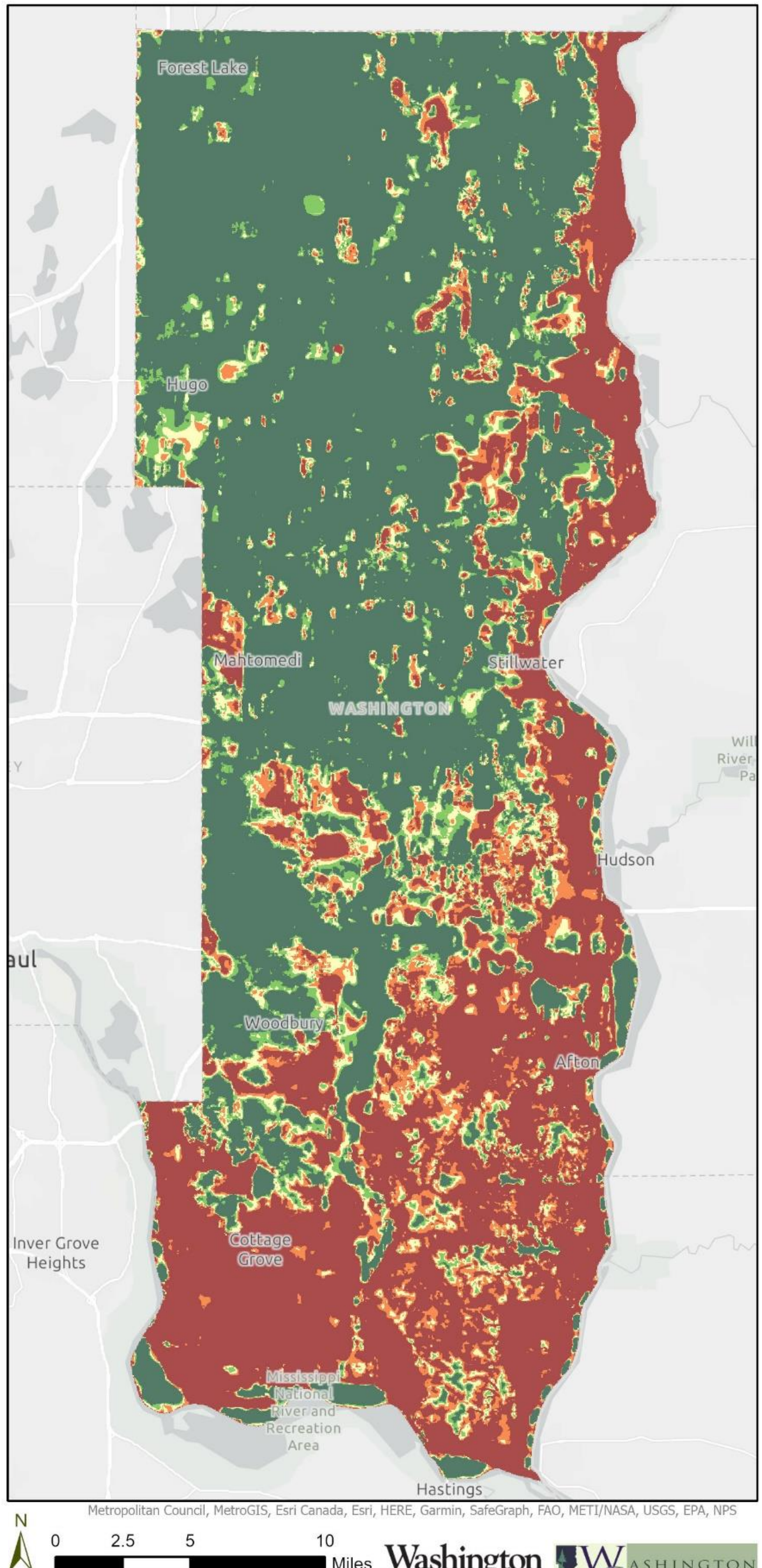


Figure 4. Pollution Sensitivity of the Bedrock Surface

Sensitivity Rating

- Very High
- High
- Moderate
- Low
- Very Low

Data Sources:
Minnesota Department of Natural Resources

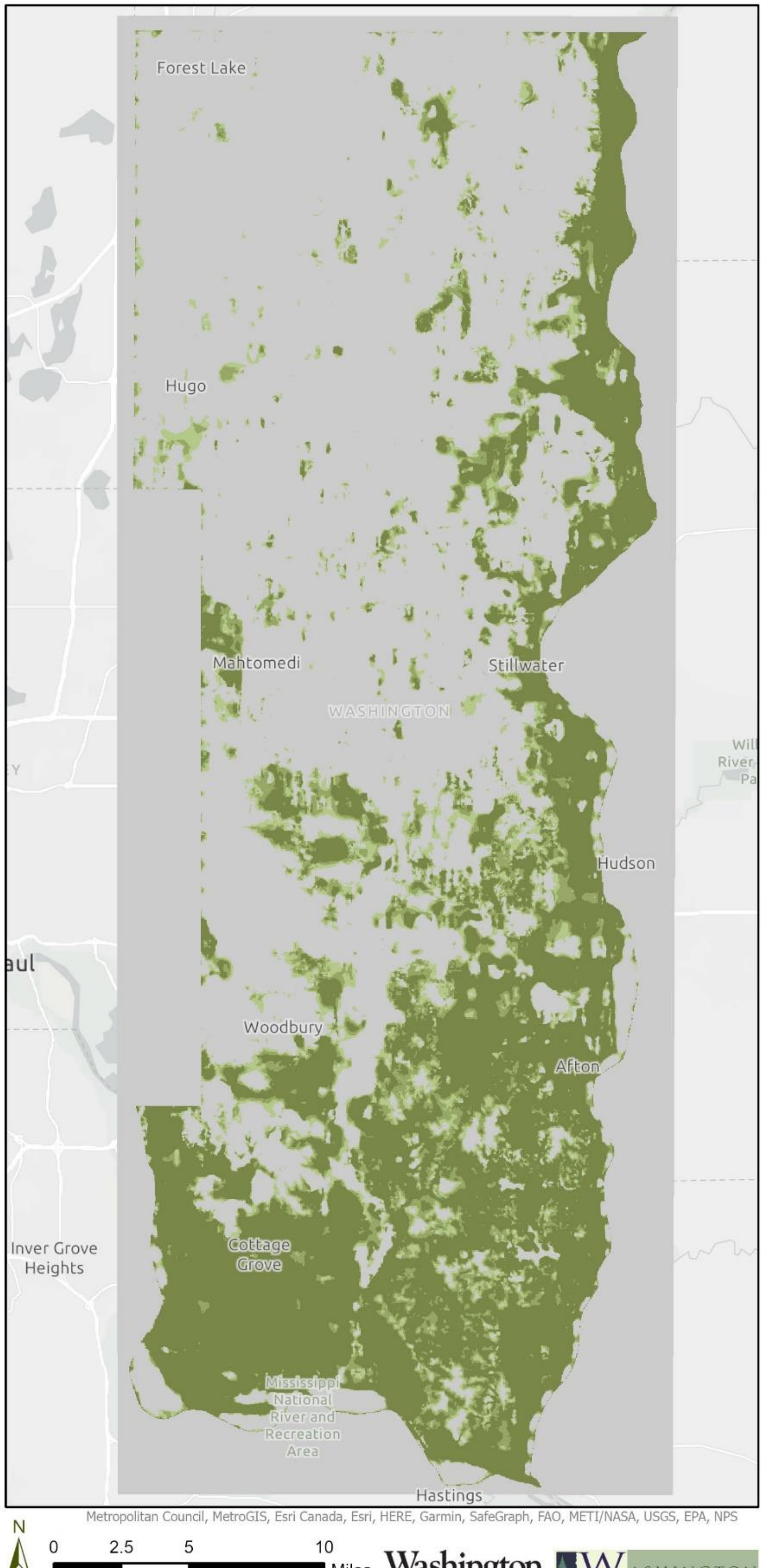


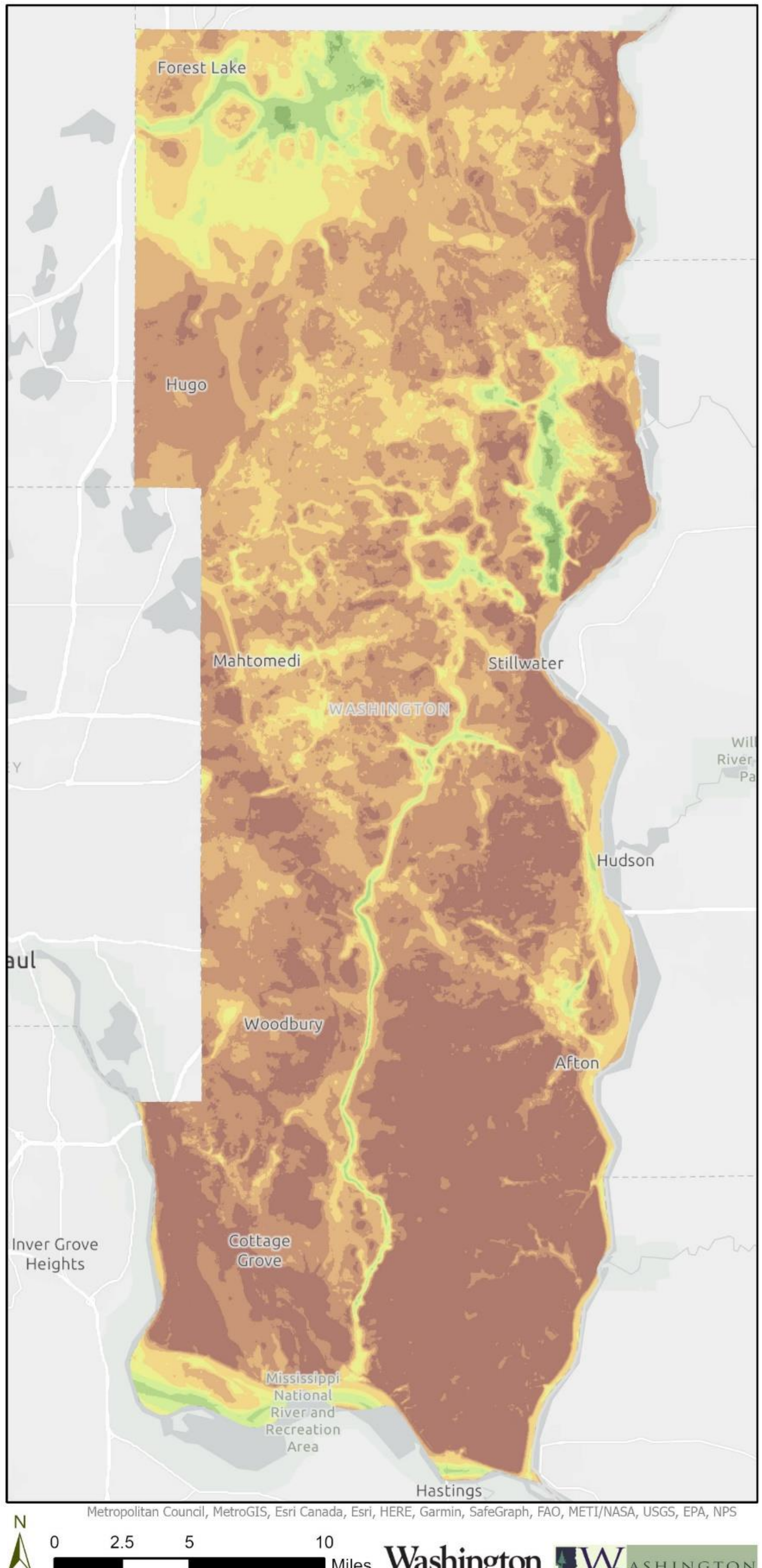
