Pine River Watershed (07010105)
Groundwater Restoration and Protection Strategies Report

April 2016

MINNESOTA

Pine River Watershed (07010105) Groundwater Restoration and Protection Strategies Report (GRAPS)

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CLEAN WATER LAND & LEGACY AMENDMENT

The development of the GRAPS report was funded by money received from the Clean Water Fund through the Clean Water, Land, and Legacy Amendment. The goal of the Clean Water Fund is to protect, enhance, and restore Minnesota's lakes, rivers, streams, and groundwater.

Contributors

The following agencies dedicated staff time and resources toward the development of the Cannon River Watershed GRAPS report:

- Minnesota Board of Water and Soil Resources (BWSR)
- Minnesota Department of Agriculture (MDA)
- Minnesota Department of Health (MDH)
- Minnesota Department of Natural Resources (DNR)
- Minnesota Pollution Control Agency (MPCA)
- Metropolitan Council (Met Council)

Photo Credit: Balsam Creek in the Pine River Watershed. Photo is courtesy of the Board of Water and Soil Resources.

Summary

Groundwater restoration and protection strategies (GRAPS) reports are an analogue to the WRAPS reports. While the focus of WRAPS are on assessment and diagnostic work that can be used to prioritize actions and strategies for implementation relative to surface water, the emphasis for GRAPS reporting is on groundwater and drinking water resources. The GRAPS report is a summary of known conditions based on existing data and information from state agencies. One of the primary objectives is to provide a baseline understanding of groundwater conditions and associated resource management concerns for the Pine River Watershed. The hope and expectation is that the information will aid local prioritization and targeting of efforts to protect and restore groundwater resources.

The Pine River Watershed, located in north central Minnesota, is characterized by sand aquifers in generally thick sandy and clayey glacial drift overlaying bedrock in the Central Groundwater Province. Sand and gravel aquifers supply water to most of the 3,120 private wells and the 286 public water supply wells in the watershed.

Land cover within the Pine River Watershed is dominated by deciduous forest, followed by woody wetlands and open water. No townships in the Pine River Watershed have more than six percent of the area in row crop production. The high percentage of natural cover is one of the key reasons good water quality exists. In the absence of vegetation, the likelihood contaminants at the land surface can infiltrate into groundwater is increased because the surficial aquifer is very sensitive to land use decisions that convert, degrade, or eliminate natural habitats.

While water quantity use is limited within the watershed, groundwater withdrawals exhibit a statically significant rising trend, whereas surface water withdrawals are declining. Approximately 93 percent of all water appropriated in 2014 within the watershed was groundwater, 7 percent of appropriated water came from surface water sources.

State and Federally supported BMPs and conservation programs are recommended, combined with land use strategies to protect groundwater quality and quantity. A general recommendation of BMPs and programs is offered in the implementation section as a basic table to target different practices under associated groundwater vulnerabilities.

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Introduction

What Is the GRAPS Report?

The State of Minnesota adopted a watershed approach to address the state's 81 major watersheds.[1] Major watersheds are denoted by an eight-digit hydrologic unit code (HUC). This watershed approach incorporates water quality assessment, watershed analysis, civic engagement, planning, implementation, and measurement of results into a 10-year cycle that addresses both watershed restoration and protection.

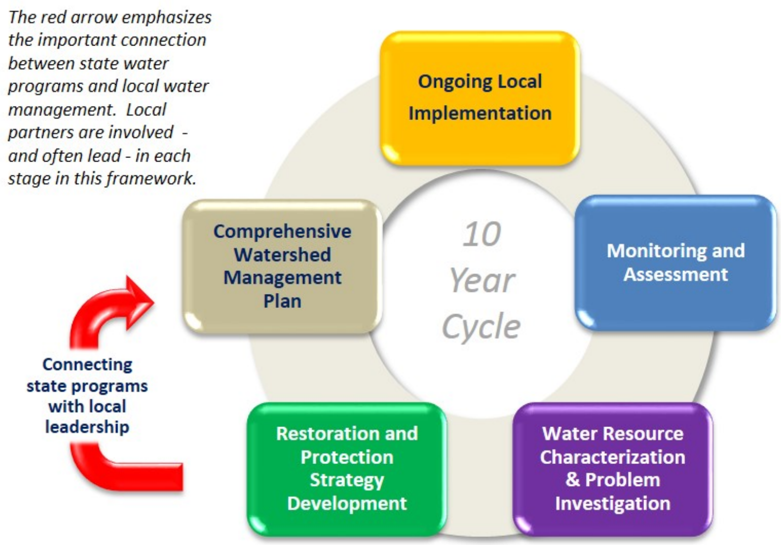

Figure 1: Watershed Approach Framework

Groundwater Restoration and Protection Strategies (GRAPS) reports are designed to help prioritize and target local efforts to restore and protect groundwater resources as part of local water planning. While groundwater is not broken into watersheds like surface water, several state agencies have worked together to compile information and strategies for groundwater below surface water watersheds. A GRAPS report uses existing state data and information about groundwater and land-use practices that affect groundwater in the watershed to identify key groundwater quality and quantity concerns. The report also suggests targeted strategies and actions to restore and protect the groundwater. GRAPS reports are meant to be used in conjunction with Watershed Restoration and Protection Strategies (WRAPS) reports in the development of local watershed management plans. WRAPS inform how to restore and protect surface water, and GRAPS inform how to restore and protect groundwater in the same geographical area.

[1] You can learn more about the Watershed Approach at Watershed approach to restoring and protecting water quality (https://www.pca.state.mn.us/water/watershed-approach-restoring-and-protecting-water-quality).

WRAPS focus on restoration, which is initiated through an intensive monitoring effort to determine if a surface water is meeting its designated use. WRAPS identify actions and the rate of adoption needed to restore water quality. GRAPS, on the other hand, is largely protection-based—identifying actions to maintain groundwater quality and quantity. However, if contaminants exist or overuse is suspected, the strategies and actions identified to address the issue, can result in restoration as well as protection. In most cases, it is very difficult determine the rate of best management practice (BMP) adoption needed to restore groundwater and is therefore not a part of GRAPS.

Pine River Watershed Overview

Geology and Land Use

The Pine River Watershed is located in the north-central portion of the state and is considered to be in the Central Groundwater Province. The Central Groundwater Province is characterized by sand aquifers in generally thick sandy and clayey glacial drift overlying Precambrian and Cretaceous bedrock. Fractured and weathered Precambrian bedrock is used locally as a water source. More information on Minnesota's groundwater provinces can be found at Groundwater Provinces (dnr.state.mn.us/groundwater/provinces/index.html). The Pine River Watershed is also in the nitrogen best management practices region known as irrigated and non-irrigated sandy soils

Land use within the Pine River Watershed is dominated by deciduous forest (46 percent), followed by woody wetlands and open water at 15 percent and 11 percent respectively. According to the Crop Land data layer (NASS 2011), no townships in the Pine River Watershed have more than six percent of the area in row crop production.

The surficial geology in the Pine River Watershed is characterized by relatively broad areas of outwash separated by regions of finer-grained glacial sediments such as till and lake clay. Bedrock is found at depths ranging from 50 to 400 feet and is generally less permeable than glacial sand and gravel bodies. As a result, most drinking water wells, both public and private, utilize the sand and gravel aquifers. These aquifers range in depth from 0 to over 200 feet below the land surface.

Groundwater Vulnerability and Wells

Aquifers that occur at the land surface are relatively vulnerable to contamination, whereas those that are covered by varying thicknesses of finer-grained sediment are relatively protected. Table 1 provides an overview of drinking water wells within the Pine River Watershed and is subdivided based on whether the wells are for private or public use.

Table 1: Basic information on drinking water wells within the Pine River Watershed

Private Wells with Known Locations	Private Wells Depth Range and Average (ft)	Private Wells in Highly Vulnerable Settings	Public Wells	Public Wells Depth Range and Average (ft)	Public Wells in Highly Vulnerable Settings
3,120	Range: 13-420 Average: 80	1,013	286	Range: 35-295 Average: 88	92

Figure 2 shows the generalized vulnerability of the uppermost aquifers in the watershed. This figure is based on 1:100,000 scale statewide landform mapping (DNR, MGS, UMD, 1997) and vulnerability ratings were assigned to various landforms based on assumptions about the vertical recharge rate to the uppermost aquifer. Where vulnerability ratings are high, uppermost aquifers likely occur at the land surface and may be recharged by infiltrating surface water over time periods as short as hours to months (Geologic Sensitivity Project Workgroup, 1991). Where vulnerability ratings are moderate or low, the uppermost aquifers are covered by varying thicknesses of lower permeability sediments. The time required for surface water to infiltrate these low-permeability sediments and reach buried aquifers should be significantly longer than in high vulnerability settings. Time scales may range from years to a decade or two in moderate vulnerability settings. Several decades to a century may be required where vulnerabilities are low (Geologic Sensitivity Project Workgroup, 1991).

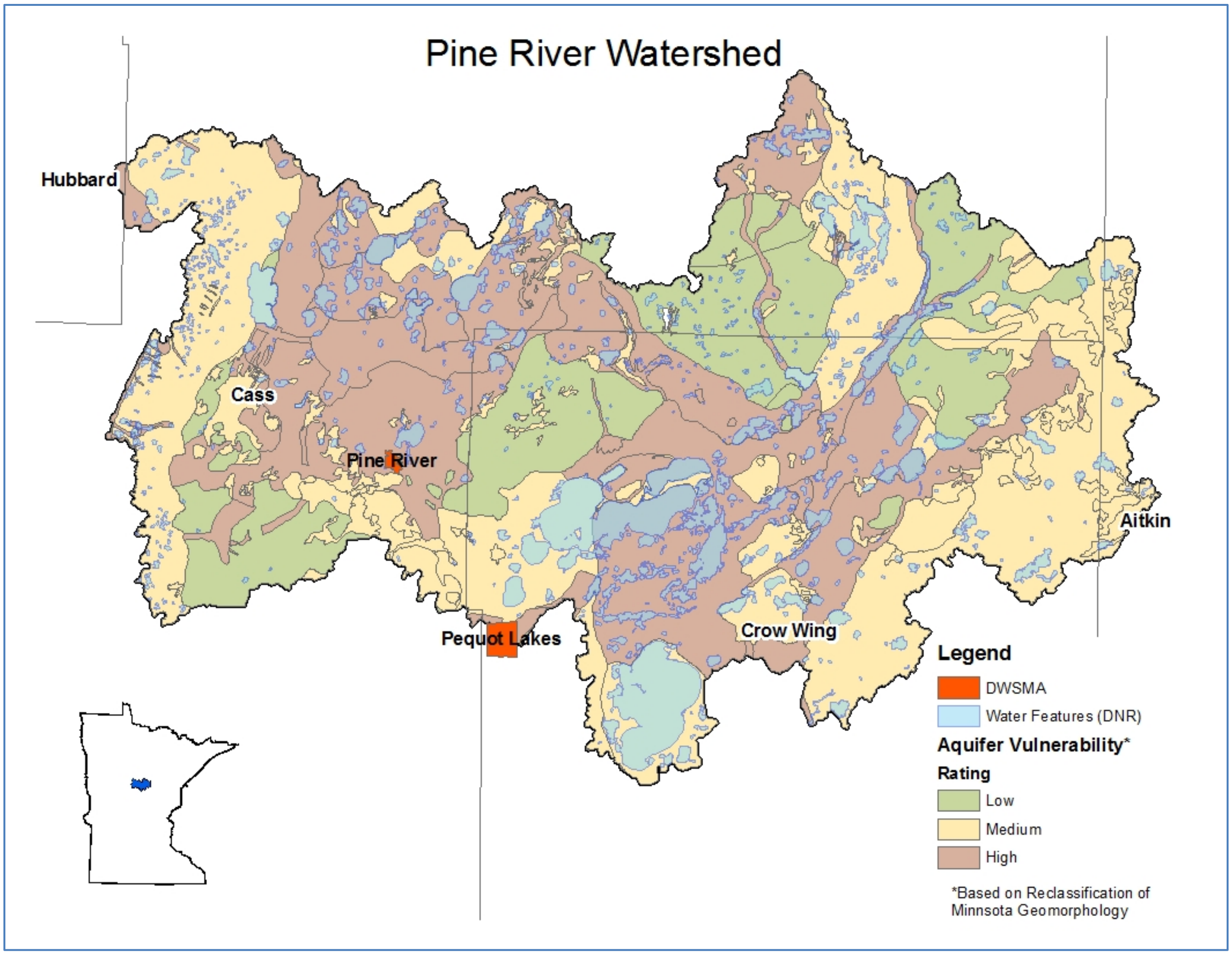

Figure 2: Vulnerability ratings for the uppermost aquifers in the Pine River Watershed. Also shown are the Drinking Water Supply Management Areas (DWSMAs) for the cities of Pine River and Pequot Lakes. The vulnerability ratings for the aquifers used by these communities are discussed in the text, and detailed maps of these areas are available on request from MDH.