Figure 5. Pollution Sensitivity of the Bedrock Surface Criteria Weight

Sensitivity Criteria Weight

- 0
- 1
- 2
- 3

Data Sources:
Minnesota Department of Natural Resources

Figure 6. Depth to Bedrock



Depth to Bedrock (Feet)

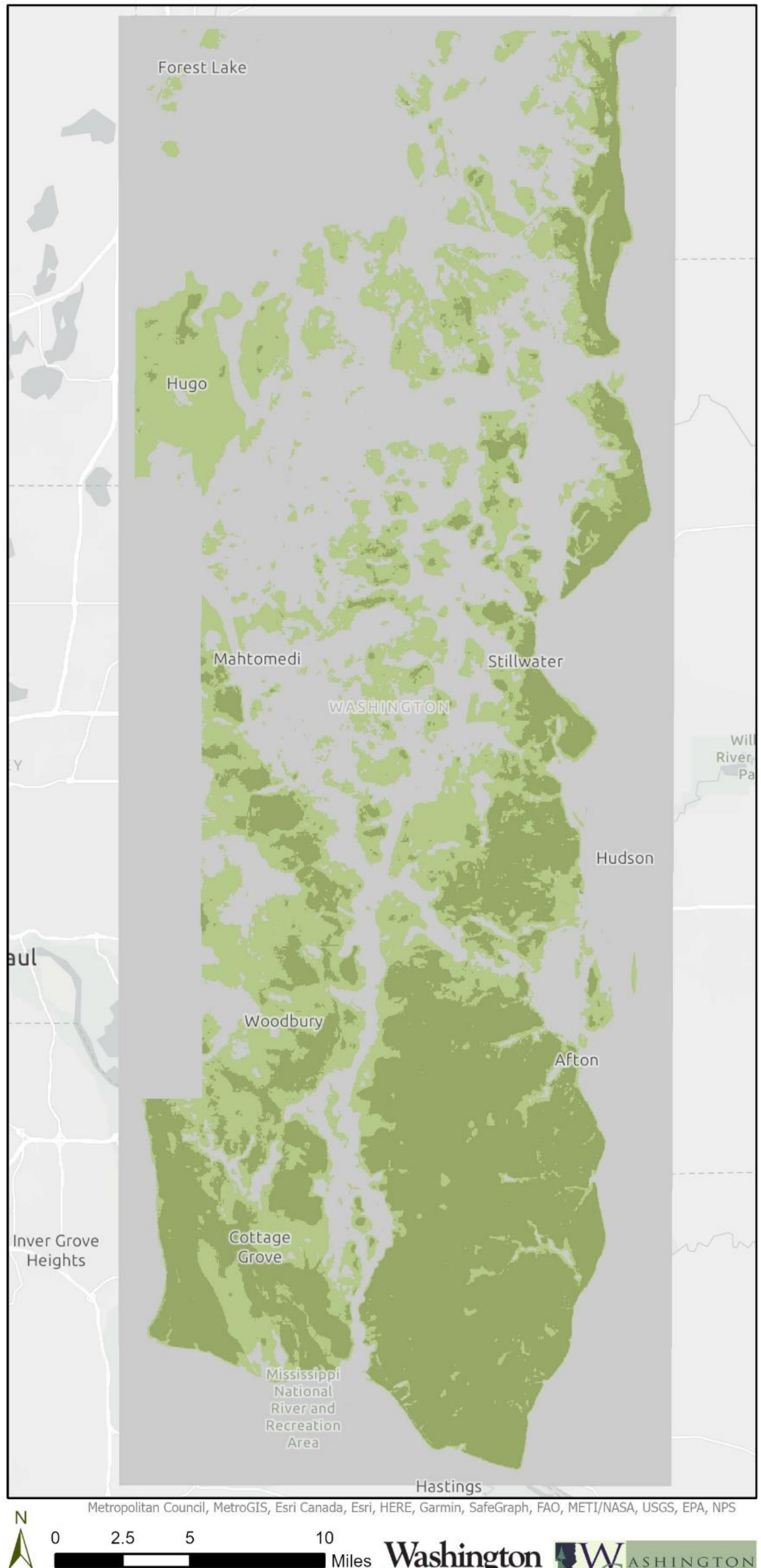
- 1-50
- 51-100
- 101-150
- 151-200
- 201-250
- 251-300
- 301-350
- 351-400
- 401-450

Data Sources:
Minnesota Geological Survey

Figure 7. Depth to Bedrock Criteria Weight

Depth to Bedrock Criteria Weight

- 0
- 1
- 2



Data Sources:
Minnesota Geological Survey

Washington County

Washington Conservation District

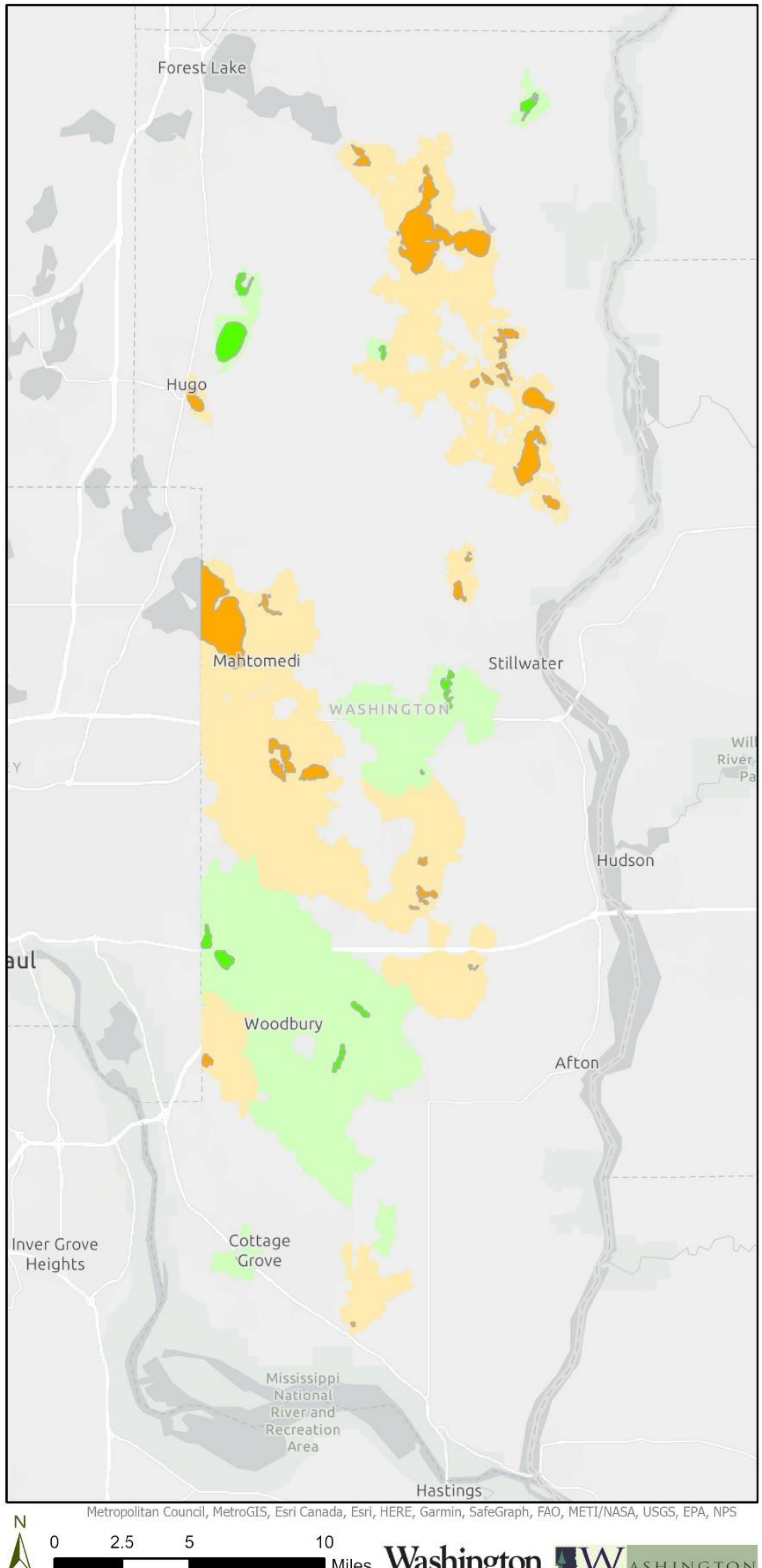


Figure 8. Recharge and Flow Through Lakes and Contributing Subwatersheds

Recharge & Flow Through Lakes

- Flow Through
- Recharge

Recharge & Flow Through Lake Subwatersheds

- Flow Through
- Recharge

Data Sources:
Washington County, Comfort Lake Forest Lake Watershed District, Carnelian Marine St. Croix Watershed District, Rice Creek Watershed District, Brown's Creek Watershed District, Valley Branch Watershed District, Ramsey Washington Metro Watershed District, South Washington Watershed District