Public water supply wells fall into three categories: community, noncommunity nontransient and transient. Both community and noncommunity nontransient wells supply water to relatively large populations on a regular basis and therefore have more stringent regulatory oversight, water quality sampling and facility management requirements when compared with transient systems. In addition, such systems are required to engage in wellhead protection planning. Figure 3 shows the distribution of the different types of public water supply wells in the Pine River Watershed in comparison with private wells for which accurate locations have been determined.

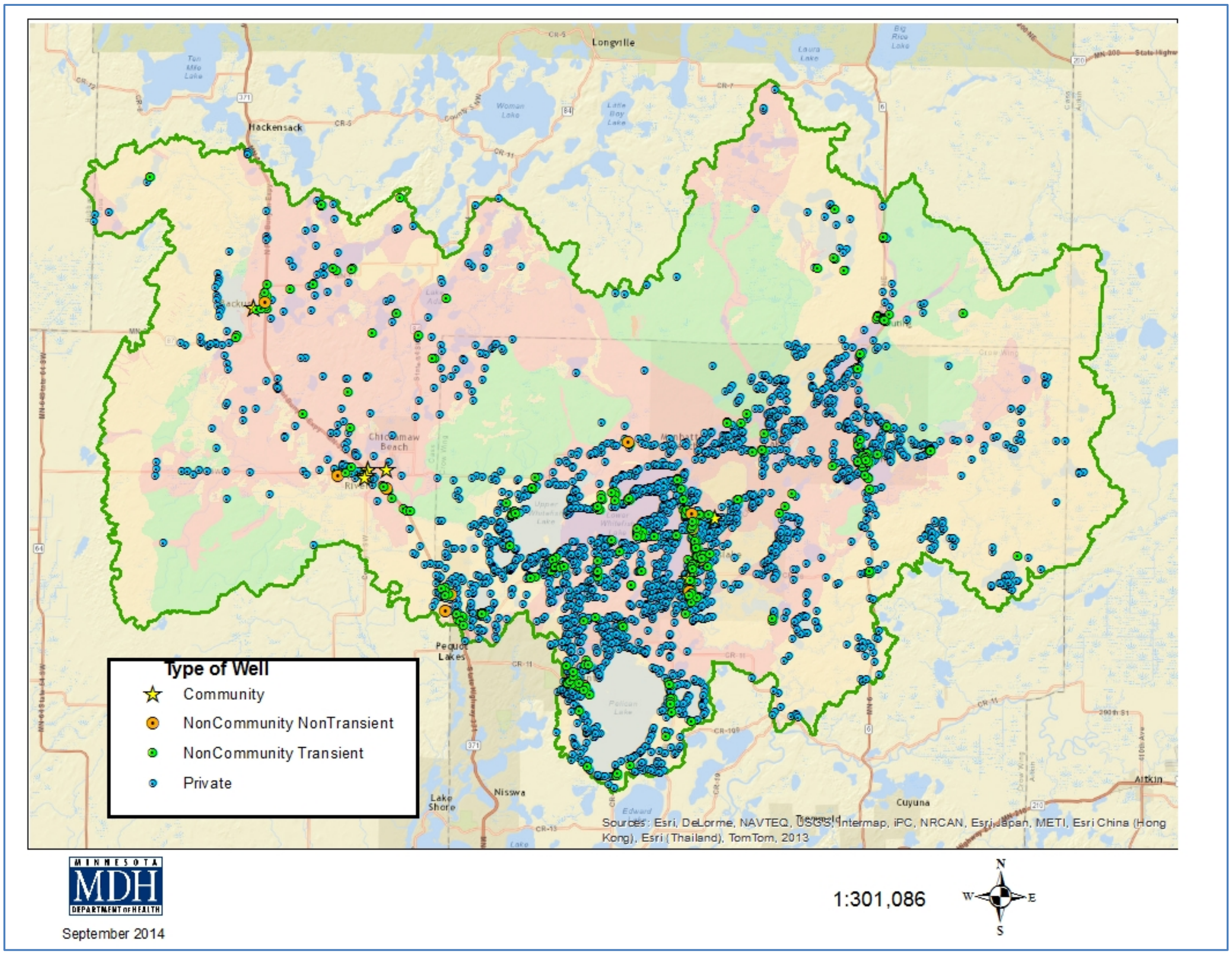

Figure 3: Distribution of wells in the Pine River Watershed. Underlying shading represents the same groundwater vulnerability ratings displayed in Figure 2.

The numbers of each type of public water supply well are listed in Table 2 and the wellhead protection planning status of community public water systems are listed in Table 3 and displayed in Figure 4.

Table 2: Public water wells in the Pine River Watershed.

Community	Noncommunity nontransient	Transient
10	12	264

Table 3: Wellhead protection planning status for community public water supply systems in the Pine River Watershed.

Communities with Completed Wellhead Protection Plans	Communities Yet to Engage in Wellhead Protection, with Estimated Start Date
Pine River and Pequot Lakes	Backus (2015), Chatham Park (2018), Nelson’s East Shore Landing (2018)

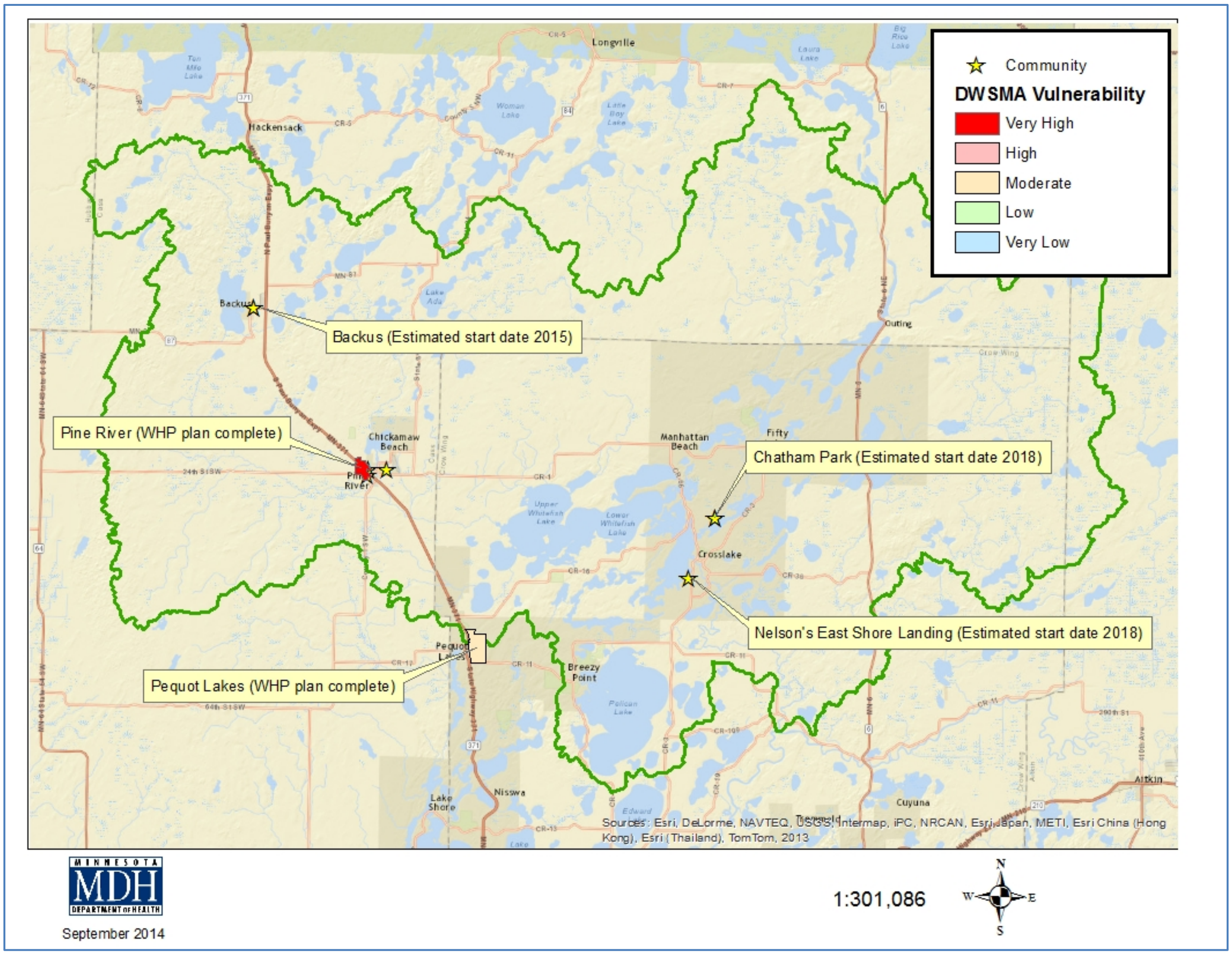

Figure 4: Community water supply systems in the Pine River Watershed and their wellhead protection planning status.

Community Water Supplies

All community water supplies must meet drinking water standards of the federal Safe Drinking Water Act. Water samples are required to be routinely collected and analyzed by MDH to ensure the water provided meets public health drinking water standards. Presently, all public water suppliers in the Pine River Watershed meet or exceed State and Federal drinking water standards.

Even though drinking water standards are met, community Public Water Suppliers are required to implement WHP Plans that are developed to proactively prevent potential contaminant threats and land uses that may negatively impact the aquifer and wells used. WHP Plans identify the recharge area of the well(s) based on volume of water pumped and characteristics of the aquifer. Strategies the in the WHP plans PWS implement are based on the vulnerability of the aquifer used and contaminants that may reach the well or aquifer.

The following table describes the vulnerability of the City of Pequot Lake and Pine River's Drinking Water Supply Management Area (DWSMA) identified as part of WHP Planning and activities associated with protection of their water supply.

Table 4: Vulnerability of the municipal Drinking Water Supply Management Areas.

PWS	DWSMA / Aquifer Vulnerability	Actions
Pequot Lakes	Moderate	Manage large Tanks, Existing Wells & Seal Unused Wells
Pine River	High	Manage all land uses & contaminants. Septic systems, Tanks, Wells, Ag and Urban related land uses.

More specific WHP plan information for Pequot Lakes and Pine River can be obtained by directly contacting the City or MDH SWP Staff. State approved WHP coverages and geospatial data can be found and downloaded from MDH at Reports and Geospatial Data (www.health.state.mn.us/divs/eh/water/swp/maps/).

As described earlier, there are a total of 276 Non-community Transient public water suppliers (restaurants, hotels, churches, etc.) that are not required to develop WHP Plans but need to simply manage contaminants within their Inner Well Management Zone identified by MDH, usually a 200' area around their well. Source Water Assessments were developed that provide information for many of these small businesses and facilities, however the quality of information varies based on the information available at the time the assessments were completed by MDH. Source Water Assessments can be found at: Source Water Assessments (www.health.state.mn.us/divs/eh/water/swp/swa/). Specific questions about a particular assessment or public water supplier should be addressed by contacting the MDH planner noted on the assessment.

Groundwater Quality Issues

Although a wide variety of groundwater contaminants may exist locally depending on aquifer vulnerability and land use, nitrate and arsenic are two that are commonly observed in many regions of the state, including the Pine River Watershed. In addition to having relatively widespread occurrence, a comprehensive database exists for these parameters because all new wells are required to be tested for them.

Nitrate

Although it can be naturally occurring, nitrate levels above 2 mg/l are considered to exceed what can be expected from natural background (Mueller and Helsel, 1996) and instead likely reflect human activity such as chemical fertilizer or human or animal waste. Of the 2,570 well water samples represented in Figure 5, 192 (approximately eight percent) exceeded the 2 mg/l threshold level identified above. Only 6 samples (0.2 percent) exceeded the drinking water standard of 10 mg/l. Wells that showed elevated nitrate tend to be concentrated in high vulnerability areas, however many other wells located in high vulnerability areas showed little to no nitrate. In some instances this is because the wells were completed in deeper, geologically protected aquifers whose vulnerability is not accounted for in Figure 2. In other instances, the absence of nitrate may be a function of low-impact land use in the vicinity of the well or the presence of favorable geochemical conditions in the aquifer. Nitrate requires relatively oxidizing conditions to persist in groundwater, and the presence of locally reducing conditions can remove nitrate.