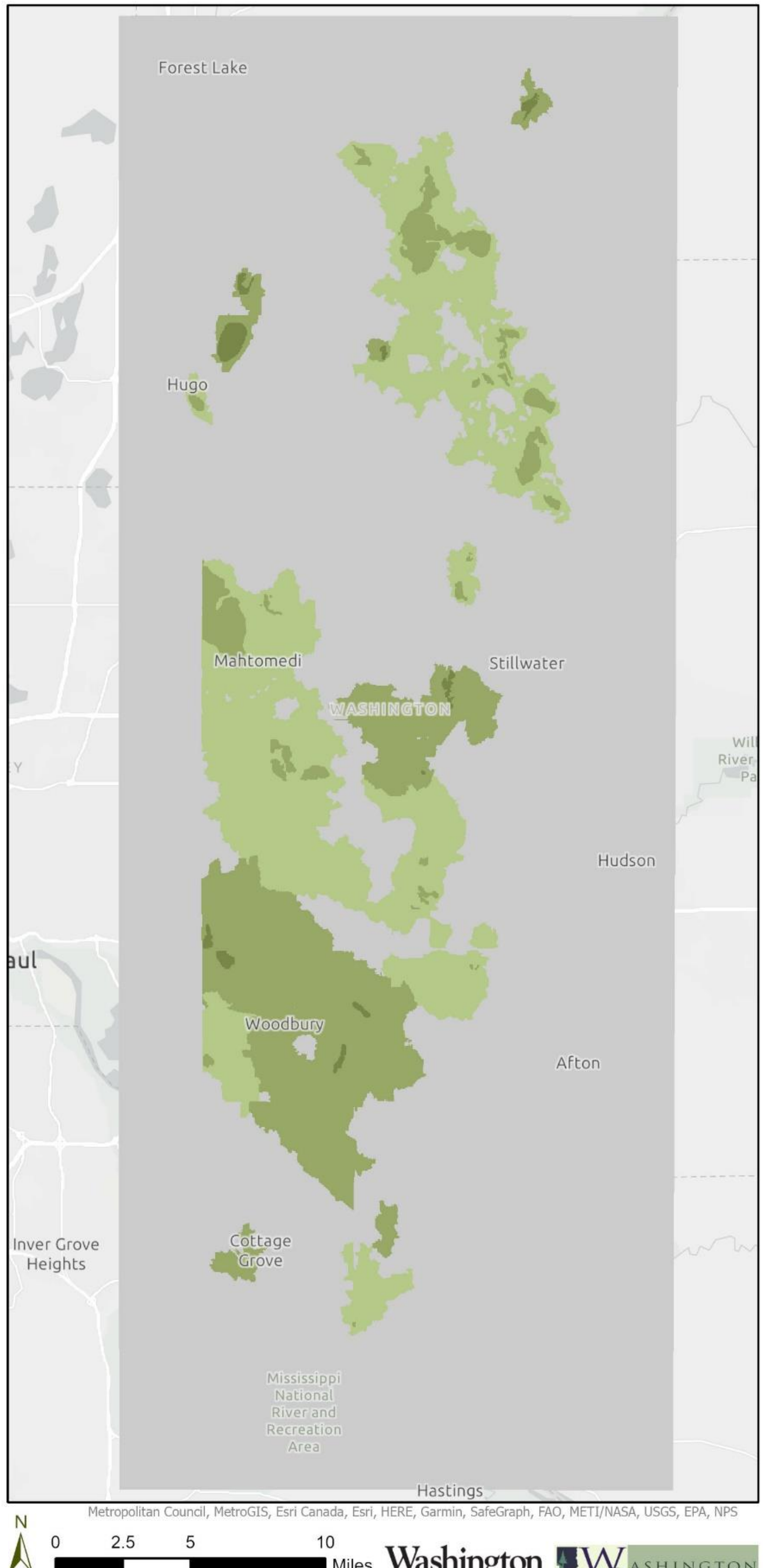


Figure 9. Recharge and Flow Through Lakes and Contributing Subwatersheds Criteria Weight

Recharge and Flow Through Lake Criteria Weight

- 2
- 3

Recharge and Flow Through Subwatershed Criteria Weight

- 0
- 1
- 2

Data Sources:
Washington County, Comfort Lake Forest Lake Watershed District, Carnelian Marine St. Croix Watershed District, Rice Creek Watershed District, Brown's Creek Watershed District, Valley Branch Watershed District, Ramsey Washington Metro Watershed District, South Washington Watershed District