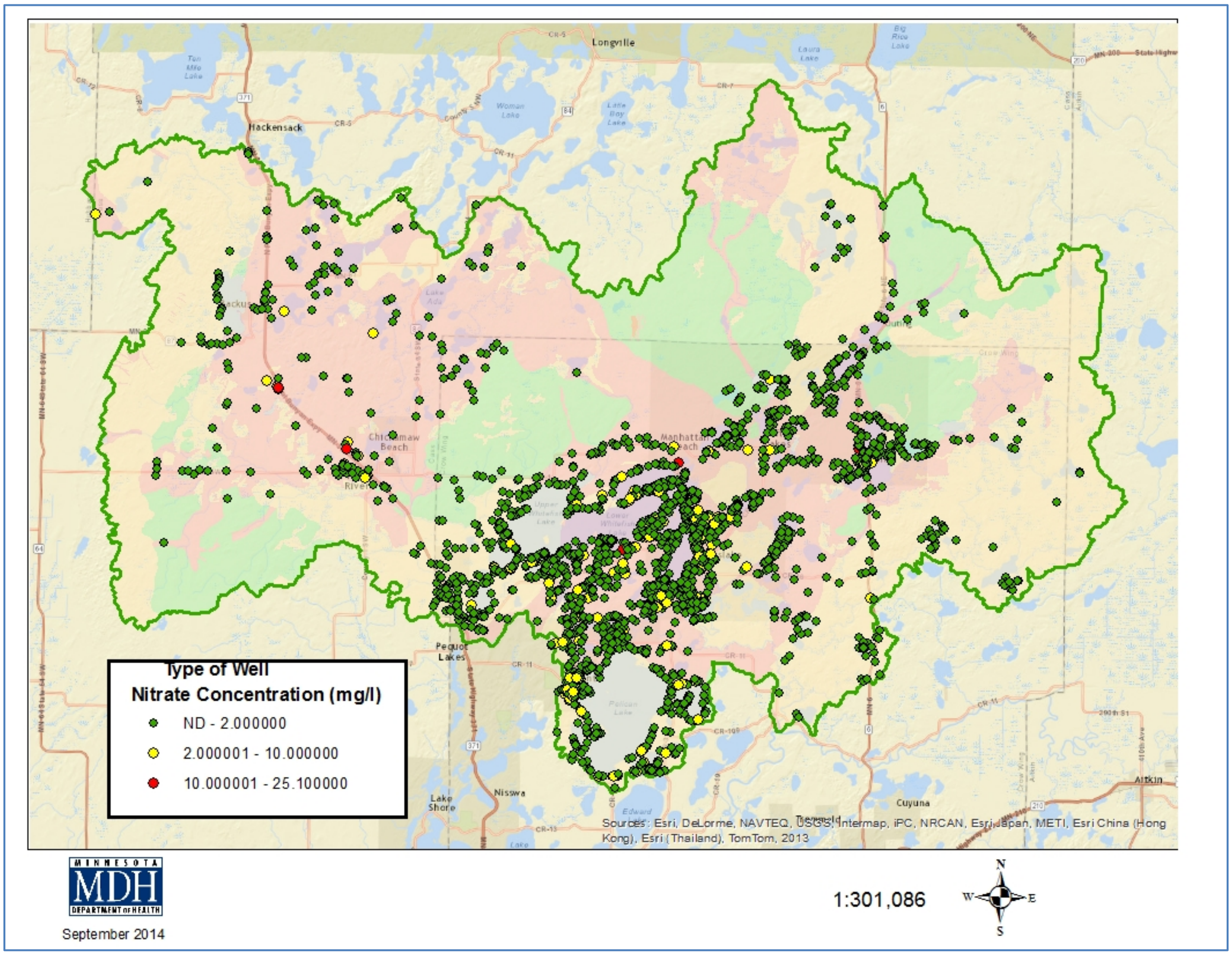

Figure 5: Nitrate concentrations measured in well water from the Pine River Watershed. Results span a wide range of sampling dates. ND = non-detect.

The Minnesota Department of Agriculture (MDA) is responsible for monitoring groundwater quality in agricultural areas of the state. The geographic area known as the central sands (which encompasses the Pine River Watershed) is particularly vulnerable with respect to agricultural chemical movement due to the hydrogeologic conditions: shallow groundwater beneath coarse, sandy-textured soils.

Agricultural activities are primarily limited to the western portion of the Pine River Watershed, which is predominantly cattle grazing, with some row crop production. Research by the MPCA has demonstrated greater pressure on grazing lands is occurring, increasing the density of animal units per acre, placing additional stress on the resources. As more intensive agricultural land use expands, changes in groundwater quality may follow due to the vulnerable nature of the aquifer.

Arsenic

Arsenic occurrence in groundwater may locally be related to human activity as a release of insecticide or wood preservative, but is more commonly naturally occurring in geologic materials. Arsenic data exists for 970 wells in the watershed (Figure 6). Of those 25 (2.6 percent) exceeded the drinking water standard of 10 µg/l. Elevated values are likely related to local geochemical conditions that allow for mobilization of the metal. These geochemical conditions tend to be moderately reducing and are often associated with the contact between sand and gravel aquifers and adjacent clay-rich sediments (Erickson and Barnes, 2004 and 2005).

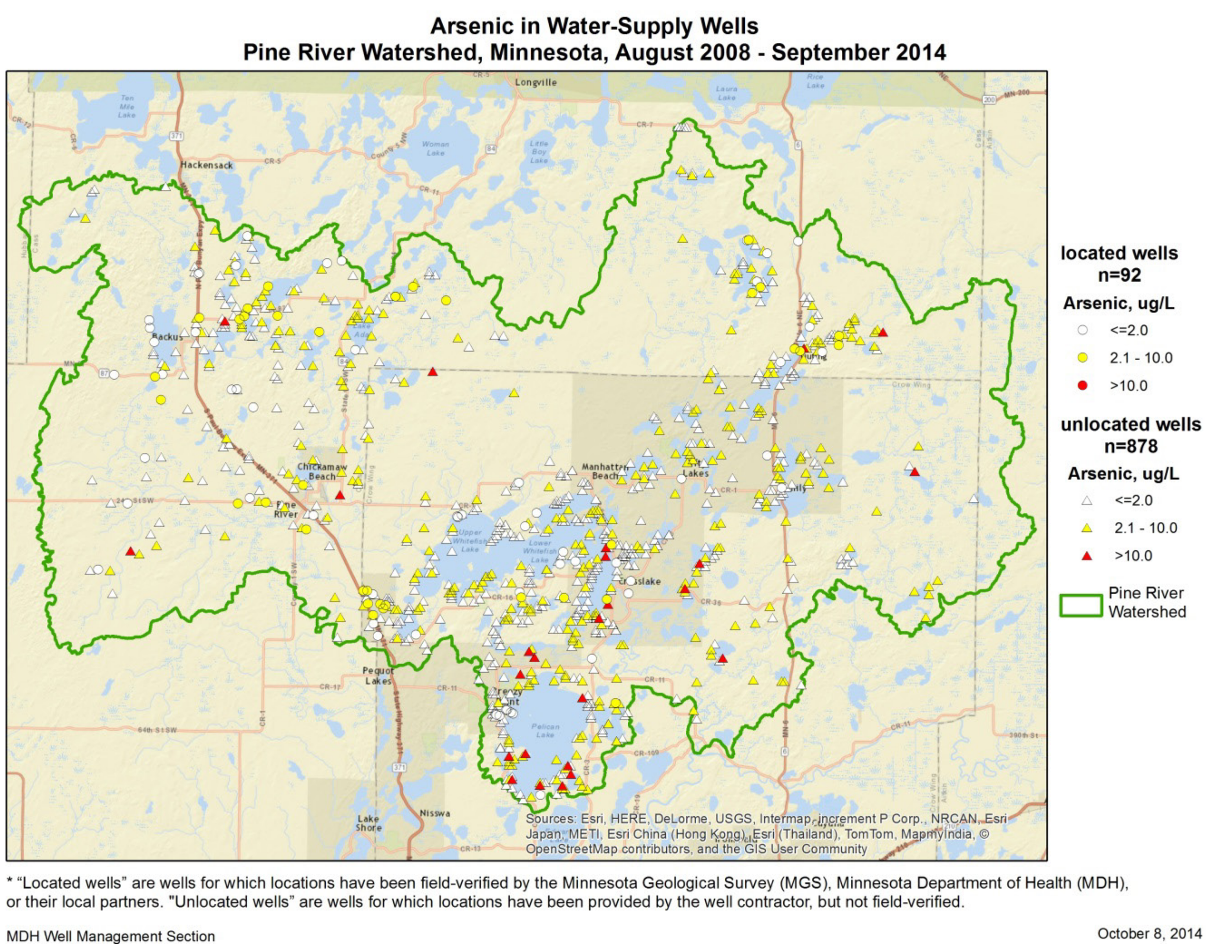

Figure 6: Arsenic concentration measured in well water from the Pine River Watershed.

Known Groundwater Contamination Sites

Closed Landfill Program

The Minnesota Pollution Control Agency (MPCA) Closed Landfill Program (CLP) is a voluntary program established by the Legislature in 1994 to properly close, monitor, and maintain Minnesota's closed municipal sanitary landfills. There are currently 109 closed landfills in the CLP. For each of these closed landfills, an area where groundwater has been contaminated, the groundwater plume, and a groundwater area of concern (AOC) are defined. More information about the CLP can be found at Closed Landfill Program (www.pca.state.mn.us/index.php/waste/waste-and-cleanup/cleanup/closed-landfills/closed-landfill-program.html).

The interactive map that shows the closed landfills and the corresponding groundwater plumes and AOCs can be found at Closed Landfill Program Sites (mpca.maps.arcgis.com/apps/Solutions/s2.html?appid=6470bb44bd83497993da5836333d1cb3).

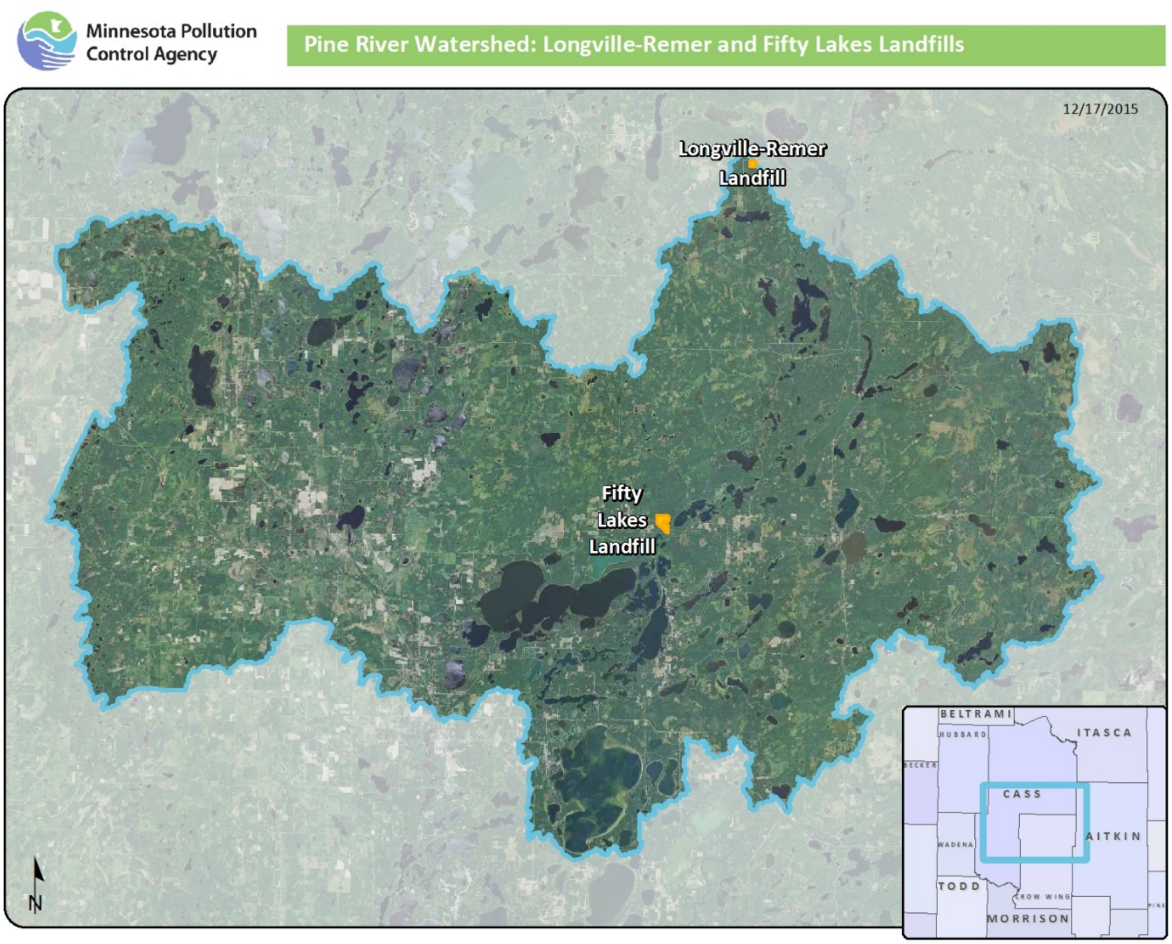

Figure 7: Closed landfills in the CLP in the Pine River Watershed.