Washington County

Washington Conservation District

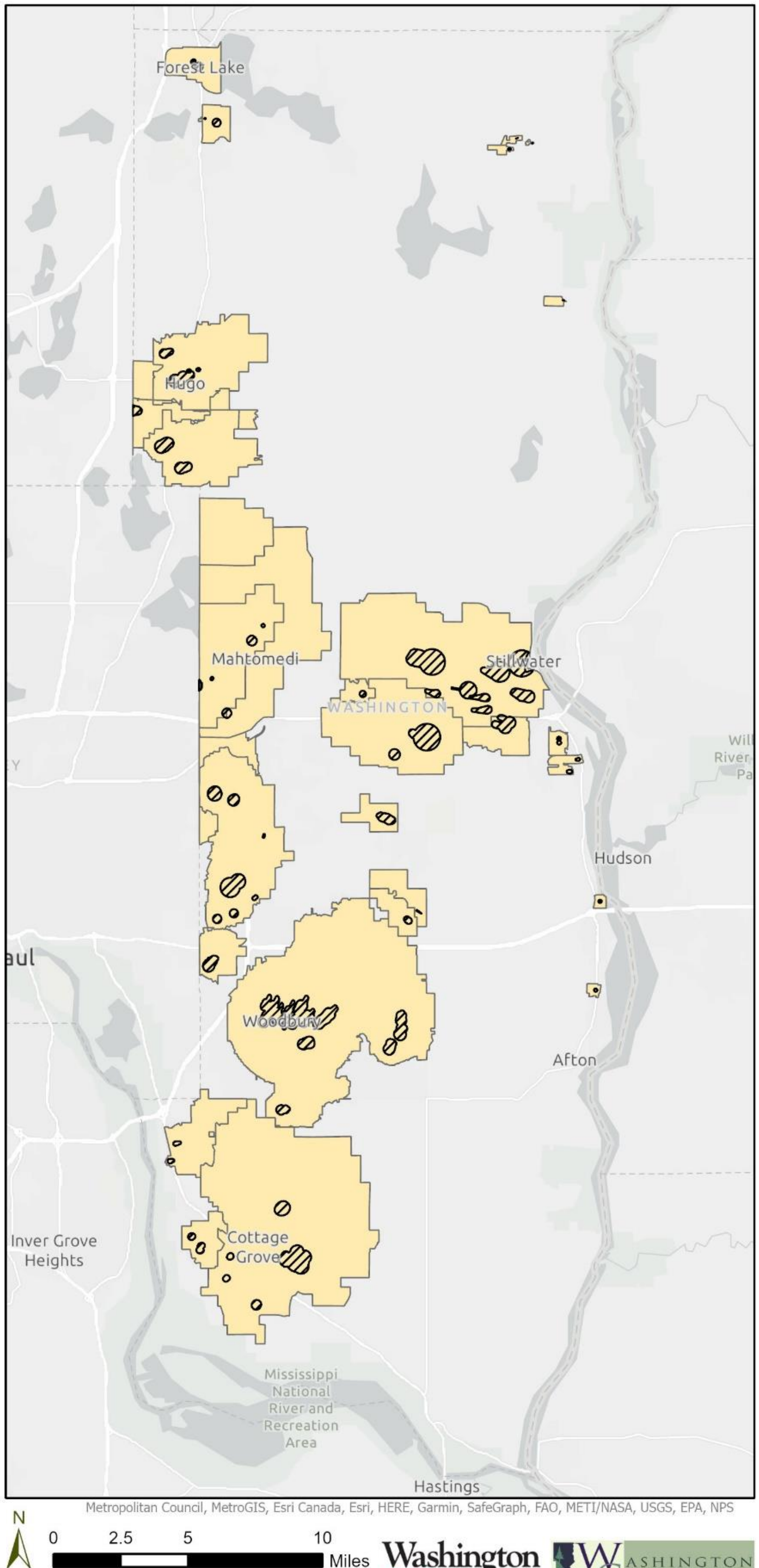


Figure 10. Well Protection Areas

Emergency Response Areas

Drinking Water Supply Management Areas

Data Sources:
Minnesota Department of Health

Washington County

Washington Conservation District

Figure 11. Well Protection Areas Criteria Weights

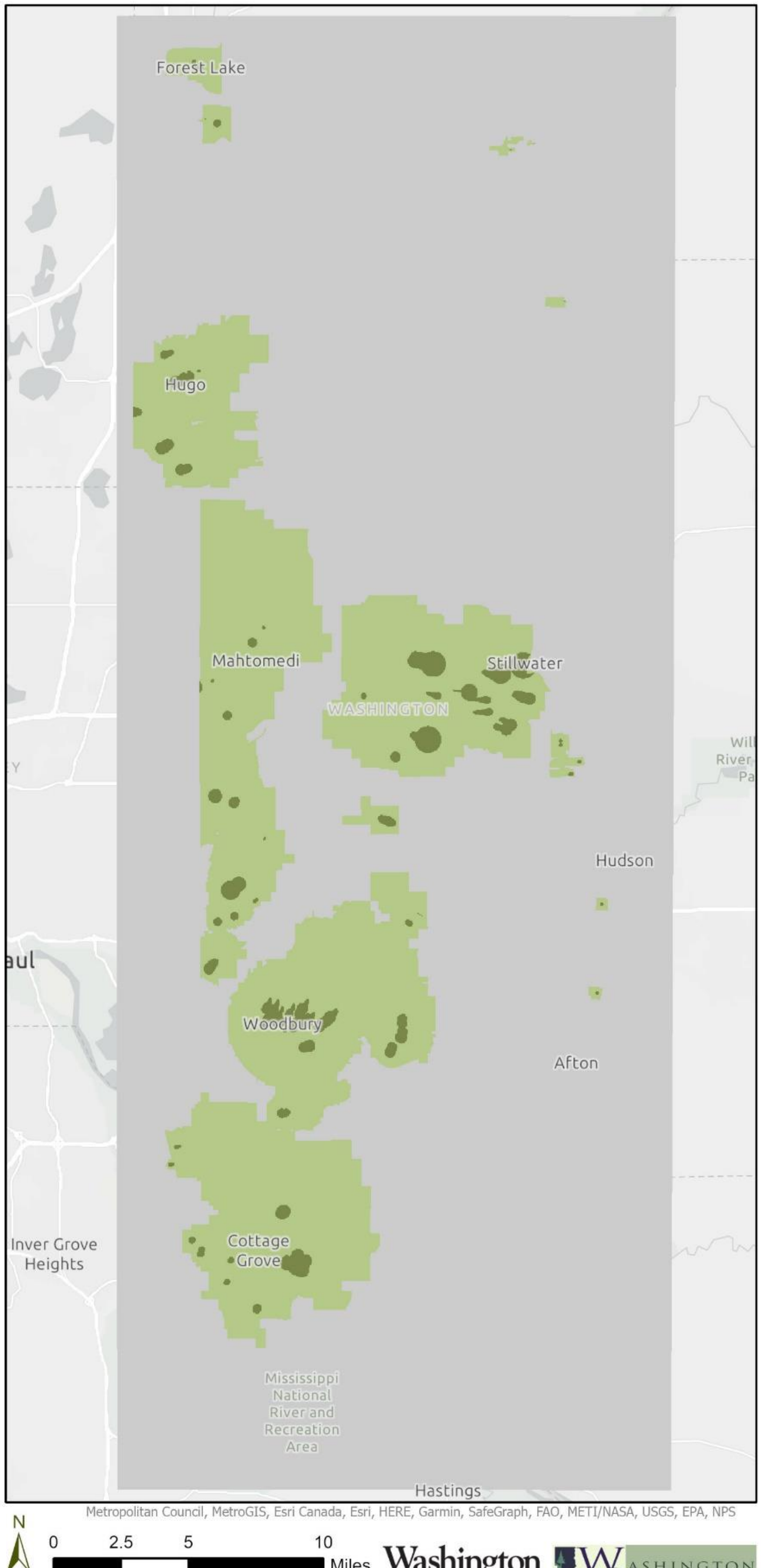
Drinking Water Supply Management Area Criteria Weight

0

1

Emergency Response Area Criteria Weight

3

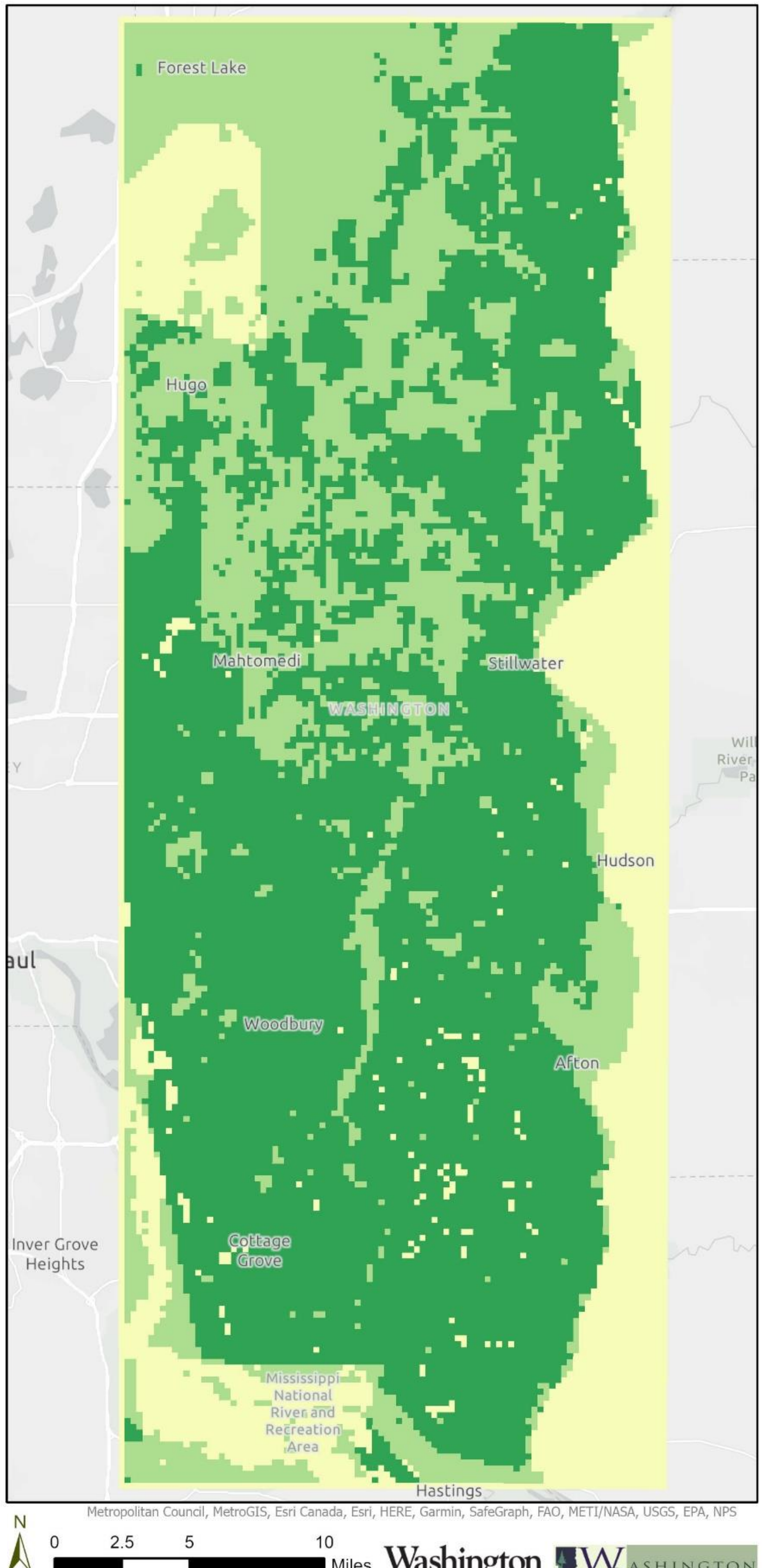


Data Sources:
Minnesota Department of Health

Figure 12. Surface Water Groundwater Interaction

Potential for Surface Water Groundwater Connection

- High
- Indeterminate
- Low



Data Sources:
Metropolitan Council

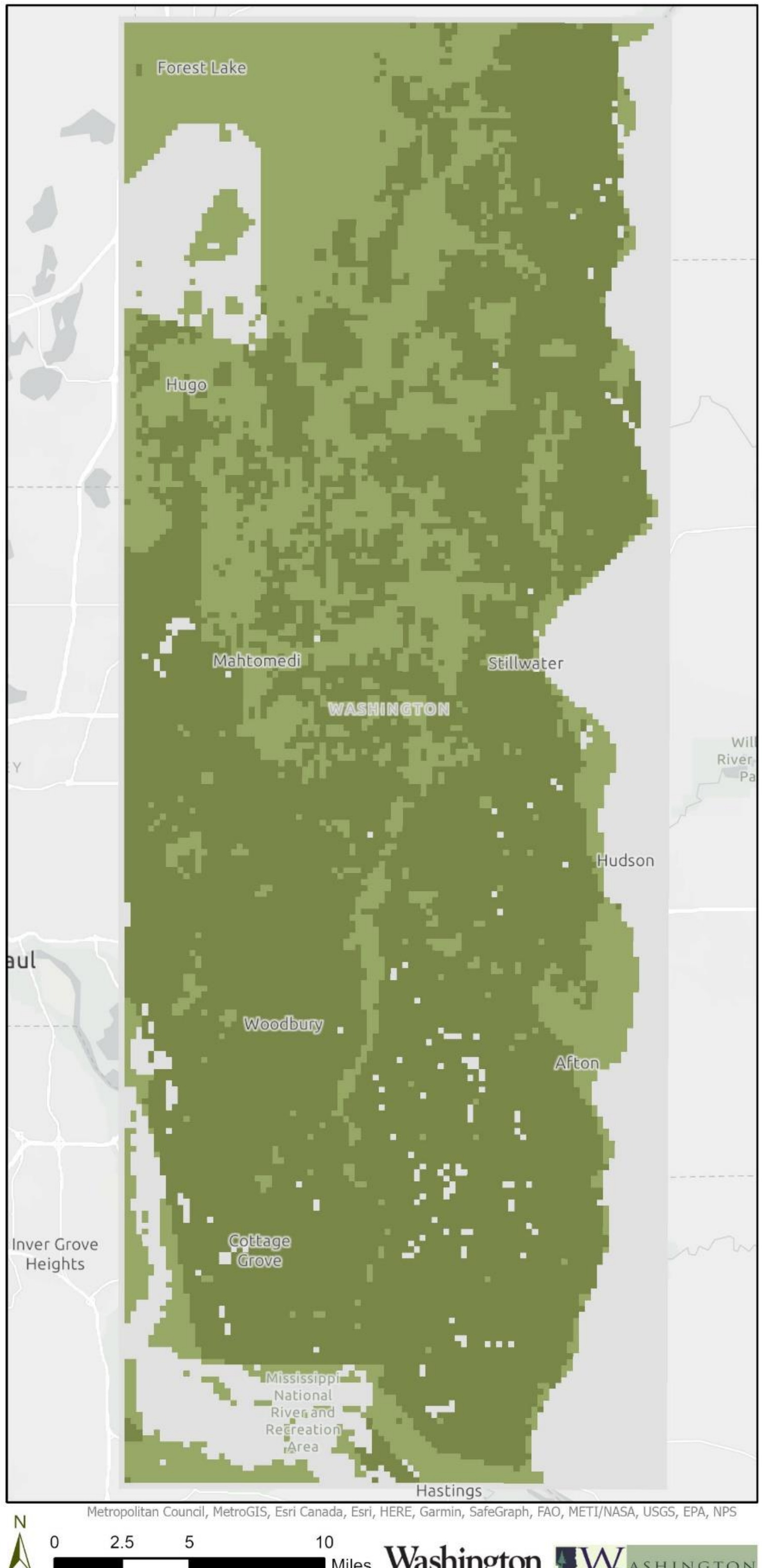


Figure 13. Surface Water Groundwater Interaction Criteria Weight

Potential for Surface Water Groundwater Connection Criteria Weight

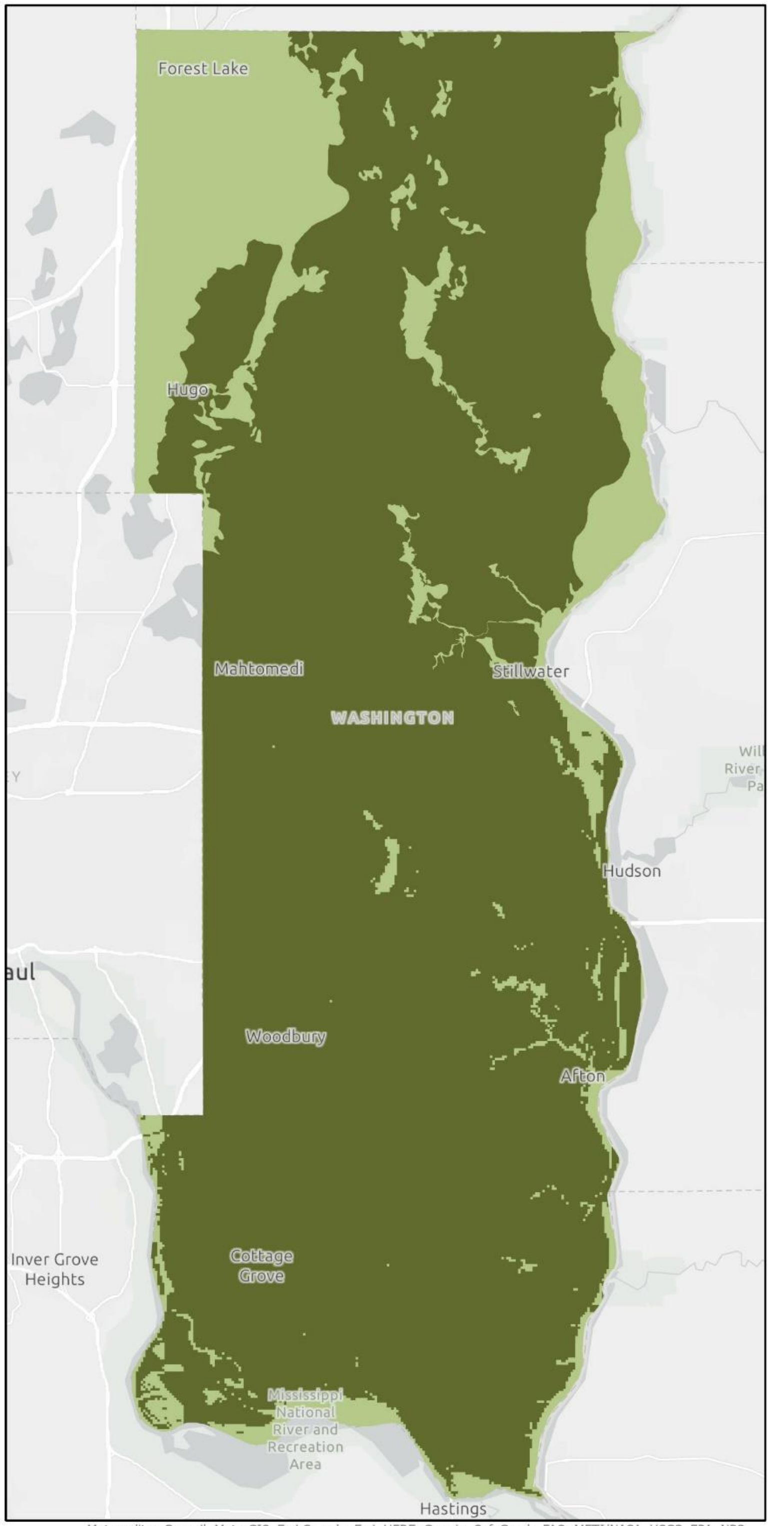
- 0
- 1
- 2

Data Sources:
Metropolitan Council

Figure 14. Groundwater Recharge and Discharge Areas

Groundwater Role

- Recharge
- Discharge



Metropolitan Council, MetroGIS, Esri Canada, Esri, HERE, Garmin, SafeGraph, FAO, METI/NASA, USGS, EPA, NPS