Other Potential Groundwater Contaminant Sources (MPCA)

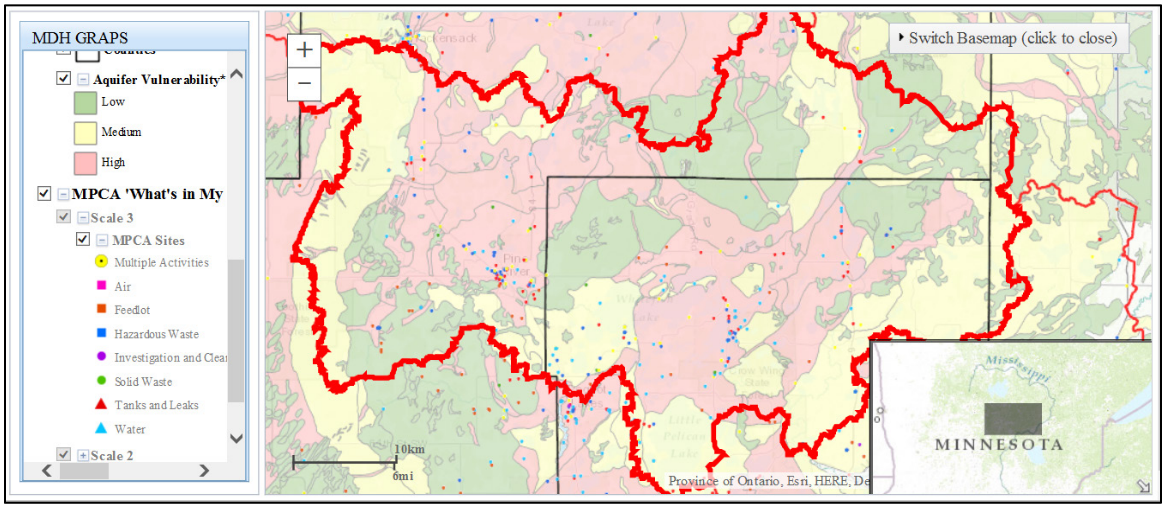

Figure 8: A screen shot of the MPCA data "What's in My Neighborhood" for the Pine River Watershed. The points on the map largely represent tanks and leaks, hazardous waste, and feedlots.

Since the early 1980s when major federal and state cleanup programs were created, the MPCA has been aggressively searching for and helping to clean up contaminated properties, from very small to large. They maintain a website database known as What's in My Neighborhood (www.pca.state.mn.us/index.php/data/wimn-whats-in-my-neighborhood/whats-in-my-neighborhood.html) which contains a searchable inventory of those properties, as well as sites that have already been cleaned up and those currently being investigated or cleaned up.

Groundwater Use and Quantity Issues

DNR Groundwater Responsibility

It is the responsibility of the MN Department of Natural Resources (DNR) to ensure sustainable supplies of groundwater for future generations, as well as to ensure that groundwater use does not degrade water quality or harm groundwater-dependent ecosystems (103G.287).

To help ensure sustainable groundwater use, the DNR has permitting authority for high capacity water use including proposed use in excess of 10,000 gallons/day or one million gallons/year. Permit holders are required to track water use and report yearly to the DNR on their usage. Information on the DNR's Permitting and Reporting System (MPARS) is at MPARS (www.dnr.state.mn.us/mpars/index.html).

Priorities for water use in Minnesota are in statute as follows: domestic use has the highest priority; other consumptive uses come next; followed by agricultural irrigation and processing; power production; commercial and industrial use; and non-essential uses such as lawn watering. The Commissioner of the DNR can deny a permit for several reasons, including interactions between individual withdrawal locations, cumulative effects of withdrawals from individual aquifers, and potential interactions between aquifers.

Hydrogeologic Characterization of the Pine River Watershed

The digital elevation map shows the Pine River Watershed (PRW) to be a fairly flat, low-lying watershed with the exception of elevated areas in the north-central, northeastern, and western portions of the watershed. Approximately half of the PRW is within the northern portion of Crow Wing County. Most of what is known about the geology and hydrogeology of the area is from the Geologic Atlases of Crow Wing County (www.dnr.state.mn.us/waters/programs/gw_section/mapping/platesum/crowcga.html), Parts A and B Aquifers in the watershed are primarily of two types: a) surficial or water table, and b) buried sand and gravel. The surficial sand aquifer in Crow Wing County covers about 40 percent of the county and typically occurs at a depth less than 25 feet below the surface. This shallow aquifer ranges from a few feet to more than 120 feet in thickness, but 80 percent of the aquifer is less than 55 feet thick. Only two percent of the aquifer is thicker than 100 feet. Due to the shallow depth of materials that separate the water table aquifer from the land surface, groundwater in the watershed is very vulnerable to contamination from man-made sources (see Pollution Sensitivity section).

In addition to the surficial sand aquifer, the Crow Wing County Geologic atlas indicates nine buried sand and gravel aquifers at depths of 100 to 200 feet below the land surface. These buried aquifers are limited in extent in the watershed, covering a total of about 24 percent of the county, but do serve as reliable sources of water. The majority of wells (72 percent) in the watershed are located in these deeper, buried sand aquifers that are more protected from surface contaminants. The remaining percentage of wells is located in surficial sands or water table aquifers.

Water Budget and Groundwater Recharge

Three estimates of groundwater recharge for the PRW are shown in Table 5. Recharge is determined by the equation Recharge = Precipitation – Runoff – Evapotranspiration. The first estimate (column 5) changes annually due to variations in climate and runoff. The two USGS estimates of recharge (columns 6 and 7) use GIS data from two separate USGS studies. Both estimates provide a watershed total recharge that doesn't vary with time. The 2015 recharge estimate uses the USGS soil-water balance model to estimate potential recharge over a 15-year period from 1996-2010 (see Potential Groundwater Recharge for the State of Minnesota Using the Soil-Water-Balance Model, 1996–2010 [pubs.usgs.gov/sir/2015/5038/]). The 2006 USGS recharge is a regional statistical regression model of recharge using data from 1971-2000.

The water balance estimates of recharge are considerably less than the two USGS estimates. This discrepancy can be a result of inaccuracy in evapotranspiration values, which are notoriously difficult to measure. Variability in precipitation over the watershed could also be a source of error. Assumptions used in the water balance equation might also be too simple, leaving out variables such as snowmelt, changes in storage, or groundwater fluctuations. The annual amount of recharge from the water balance estimates are an important indication that recharge amounts vary from year to year; in some years, there may have very little or no recharge at all (e.g., 2011, 2013). A groundwater review document for the Pine River Watershed from the MPCA displays no significant trend in precipitation over the last 20 years. Any future changes in climate in the watershed are not accounted for in these models.

Table 5: Water supply (recharge) in the watershed is determined by the balance between precipitation received by the watershed and water lost through evapotranspiration, runoff, and water use (not included).

Pine River watershed water budget						
Year	**Precip (in/yr)**	**Runoff (in/Yr)***	**Estimated ET (in/yr)**	**water balance recharge (in/yr)**	**2015 USGS recharge (in/yr)**	**2006 USGS recharge (in/yr)**
2009	28.0	5.8	21	1.5	5	7
2010	29.6	6.1	22	1.2		
2011	23.5	7.3	19	-2.8		
2012	37.2	8.0	26	3.7		
2013	29.8	7.7	21	0.6		
*calculated from Pine River nr Mission DNR gage H11051001						

Aquifer Pollution Sensitivity

Aquifer pollution sensitivity is a similar concept to groundwater vulnerability, an assessment of the ease which water and contaminants can move from the land surface to the aquifer in question. It is determined for counties that have geologic atlases developed and represents a more refined assessment of vulnerability than is currently available on a statewide level based strictly on geomorphology (Figure 2). For the Pine River watershed, only Crow Wing County has a completed geologic atlas and related aquifer pollution sensitivity plate. For the surficial (water table) aquifer in Crow Wing County this figure shows very high pollution sensitivity for the sand and gravel deposits that are found throughout most of that county (Pollution Sensitivity of the Buried and Surficial Aquifers [files.dnr.state.mn.us/waters/groundwater_section/mapping/cga/c16_crow/pdf_files/plate09.pdf]). A map of pollution sensitivity for surficial aquifers in the Cass County portion of the Pine River Watershed is expected to be available at the earliest by 2021.

Pollution sensitivity maps for the deeper, buried sand and gravel aquifers in Crow Wing County are available at Crow Wing County Geologic Atlas (www.dnr.state.mn.us/waters/programs/gw_section/mapping/platesum/crowcga.html). Of the nine buried sand and gravel aquifers in the PRW, all show significant areas of moderate to very high pollution sensitivity. Moderate to high pollution sensitivity of these buried aquifers means that: 1) surface water either has recently seeped, or has a high potential to seep, into buried aquifers from the water table aquifer, and/or 2) surface water has been detected in buried aquifers. Geochemical and temperature data from groundwater samples support this interpretation.

A statewide map showing pollution sensitivity of water table aquifers is being created by DNR's County Geologic Atlas Program and will be available in 2016. This should aid in interpretation of pollution sensitivity in Cass County until its geologic atlas is completed.

Groundwater Use and Quality

Approximately 93 percent of all water appropriated in 2014 within the PRW (1.65 million gallons per year) was groundwater; seven percent of appropriated water came from surface water sources.

The deeper, buried sand aquifers provided 41 percent of all groundwater appropriated in 2014. The water table aquifers provided 31 percent of appropriated groundwater, and the remaining 21 percent of appropriated water came from aquifers with unknown classification. Agricultural crop irrigation used the greatest share (43 percent) of permitted groundwater in the watershed (Figure 9). A slightly greater combined share of groundwater (48 percent) was used collectively for aquaculture (DNR's fish hatchery) and golf course irrigation. Private domestic water use is not included in these totals.

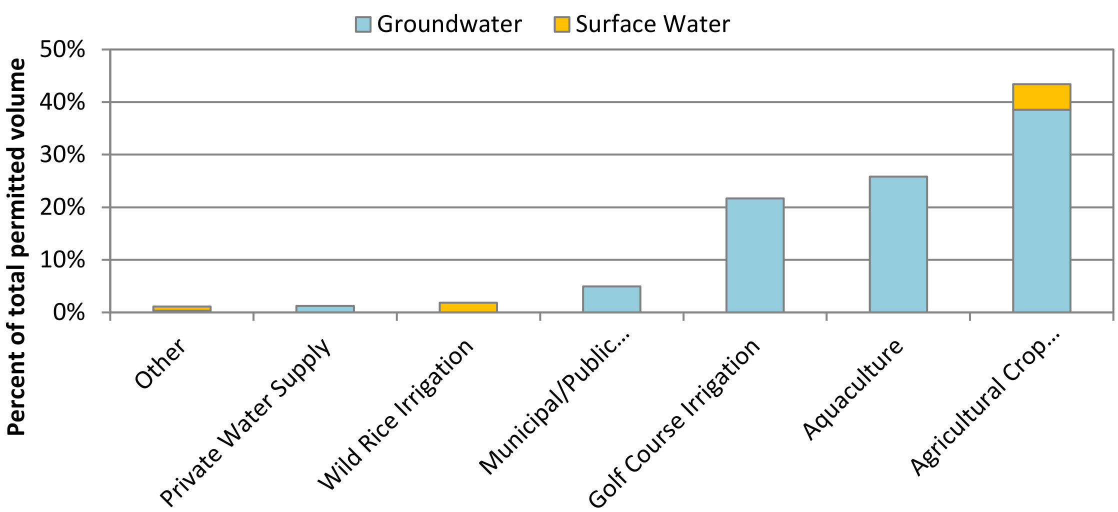

Figure 9: 2014 Permitted water use percentages for the Pine River Watershed

Analysis using MPARS shows that between 1991 and 2011, groundwater withdrawals showed an increasing trend in the watershed at the same time as surface water withdrawals decreased (Figure 10).

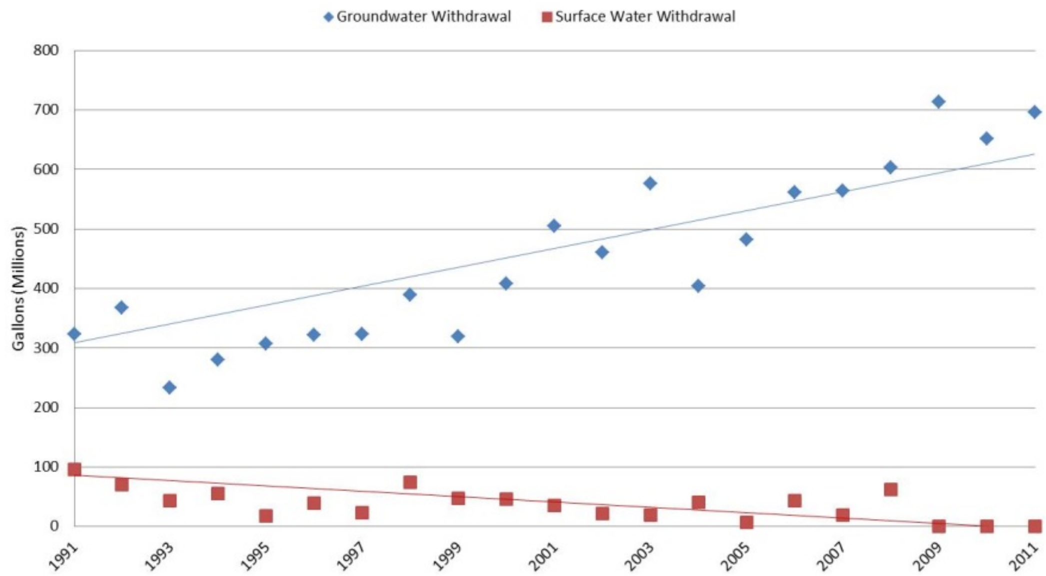

Figure 10: Groundwater and surface water usage, 1991-2011, in the Pine River Watershed.

Known Well Interference Issues

Part of the DNR's water appropriation permitting authority includes investigating and mediating situations where permitted use of water creates a decline in water levels for neighboring water users. These situations are commonly referred to as well interferences. To date there have been no reported well interference complaints in the PRW.