N

0 2.5 5 10 Miles

Washington County

Washington Conservation District

Data Sources:
Washington County

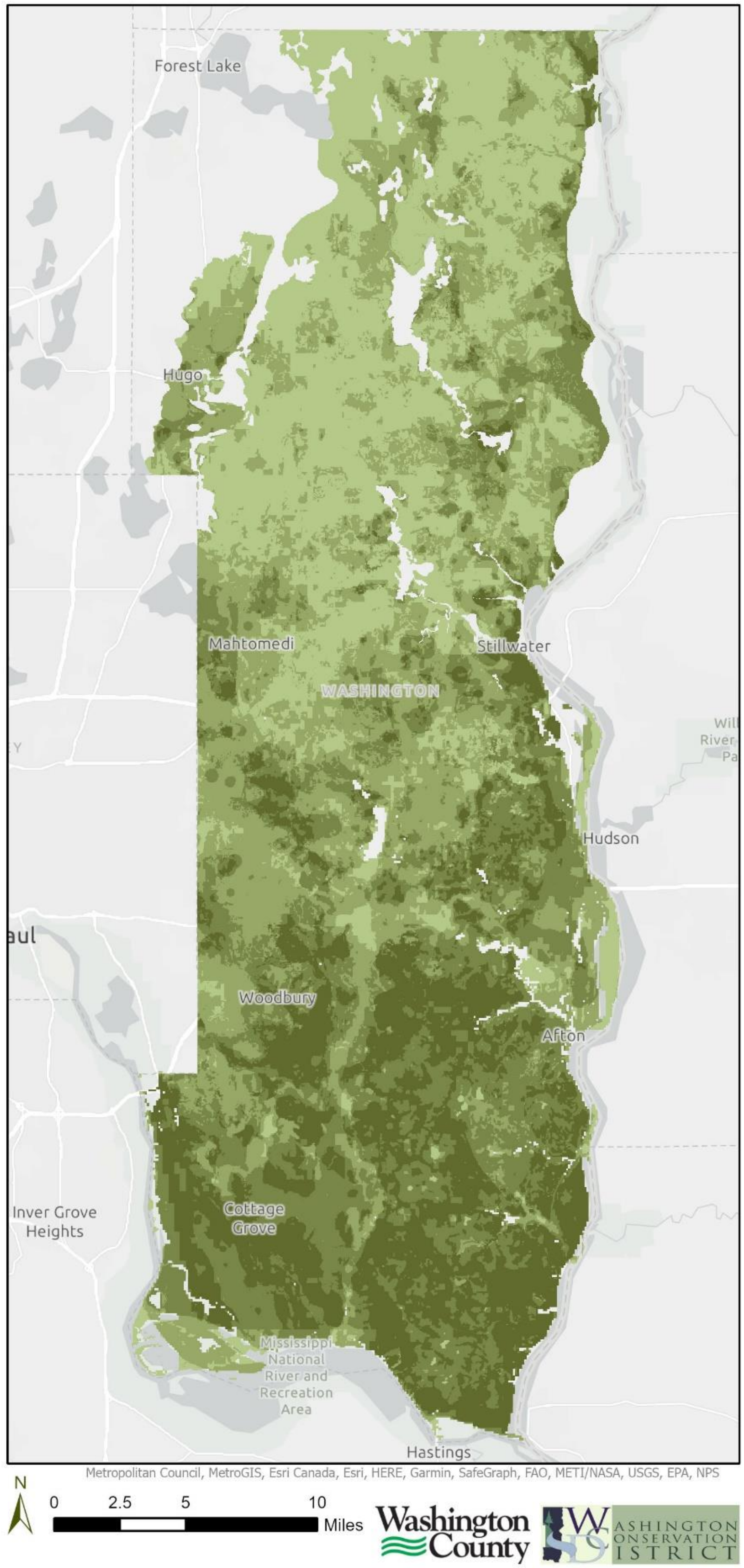


Figure 15. Groundwater Recharge Protection Prioritization

Prioritization Score

- 0 Very Low
- 1-3 Low
- 4-6 Moderate
- 7-9 High
- 10-16 Very High

Data Sources:
Washington Conservation District

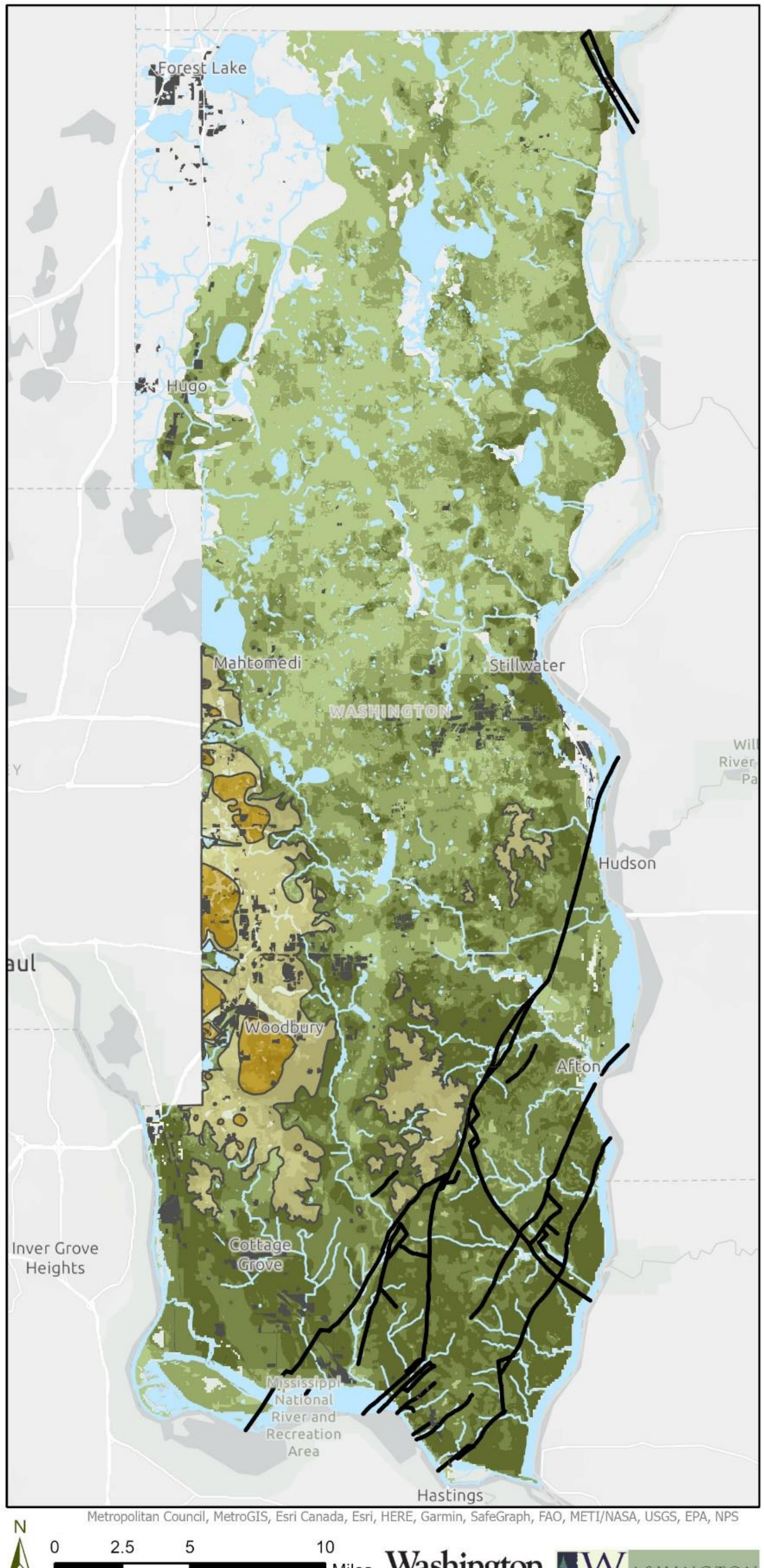


Figure 16. Groundwater Recharge Protection Prioritization with Supplemental Data

Prioritization Score

- 0 Very Low
- 1-3 Low
- 4-6 Moderate
- 7-9 High
- 10-16 Very High
- Bedrock Faults
- Decorah Shale
- Platteville and Glenwood Formations