Land Use/Land Cover Trends and Demographic Projections

Groundwater quality in the PWR's surficial aquifers is very sensitive to land use decisions that convert, degrade, or eliminate natural habitats. In the absence of vegetation, the likelihood that contaminants at the surface can infiltrate into groundwater is increased. One of the key reasons that the PRW has very good water quality is because a high percentage of its surface area remains in natural cover type (Figure 11). The most recent 2011 National Land Cover Data indicate that natural cover types, like forests and wetlands, made up about 78 percent of the watershed's total 502,200 acres. From 2001 to 2011 there has only been a one percent increase in impervious cover in the watershed due to development and a one percent increase in land converted to agriculture, the highest permitted use of groundwater in the watershed.

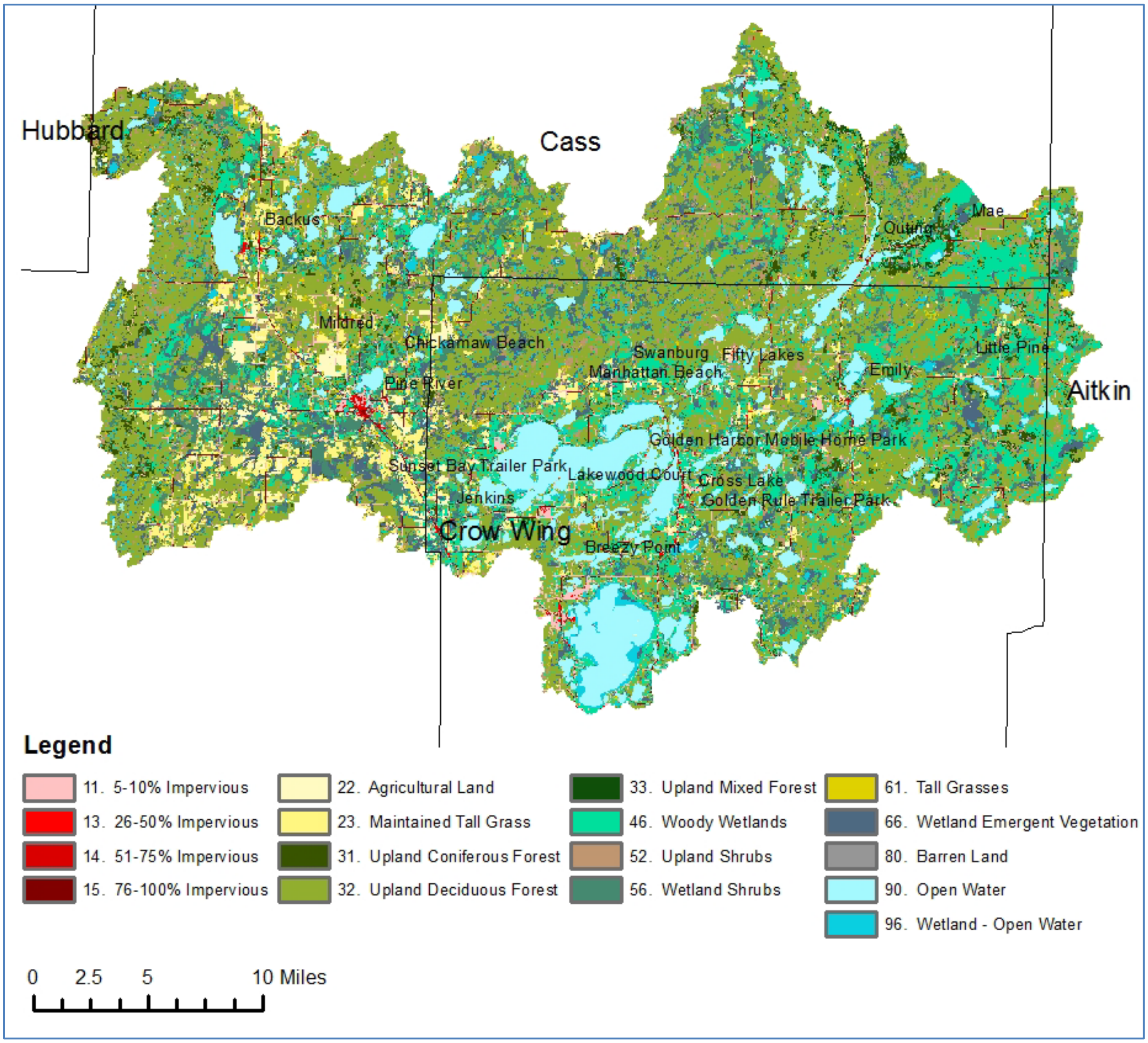

Figure 11: 2011 National Land Cover Data for the Pine River Watershed.

Demographic projections issued by the Minnesota State Demographic Center indicate that Cass County will experience a six percent growth in population and Crow Wing a nine percent increase by 2045. Depending on the locations, and extent, of future land conversions in the watershed, land use decisions could affect groundwater quality and availability for humans as well as for groundwater-dependent or groundwater-associated plant and animal communities in the future.

Groundwater Dependent Natural Resources

About 10 percent of the PRW is open water. The watershed has 70,000 acres of publicly protected water bodies and 500-miles of rivers and streams.

Groundwater-Dependent Trout Streams and Calcareous Fens

Trout streams and calcareous fens are protected, respectively, under Minnesota Statutes 103G.285, subd.5, and 103G.223 from water appropriations that may deplete water flows due to pumping. There are trout streams in the PRW, but there are no known groundwater withdrawal impacts to trout streams (Figure 12). There are no calcareous fens in the PRW.

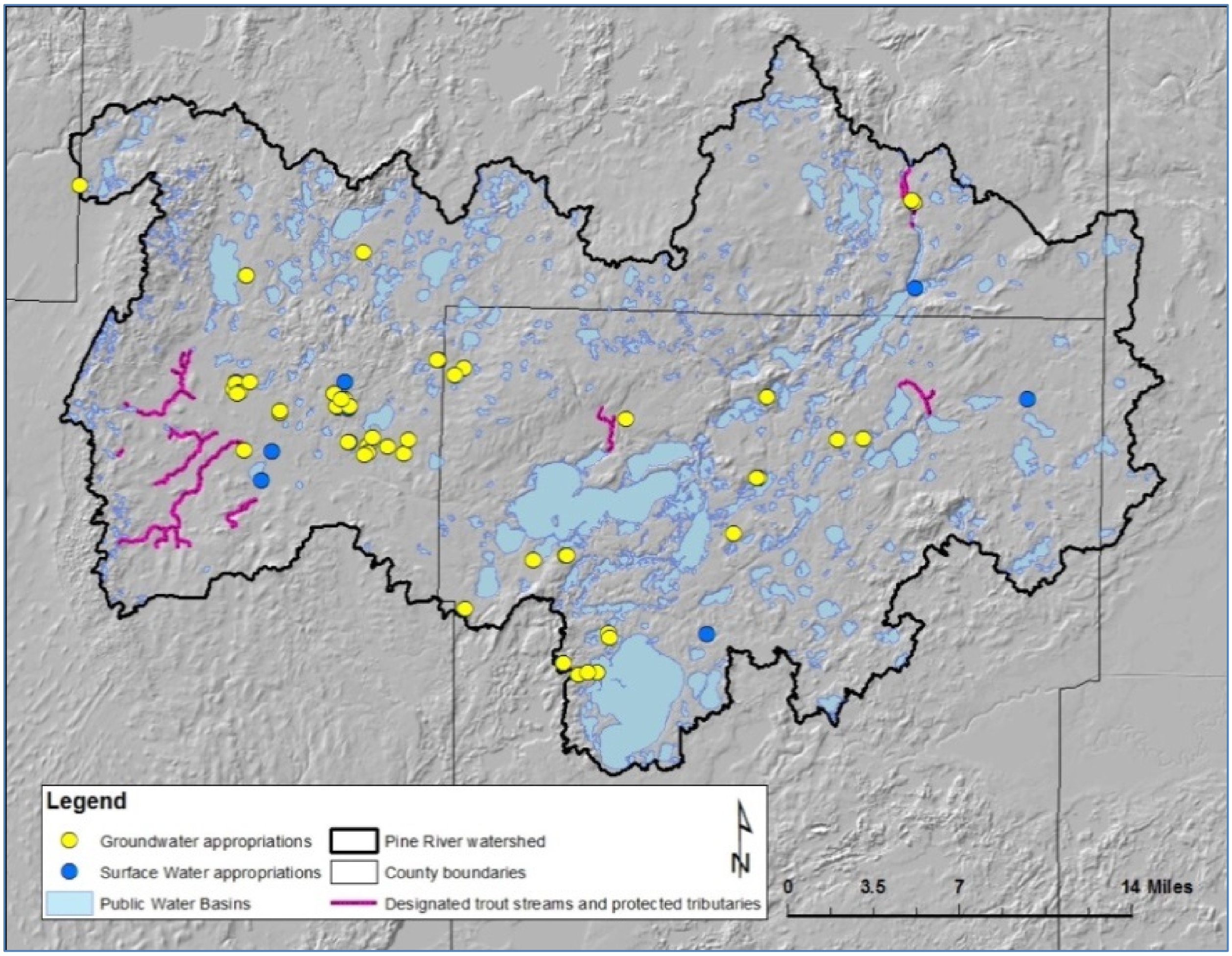

Figure 12: Designated trout streams and locations of 2014 permitted water appropriations in the Pine River Watershed

Lakes of Biological Significance and Groundwater Flow Dominated Lakes

The PRW has an abundance of lakes that have unique plant and animal species, which is a measure of their biological significance. DNR's 2015 statewide analysis ([DNR Hydrography-Lakes of Biological Significance](https://gisdata.mn.gov/dataset?q=lbs) [https://gisdata.mn.gov/dataset?q=lbs]) of multiple data sets on aquatic plant, fish, amphibian, and bird communities revealed that there are 64 lakes of moderate, high, and outstanding biological significance in the Pine River Watershed (Fig. 5). These lakes include, for example, wild rice lakes, lakes with exceptional fish populations, and lakes with nesting areas for endangered, threatened, or special concern species of colonial water birds.

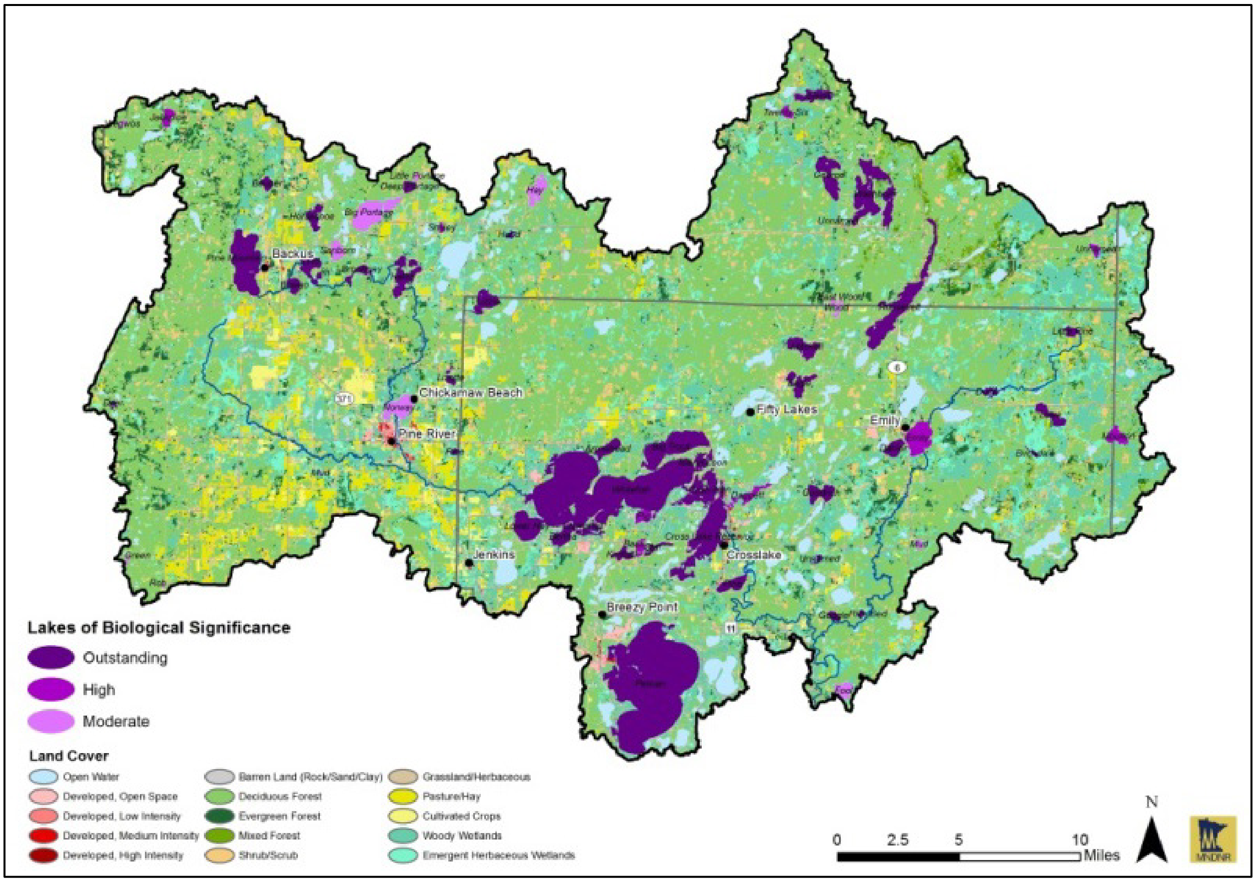

Figure 13: Lakes of biological significance in the Pine River Watershed

There are three different types of lakes in the PRW, based on research done to prepare the Crow Wing County Geologic Atlas, Part B (Plate 10): those dominated by surface water flows; those dominated by groundwater flows; and those that receive both surface and groundwater.

DNR subject matter experts say that lakes with small catchments often are dominated by groundwater rather than surface water flows. Experience suggests that when the ratio of total upstream land area (UPSUM_AC) to acreage of the public water basin (PW_ACRES) is small (e.g., 5:1 or 10:1), the lake has a high probability of being groundwater dominated (Table 6).

Applying this thinking to the lakes of biological significance, the PRW has 25 lakes with ratios around 11 or smaller, suggesting that this subset of lakes might be explored further as possible groundwater-dominated lakes. Additional information from lake hydrographs over time relative to the lake outlet could help confirm the source of lake flowage.

Table 6: Groundwater dominated lakes in the Pine River Watershed.

LAKE	COUNTY	BIO SIGN	UPSUM_AC	PW_ACRES	RATIO
Twenty-Six	Cass	High	299.22	153.74	1.95
Island-Loon	Crow Wing	Outstanding	521.98	247.53	2.11
Fool	Crow Wing	Moderate	648.75	284.18	2.28
Pelican	Crow Wing	Outstanding	20073.90	8568.58	2.34
Pig	Crow Wing	High	464.89	193.56	2.40
Clamshell	Crow Wing	Outstanding	658.16	223.82	2.94
Lizotte	Cass	Outstanding	447.09	136.26	3.28
Horseshoe	Cass	Outstanding	990.82	264.82	3.74
Green	Cass	Moderate	182.13	46.21	3.94
Hay	Cass	Moderate	2098.66	418.30	5.02
Unnamed	Cass	High	485.92	96.55	5.03
Pine	Crow Wing	Outstanding	1657.47	329.68	5.03
Bertha	Crow Wing	Outstanding	1881.88	343.13	5.48
Big Trout	Crow Wing	Outstanding	8156.03	1368.08	5.96
Sanborn	Cass	Moderate	1337.08	220.71	6.06
Moulton	Aitkin	High	1625.41	267.46	6.08
Wegwos	Cass	Moderate	317.47	42.90	7.40
Dahler	Crow Wing	Outstanding	2012.26	268.55	7.49
Jackpine	Cass	High	1230.42	160.77	7.65
Wood	Crow Wing	Moderate	763.37	95.06	8.03
Deer	Cass	Outstanding	444.43	54.95	8.09
Big Portage	Cass	Moderate	7368.00	902.34	8.17
Mud	Cass	Moderate	309.81	35.49	8.73
Star	Crow Wing	Outstanding	1432.98	131.73	10.88
Deep Portage	Cass	Outstanding	1508.62	134.86	11.19

The fact that most lakes and other surface water bodies in Crow Wing County, and probably the watershed, are directly connected to groundwater means that high capacity groundwater pumping in proximity to groundwater-dependent plant and animal communities could potentially harm them. Knowing whether surface or groundwater or both contribute to lakes in the watershed should help inform the selection of best management practices to protect groundwater.

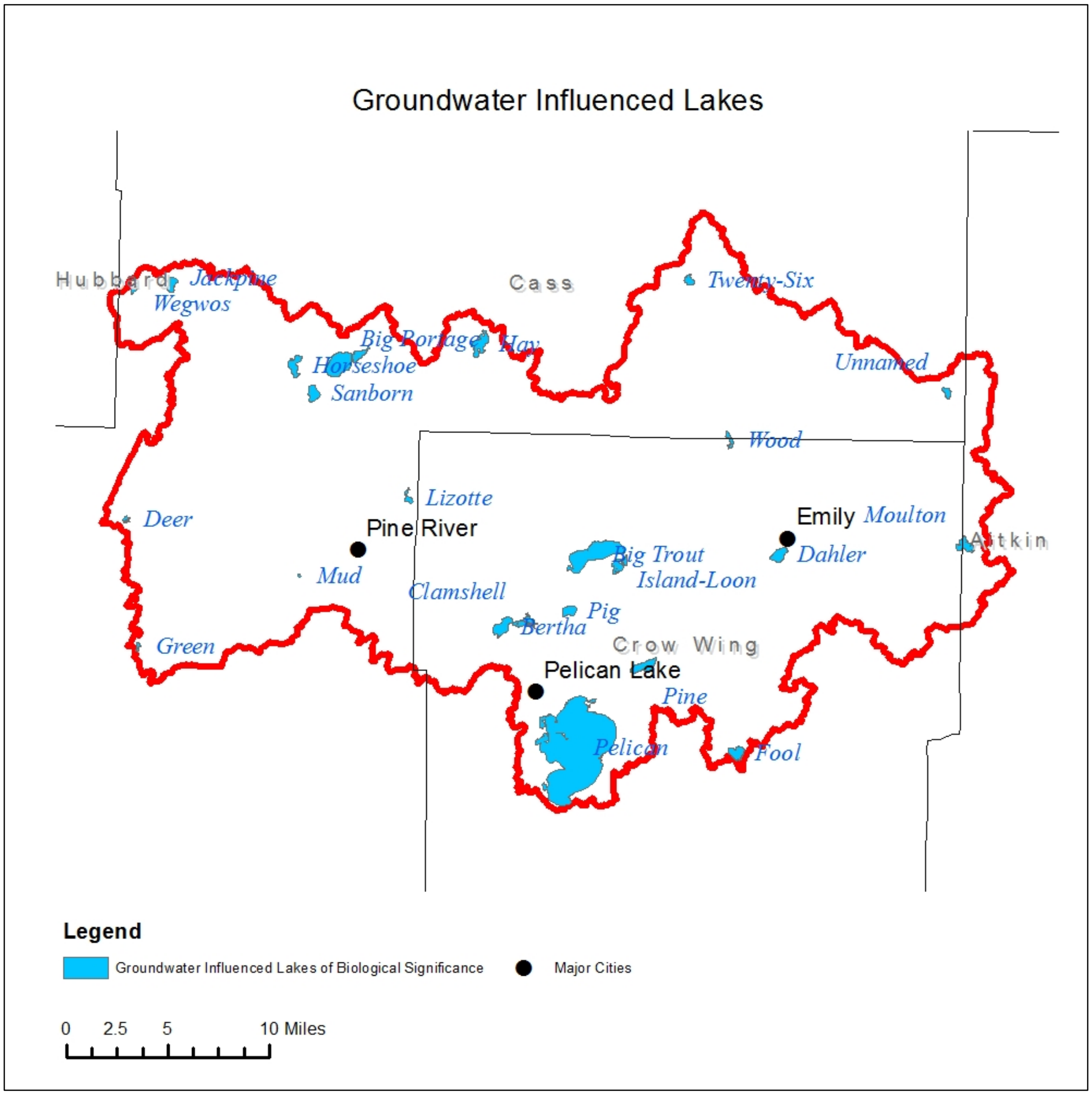

Figure 14: Potential lakes of biological significance that are groundwater influenced.

Groundwater-Dependent or -Associated Plants and Animals

As Table 7 shows, there are no imperiled (S1) or critically imperiled (S2) native plant communities closely associated with groundwater in the watershed. Of the 11 native plant communities in the PRW that are closely associated with groundwater, four have an S3 conservation status rank, meaning they are vulnerable to elimination from Minnesota. (More information regarding Biodiversity Significance ranking can be found at [MBS Site Biodiversity Significance Ranks](www.dnr.state.mn.us/eco/mcbs/biodiversity_guidelines.html) (www.dnr.state.mn.us/eco/mcbs/biodiversity_guidelines.html).

Table 7: Native Plant Communities Associated or Influenced by Groundwater with assigned conservation status ranks (S-ranks) that reflect the risk of elimination of the community from Minnesota. S1 = Critically Imperiled; S2 =

Imperiled; S3 = Vulnerable to elimination from Minnesota; S4 = apparently secure; uncommon, but not rare; S5 = secure; common; widespread; abundant

Native Plant Communities in the Pine River Watershed	*Conservation Status Rank	Closely associated to groundwater	Influenced by groundwater
APn80a1 - Black Spruce Bog, treed subtype	S4		Yes
APn80a2 - Black Spruce Bog, semi- treed subtype	S4		Yes
APn81a - Poor Black Spruce Swamp	S5		Yes
APn81b1 - Poor Tamarack - Black Spruce Swamp, Black Spruce Subtype	S4		Yes
APn90 - Northern Open Bog			Yes
APn91 - Northern Poor Fen		Yes	
APn91a - Low Shrub Poor Fen	S5	Yes	
APn91b - Graminoid Poor Fen (Basin)	S3	Yes	
FDc23a1 - Jack Pine - (Yarrow) Woodland, Ericaceous Shrub Subtype	S1S2	No	
FDc23a2 - Jack Pine - (Yarrow) Woodland, But Oak - Aspen Subtype	S1S2	No	
FDc24a1 - Jack Pine - (Bush Honeysuckle) Woodland, Bracken Subtype	S1S2	No	
FDc25b - Oak - Aspen Woodland	S2	No	
FDc34 - Central Dry-Mesic Pine-Hardwood Forest		No	
FDc34a - Red Pine - White Pine Forest	S2	No	
FDc34b - Oak - Aspen Forest	S3	No	
FDn33 - Northern Dry-Mesic Mixed Woodland		No	
FFn67a - Silver Maple - (Sensitive Fern) Floodplain Forest	S3	No	
FPn63b - White Cedar Swamp (Northcentral)	S3	Yes	
FPn72a - Rich Tamarack Swamp (Eastcentral)	S3	Yes	
FPn73a - Alder - (Maple - Loosestrife) Swamp	S5		Yes
FPn82 - Northern Rich Tamarack Swamp (Western Basin)			Yes
FPn82a - Rich Tamarack - (Alder) Swamp	S5		Yes
FPn82b - Extremely Rich Tamarack Swamp	S4	Yes	
MHc26a -Oak - Aspen - Red Maple Forest	S4	No	
MHc26b - Red Oak- Sugar Maple - Basswood - (Large-flowered Trillium) Forest	S4	No	
MHn35a - Aspen - Birch- Basswood Forest	S4	No	
MHc36b - Red oak - Basswood Forest (Calcareous Till)	S4	No	
MHn44 - Northern Wet-Mesic Boreal Hardwood-Conifer Forest		No	
MHn46a - Aspen - Ash Forest	S4	No	
MHc47a - Basswood - Black Ash Forest	S3	No	
MRn83 - Northern Mixed Cattail Marsh			Yes

OPn92a - Graminoid Rich Fen (Basin)	S4	Yes	
OPn92b - Graminoid - Sphagnum Rich Fen (Basin)	S4	Yes	
WFn53b - Lowland White Cedar Forest (Northern)	S3	Yes	
WFn55b - Black Ash - Yellow Birch - Red Maple - Basswood Swamp (EC)	S3		Yes
WFn55c - Black Ash - Mountain Maple Swamp (Northern)	S4	Yes	
WFn64a - Black Ash - Conifer Swamp (Northeastern)	S4	Yes	
WFn74 - Northern Wet Alder Swamp			Yes
WMn82a - Willow - Dogwood Shrub Swamp	S5		Yes
WMn82b - Sedge Meadow	S4 or S5		Yes
WMn82b1 - Sedge Meadow, Bluejoint Subtype	S5		Yes
WMn82b3 - Sedge Meadow, Beaked Sedge Subtype	S4		Yes
WMn82b4 - Sedge Meadow, Lake Sedge Subtype	S5		Yes

In addition to native plant community surveys, the DNR also records the locations of endangered, threatened, and specie of special concern. There are five endangered (red) and threatened (peach) species in the PRW, including four aquatic plant species and the Blanding's turtle (Table 8). The Blanding's turtle requires both uplands and wetlands for its life cycle and returns to the same sites over time. Changes in groundwater levels can alter the abundance, depth, and areal extent of wetlands used by the turtles and affect individual turtle survivorship. For more information regarding rare plants and animals, go to DNR's Rare Species Guide (www.dnr.state.mn.us/rsg/index.html).

Table 8: State-listed species associated with groundwater-influenced habitats in the Pine River Watershed. END = endangered, THR = threatened, SPC = special concern species = extremely uncommon, Watchlist = DNR observation. Species with status rank of END and THR are subject to protection by Minnesota's Endangered and Threatened Species law. For more information see [Minnesota's Endangered, Threatened, and Special Concern Species](www.dnr.state.mn.us/ets/index.html) (www.dnr.state.mn.us/ets/index.html).