- Impervious Surfaces
- Lakes
- Streams

Data Sources:
Washington Conservation District, Minnesota Department of Natural Resources, Minnesota Geological Survey

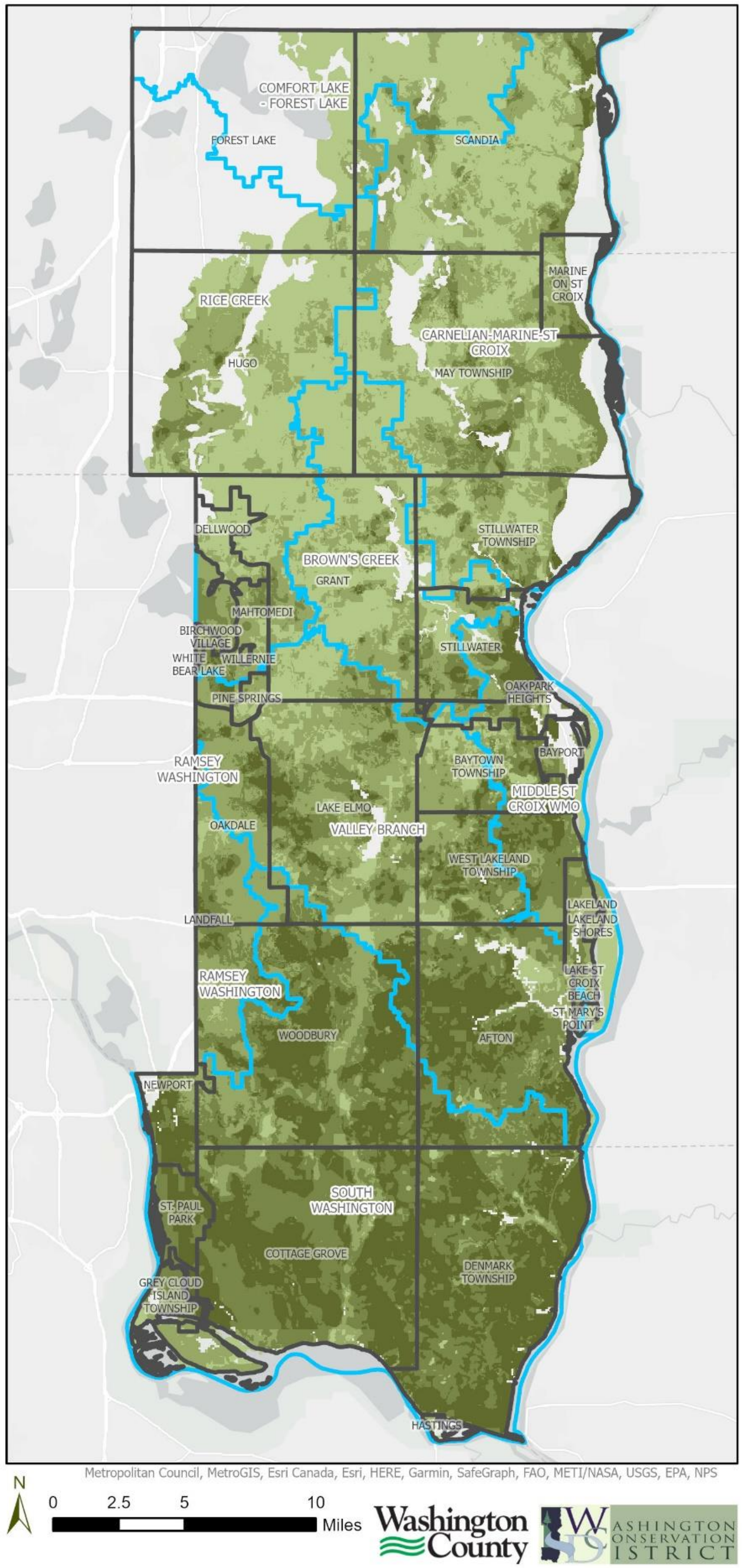


Figure 17. Groundwater Recharge Protection Prioritization with Municipalities and Watershed Districts

Prioritization Score

- 0 Very Low
- 1-3 Low
- 4-6 Moderate
- 7-9 High
- 10-16 Very High
- Municipalities
- Watershed Management Units

Data Sources:
Washington Conservation District, Minnesota Department of Natural Resources, Minnesota Geological Survey

Washington County

Washington Conservation District