Scientific Name	Common Name	Category	State Rarity Rank	Habitat
Lasmigona compressa	Creek Heelsplitter	Invertebrate Animal	SPC	aquatic - rivers
Ligumia recta	Black Sandshell	Invertebrate Animal	SPC	aquatic - rivers
Alisma gramineum	Narrow-leaved Water Plantain	Vascular Plant	SPC	aquatic
Bidens discoidea	Bur-marigold	Vascular Plant	SPC	aquatic - lakes
Ceratophyllum echinatum	Spiny Hornwort	Vascular Plant	Watchlist	aquatic
Cladium mariscoides	Twig-rush	Vascular Plant	SPC	lake shore
Elatine triandra	Three Stamened Waterwort	Vascular Plant	SPC	aquatic
Eleocharis quinqueflora	Few-flowered Spike-rush	Vascular Plant	SPC	rich fens, poor fens
Eleocharis robbinsii	Robbin's Spike-rush	Vascular Plant	THR	aquatic - lakes
Fimbristylis autumnalis	Autumn Fimbristylis	Vascular Plant	SPC	lake shore
Littorella americana	American Shore-plantain	Vascular Plant	SPC	aquatic - lakes
Lycopus virginicus	Virginia Water Horehound	Vascular Plant	Watchlist	Sedge meadow
Malaxis monophyllos var. brachypoda	White Adder's-mouth	Vascular Plant	SPC	Mixed hardwood swamp
Najas gracillima	Thread-like Naiad	Vascular Plant	SPC	aquatic - lakes
Najas guadalupensis ssp. olivacea	Olivaceous Guadalupe Island Naiad	Vascular Plant	SPC	aquatic
Potamogeton oakesianus	Oakes' Pondweed	Vascular Plant	END	aquatic - lakes
Potamogeton pulcher	Spotted Pondweed	Vascular Plant	END	aquatic
Rubus vermontanus	A Bramble	Vascular Plant	SPC	Mesic hardwood forests
Torreyochloa pallida	Torrey's Manna-grass	Vascular Plant	SPC	beaver impoundments
Utricularia purpurea	Purple-flowered Bladderwort	Vascular Plant	END	aquatic - lakes
Botaurus lentiginosus	American Bittern	Vertebrate Animal	Watchlist	Emergent marsh
Buteo lineatus	Red-shouldered Hawk	Vertebrate Animal	SPC	Mesic hardwood forests with wetlands
Coturnicops noveboracensis	Yellow Rail	Vertebrate Animal	SPC	Sedge meadow
Cygnus buccinator	Trumpeter Swan	Vertebrate Animal	SPC	lakes
Emydoidea blandingii	Blanding's Turtle	Vertebrate Animal	THR	rivers, ponds, marsh; upland grasslands

Scientific Name	Common Name	Category	State Rarity Rank	Habitat
Etheostoma microperca	Least Darter	Vertebrate Animal	SPC	aquatic - lakes and streams
Grus canadensis	Sandhill Crane	Vertebrate Animal	Watchlist	Emergent marsh
Haliaeetus leucocephalus	Bald Eagle	Vertebrate Animal	Watchlist	forests, lakes

Special Well and Boring Construction Areas

A Special Well and Boring Construction Area, sometimes also called a well advisory, is a mechanism which provides for controls on the drilling or alteration of public and private water-supply wells, and monitoring wells in an area where groundwater contamination has, or may, result in risks to the public health. The purposes of a Special Well and Boring Construction Area are to inform the public of potential health risks in areas of groundwater contamination, provide for the construction of safe water supplies, and prevent the spread of contamination due to the improper drilling of wells or borings.

There are no Special Well and Boring Construction Areas in the Pine River Watershed.

Risks Associated with Changing Land Use Practices

Where sensitive geologic conditions exist, there may be considerable risk to vulnerable groundwater resources where relatively low impact land uses such as forested land are converted to potentially high impact land uses such as row crop agriculture, high density unsewered housing or industrial use including mining or hazardous waste generation/handling. Figure 2 is a useful starting point for determining where these types of developments could have the greatest impact, but as mentioned previously, more detailed information or mapping should be consulted where available.

Local Groundwater Studies

Geologic Atlases

That portion of the Pine River Watershed that falls within Crow Wing County is covered by a geologic atlas that was completed in 2007. Geologic atlases are currently under way for Cass and Hubbard Counties (Source: MGS and DNR websites). When those atlases are complete, 1:100,000 scale geologic mapping will be available for most of this watershed, exceptions being the relatively small areas within Aitkin County. These maps describe geologic conditions at depth as well as at the land surface. This feature allows for assessment of the vulnerability of specific aquifers to contamination.

Wellhead Protection Plans

In addition to the geologic atlases noted above, Wellhead Protection Plans have been completed for the communities of Pine River and Pequot Lakes. These plans include detailed hydrogeologic assessments for the Drinking Water Supply Management Areas (DWSMAs) that have been delineated for these communities. The vulnerability assessments for these DWSMAs are specific to the aquifers used by the communities. In the case of Pine River, the aquifer being used by the city is the surficial sand and gravel unit, so the vulnerability shown in Figure 2 for this area (high) is also reflective of the Pine River DWSMA (Figure 4). At Pequot Lakes, the city draws its drinking water from a sand and gravel body that is buried by clay, so the vulnerability of the city's DWSMA shown in Figure 4 (moderate) is lower than that shown for the water table aquifer in Figure 2 (high).

Conjunctive wellhead protection areas are those in which a surface water feature has been identified as contributing a significant quantity of recharge to the time-of-travel based groundwater capture zone for a public water supply well. In these instances, the watershed area of the contributing surface water feature is added to the groundwater capture area to create a composite protection area.

At this time there are no conjunctive wellhead protection areas delineated within the Pine River Watershed.

General Groundwater Restoration and Protection Strategies

Strategies for managing land use to minimize the impact to drinking water supplies should be tailored to the vulnerability of the drinking water source. For those portions of the watershed where the uppermost aquifer is used for drinking water, its vulnerability is shown in Figure 2 and ranges from high to low depending on local soil conditions. An example of a community that utilizes the uppermost aquifer is the city of Pine River, who's DWSMA has been classified as highly vulnerable. Where deeper aquifers are used, their vulnerability is dependent on the thickness, continuity and permeability of overlying fine-grained sediment and ranges from moderate to low. An example includes the city of Pequot Lakes, who's DWSMA has been classified as moderately vulnerable.

When considering strategies for protection of drinking water of private well owners, prioritize efforts in the watershed where people live that are served by private wells in conjunction with the vulnerability of the aquifer being used. Strategies for protection should coincide with the overall geologic vulnerability of the area. For example, nitrogen management strategies should be targeted to highly vulnerable areas as shown in Figure 2.

Much of the information contained within this plan is managed by various state agencies and should be used to support local resource staff and decision makers to target appropriate strategies to protect groundwater and drinking water resources in the watershed. In some cases, information may be primarily useful in supporting land use planning decisions. For example the closed landfill program is highly regulated by the MPCA, but it is important to know where these sites are located to assist local staff and decision makers establish appropriate land use controls to mitigate any risk to residents.

Table 9 below references the difference between the geologic aquifer vulnerabilities. This information is used to understand how quickly a potential contaminant can reach the aquifer. The more vulnerable the aquifer, the more land uses that need to be managed to protect drinking water supplies.

The general land use management strategies that are appropriate for a given aquifer vulnerability in the Pine River watershed are referenced in Table 10.

Table 9: Example management strategies based on land use and existing geologic aquifer vulnerability.

Geologic Vulnerability Areas	Aquifer Recharge	Potential Contaminant Sources to Manage (Example Strategies)
High	Aquifers receive recharge from the land surface within very short time periods - days to months (Geologic Sensitivity Project Workgroup, 1991). Contaminants may reach the aquifers without significant dilution or degradation. Many different types of land uses must managed.	Unused, unsealed wells SSTS Hazardous waste generators Stormwater Chemical or fuel storage tanks Transportation Corridors Turf Nitrogen Fertilizer and Pesticides
Moderate	Aquifers receive recharge from the land surface within time periods ranging from years to one or two decades (Geologic Sensitivity Project Workgroup, 1991). Contamination is diminished for many contaminants due to increased attenuation. Fewer land uses than high vulnerability must be managed.	Unused, unsealed wells Chemical or fuel storage tanks Transportation Corridors
Low	Aquifers receive recharge from the land surface within time periods ranging from several decades to a century (Geologic Sensitivity Project Workgroup, 1991). Few land uses must be managed due to the long recharge time.	Unused, Unsealed Wells

Table 10: Groundwater Protection and Restoration Strategies for the Pine River Watershed. All strategies can be applied watershed-wide.

Groundwater Strategy Category	Strategy	**Groundwater Vulnerability	Action/Partner: SWCD	Action/Partner: *Local Planning	Action/Partner: BWSR	Action/Partner: DNR	Action/Partner: MDA	Action/Partner: MDH	Action/Partner: MPCA
General Education & Awareness	Educate the public and decision makers about the importance of groundwater and the vulnerability of drinking water resources from land uses and contaminants in the watershed.	High Moderate Low	X	X	X	X	X	X	X
General Education & Awareness	Inform the public about the hydrologic connectivity of surface water and groundwater in the Pine River Watershed.	High Moderate Low	X	X					
General Education & Awareness	Evaluate the protection needs of drinking water resources in the watershed. Consider development of a "drinking water protection" page on the SWCD or County website or other communication tool that can be used to share information with citizens on what they can do to protect both public and private sources of drinking water.	High Moderate Low	X	X					
General Education & Awareness	Educate the public about a variety of water conservation practices they can adopt and implement in their homes and businesses.	High Moderate Low	X	X					
Water Resource, Land use planning and Controls	Annually convene a State / local groundwater technical group to discuss and coordinate groundwater and drinking water protection activities identified in WHP plans, 1W1P, GRAPS and other local water resource plans.	High Moderate Low	X	X	X	X	X	X	X
Water Resource, Land use planning and Controls	Integrate wellhead protection (WHP) plan strategies into local plans, such as the County Water Plan and land use plans.	High Moderate Low	X	X					
Water Resource, Land use planning and Controls	Assist in the development and implementation of wellhead protection plans.	High Moderate Low	X	X				X	

Groundwater Strategy Category	Strategy	**Groundwater Vulnerability	Action/Partner: SWCD	Action/Partner: *Local Planning	Action/Partner: BWSR	Action/Partner: DNR	Action/Partner: MDA	Action/Partner: MDH	Action/Partner: MPCA
Water Resource, Land use planning and Controls	Evaluate local controls and include as needed: Basic geology, water quality and quantity information and related implications or issues for future planning and development in their area. WHP areas, private wells and drinking water protection issues, needs and goals. Unique groundwater dependent ecological features, fauna, and habitat to help protect them from future land use impacts through local controls. Requirements for existing or new land uses for potential threats particularly where the uppermost aquifer is vulnerable and relied upon as a drinking water source. (Examples: Gravel Pits, Batch Plants and other types of uses that may have the potential to directly impact drinking water through ancillary uses, accidental spills or releases.) Regional or large scale land conversions from forested to more intensive land and groundwater uses. (Examples: Forested to Irrigated Row Crop Production or large Wet industry or industrial use or user that may impact groundwater quantity or quality) Existing former landfill, dump sites or groundwater contaminated areas identified by the MPCA as needed in future land use planning decisions.	High Moderate Low		X		X		X	X
Groundwater Sustainability	Assist communities serving over 1,000 people with water conservation measures outlined in their DNR municipal water supply plans.	High Moderate Low	X	X					
Groundwater Sustainability	Promote voluntary conservation measures, including reuse, use of emerging technology to increase water conservation at the field or local level.	High Moderate Low	X	X					
Protection of Groundwater Dependent Ecosystems	When applying conservation practices utilize the statewide list of groundwater-dependent native plant communities to identify and protect these sensitive ecosystems.	High Moderate Low	X			X			

Groundwater Strategy Category	Strategy	**Groundwater Vulnerability	Action/Partner: SWCD	Action/Partner: *Local Planning	Action/Partner: BWSR	Action/Partner: DNR	Action/Partner: MDA	Action/Partner: MDH	Action/Partner: MPCA
Protection of Groundwater Dependent Ecosystems	Establish riparian vegetation in DNR's Shoreland areas to slow the flow of surface water runoff and allow for pollutant removal as the water infiltrates into the ground.	High Moderate Low	X	X					
Protection of Groundwater Dependent Ecosystems	Promote land acquisition or conservation easements on private lands to protect groundwater recharge areas from inappropriate land uses.	High Moderate Low	X	X	X				
Efficient Groundwater Use	If groundwater dependent native plant communities with a conservation status rank of S1 or S2 or rare species exist, develop a co-monitored network of groundwater monitoring wells and native plant communities and/or rare species to assess changing groundwater conditions.	High Moderate Low	X	X		X			
Efficient Groundwater Use	Support public education about rare plant and animal species that are closely tied to groundwater. For example, incorporate high profile rare species or native plant communities into groundwater fact sheets for the public.	High Moderate Low	X	X		X			
Protection of Groundwater Recharge Areas	Avoid conversion of County (tax forfeit) forest lands and DNR-managed Trust forest lands, to agriculture, highways, or urban development.	High Moderate Low		X					
Protection of Groundwater Recharge Areas	Protect forested riparian areas at the water table interface by promoting Best Management Practices for timber harvesting across ownerships.	High Moderate Low	X			X			
Protection of Groundwater Recharge Areas	Promote wetland conservation and restoration to support recharge areas with ground-water dependent native plant communities and rare species.	High Moderate Low	X	X	X				
Protection of Groundwater Recharge Areas	Limit ditching and channelization that pulls water through the landscape in areas with groundwater dependent native plant communities and rare species.	High Moderate Low		X		X			
Private Wells	Identify strategies to protect private wells based on the vulnerability of the aquifer used as the source of drinking water.	High Moderate Low	X	X				X	

Groundwater Strategy Category	Strategy	**Groundwater Vulnerability	Action/Partner: SWCD	Action/Partner: *Local Planning	Action/Partner: BWSR	Action/Partner: DNR	Action/Partner: MDA	Action/Partner: MDH	Action/Partner: MPCA
Private Wells	Provide information about arsenic in drinking water, particularly in areas of the watershed known or suspected to have elevated arsenic.	High Moderate Low	X	X				X	
Private Wells	Make information available to private well owners about local drinking water quality and opportunities to have their water tested.	High Moderate Low	X	X			X	X	
Private Wells	Identify and promote the proper sealing of unsealed, unused wells. Prioritize wells to be sealed in populated areas and WHP areas.	High Moderate Low	X	X	X			X	
Private Wells	Promote proper management of wells through MDH tools such as the 'Well Owners Handbook." Examples may be promotion of best practices at local tradeshows and lake association events.	High Moderate Low	X	X				X	
Agriculture Land Use BMP's	Target and prioritize promotion of Nitrogen BMP's to row crop producers and crop consultants in geologically vulnerable areas and coarse textured soils of the watershed. Specific BMP information is available in Appendix A.	High	X				X		
Agriculture Land Use BMP's	Promote livestock BMP's (rotational grazing, buffers, feedlot and manure containment, etc.) in groundwater sensitive areas to protect surface water and groundwater recharge areas.	High	X				X		X
Agriculture Land Use BMP's	Work with MDA and private well township nitrate testing as needed in the promotion and adoption of nitrogen BMP's by growers as described in the State Nitrogen Fertilizer Management Plan.	High	X	X			X		
Stormwater Management	Manage stormwater runoff to minimize adverse impacts to groundwater. Refer to MDH Stormwater Infiltration Guidance for sites in a Drinking Water Supply Management Area (DWSMA).	High	X	X					X
On-Site Septic Systems (SSTS) (MN SSTS Rule 7080)	Evaluate local government SSTS Programs and practices to protect groundwater and drinking water resources including: Further identification, prioritization and upgrade of noncompliant septic systems in critical areas, such as highly vulnerable WHP areas, lakeshore and unincorporated areas with high density of private wells.	High	X	X					X

Groundwater Strategy Category	Strategy	**Groundwater Vulnerability	Action/Partner: SWCD	Action/Partner: *Local Planning	Action/Partner: BWSR	Action/Partner: DNR	Action/Partner: MDA	Action/Partner: MDH	Action/Partner: MPCA
	Evaluate and improve as needed implementation of regulatory SSTS upgrade requirements for noncompliant systems at the time of property transfer. Prioritize promotion of SSTS education, management and maintenance in high vulnerable WHP areas, lakeshore and unincorporated areas with high density of private wells. Educate citizens about the potential implications of a failing or noncompliant septic system on local drinking water resources. Evaluate the need and availability of low interest loans, cost share assistance to qualified homeowners in the critical areas related to drinking water identified above. Assist small communities or densely populated areas where drinking water resources could be threatened where centralized wastewater treatment options may be applicable. Evaluate & improve as needed implementation of local regulation and/or education about the proper application of septage.								
On-Site Septic Systems (SSTS) (MN SSTS Rule 7080)	Promote connection of SSTS to municipal sanitary sewer systems where applicable.	High		X					
Turf Management	Provide information on best practices for turf management to the public, particularly on: Fertilizer Application Crediting for Grass Clippings Lawn Watering Herbicide and Pesticide Application	High	X	X					
Forestry	Evaluate tools to shield forested land from being converted to protect groundwater and drinking water supplies, including: Conservation Easements USDA Farm Bill Programs, such as WHIP Forest Stewardship Plans	High	X	X	X	X			

* Local Planning includes County Water Planner and Planning and Zoning Staff.
** High, Medium, and Low Vulnerability to Groundwater Contamination. Refer to Table 9 for a description of each vulnerability.

Specific Groundwater Restoration and Protection Strategies

In areas of the watershed where specific groundwater restoration and protection strategies have already been identified through other programs at the local, state or federal level, these should supersede the more general management strategies noted above if they pertain to the same aquifer. Examples where this might occur include wellhead protection areas, special well construction areas and superfund and other cleanup sites. Currently there exist two wellhead protection areas in the Pine River Watershed, those belonging to the cities of Pine River and Pequot Lakes. Please refer to the Wellhead Protection Plans for those communities for additional information. Note that if specific groundwater management strategies pertain to aquifers deeper than the uppermost, it may still be beneficial to implement the more general strategies outlined in the preceding section to provide protection to shallow groundwater users.

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Appendices

Glossary of Key Terms

Aquifer

An aquifer is an underground layer of water-bearing permeable rock, rock fractures or unconsolidated materials (gravel, sand, or silt) from which groundwater can be extracted using a water well.

Aquifer Pollution Sensitivity

The Minnesota Department of Natural Resources (DNR) defines an area as sensitive if natural geologic factors create a significant risk of groundwater degradation through the migration of waterborne contaminants (MS § 103H.101).

Impairment

Water bodies are listed as impaired if water quality standards are not met for designated uses including: drinking water, fishing and swimming.

Protection

This term is used to characterize actions taken in watersheds to maintain conditions and beneficial uses of waters not known to be impaired.

Restoration

This term is used to characterize actions taken in watersheds to improve conditions, eventually to meet water quality standards and achieve beneficial uses of impaired waters.

Source (or Pollutant Source)

This term is distinguished from 'stressor' to mean only those actions, places or entities that deliver/discharge pollutants (e.g., sediment, phosphorus, nitrogen, pathogens).

Source Water Protection

Source water refers to water from streams, rivers, lakes or underground aquifers—that is used for drinking.

Vulnerability

Vulnerability refers to the susceptibility of a water supply to contamination from activities at the land surface.

Water Table

The boundary between the water filled rock and sediment of an aquifer and the dry rock and sediment above it. The depth to the water table is highly variable. It can range from zero when it is at land surface, such as at a lake or wetland, to hundreds or even thousands of feet deep. In Minnesota, the water table is generally close to the land surface, typically within a few tens of feet in much of the state.

Pesticide and Fertilizer Management on Agricultural Lands

Minnesota Department of Agriculture Recommendations

The Minnesota Department of Agriculture (MDA) requires that legal requirements for the use, storage and disposal of agricultural fertilizers and pesticides be followed. In addition, the MDA recommends the use of voluntary water quality best management practices for fertilizer and pesticides. Legal requirements for pesticide use, storage, and disposal are predominately found on the pesticide label and also at Managing Pesticides, Waste Pesticides & Empty Pesticide Containers (www.mda.state.mn.us/protecting/bmps/waste.aspx). Best management practices for pesticides are also on the same website. Legal requirements for fertilizer use and storage are at Fertilizers (www.mda.state.mn.us/chemicals/fertilizers). Best management practices for nitrogen fertilizer are also on the same website.

Below are additional details about pesticide and fertilizer best management practices that apply to areas of vulnerable groundwater geology in the Pine River watershed area, which are shown in Figure 1. The goal of the best management practices is to prevent or minimize the contamination of groundwater from fertilizers and pesticides.

BMPs for Nitrogen Use on Course Textured Soils:

The MDA is responsible for the development, promotion, and evaluation of best management practices (BMPs) to reduce contamination of groundwater from fertilizer use. The MDA enlisted the assistance of the University of Minnesota to develop best management practices (BMPs) for nitrogen fertilizer use on coarse texture soils. Coarse textured soils, also known as sandy soils, dominate the landscape in the central and east-central regions of the state and are common in the Pine River watershed area. Often irrigation is used on these soils to grow corn, soybeans, potatoes and dry beans. The goal of the BMPs is to maximize crop utilization of nitrogen while minimizing the loss of nitrogen to groundwater and surface water.

The BMPs for nitrogen fertilizer use on coarse texture soils are found at Nitrogen Fertilizer Best Management Practices (www.mda.state.mn.us/nitrogenbmps). It is the MDA's recommendation that these BMPs be followed by those growing crops on coarse textured soils in the Pine River watershed area. The BMPs include recommended, acceptable with greater risk, and not recommended practices:

Recommended practices include using an appropriate nitrogen (N) fertilization rate, accounting for N in all applied fertilizer products, using split applications of N for corn and edible beans, using a nitrification inhibitor on early applied side dressed N, utilizing appropriate legume and manure credits, and incorporating N fertilizer.

Practices that are acceptable but with greater risk include using a single spring preplant nitrogen (N) application with a nitrification inhibitor, using a single sidedress application of anhydrous ammonia or urea early in the season without an nitrification inhibitor, and using a spring preplant application of ESN (a slow release, urea N fertilizer).

Practices that are not recommended include any fall application of nitrogen (N) fertilizer, not accounting for legume and manure N credits, spring preplant N applications on corn without a nitrification inhibitor, fertigation of N after corn has tasseled, and application of ESN after edible beans are planted.

University of Minnesota Extension publication #08556 is available at Nitrogen Fertilizer Best Management Practices (www.mda.state.mn.us/nitrogenbmps) and can be referenced for full details on these BMPs.

BMPs for Nitrogen Use on Irrigated Potatoes:

The MDA also enlisted the assistance of the University of Minnesota to develop best management practices (BMPs) for nitrogen fertilizer use on irrigated potatoes.

The BMPs for nitrogen fertilizer use on irrigated potatoes are found at Nitrogen Fertilizer Best Management Practices (www.mda.state.mn.us/nitrogenbmps). It is the MDA's recommendation that these BMPs be followed by those growing irrigated potatoes in the Pine River watershed area. The BMPs include recommended and not recommended practices:

Recommended practices include selecting a realistic nitrogen (N) rate, account for N supplied by previous crops and irrigation water, time N applications to match the needs of the crop, using irrigation management, and using cover crops whenever possible.

Practices that are not recommended include not applying nitrogen (N) fertilizer in the fall on coarse texture soils, not over-apply N in starter applications, not using nitrate forms of N in starter fertilizer, not using ESN (a slow release, urea N fertilizer) on early potato varieties, and not applying ESN to mid to late varieties after emergence.

University of Minnesota Extension publication #08559 is available at Nitrogen Fertilizer Best Management Practices (www.mda.state.mn.us/nitrogenbmps) and can be referenced for full details on these BMPs.

BMPs for Agricultural Herbicides:

The Minnesota Department of Agriculture (MDA) has developed best management practices (BMPs) to address herbicide use and water resource protection. The BMPs include mandatory label requirements and a series of voluntary practices to guide farmers on herbicide use. These practices can reduce herbicide leaching into groundwater or runoff into surface water while giving consideration to the specific needs of farming operations.

The BMPs were initially developed in 2004 to address the presence of the herbicides acetochlor, alachlor, atrazine, metolachlor and metribuzin, or their breakdown products, in Minnesota's groundwater or surface water from normal agricultural use. The BMPs were developed by the MDA and University of Minnesota Extension, in consultation with other interested parties.

Groundwater protection BMPs begin with strict adherence to mandatory use requirements as established on individual product labels. Each product label should be reviewed for any application setback distances from surface waters, drinking water wells, or other sensitive sites, and for maximum application rates. After following mandatory use requirements, optional BMPs include using reduced application rates, applying herbicides in split applications, using herbicide with low leaching potential in vulnerable groundwater areas, rotating herbicide products used, using precision application methods, and developing an irrigation management plan where irrigation is used.

Full details on the BMPs for agricultural herbicides are available at Water Quality BMP Fact Sheets & Posters (www.mda.state.mn.us/herbicidebmps). It is the MDA's recommendation that these BMPs be followed by those using agricultural herbicides in the Pine River watershed area in addition to closely adhering to the use directions found on pesticide product labels.

BMPs for Pesticide Management and Handling:

The Minnesota Department of Agriculture (MDA) worked collaboratively with the University of Minnesota to develop best management practices (BMPs) for pesticide use and handling that can help protect groundwater. They are available at Pesticide Best Management Practices (www.mda.state.mn.us/en/protecting/bmps/voluntarybmps.aspx) and include:

- Guidelines for Developing and Maintaining an Incident Response Plan (spills and other accidents)
- Handling Pesticides Safely
- Managing Pesticides, Waste Pesticides and Empty Pesticide Containers
- Mixing, Loading, and Storing Pesticides
- Non-Pesticide Voluntary Best Management Practices that Help Control Pests
- Pesticide Application How-To's
- Pesticide Selection How-To's
- Timing of Pesticide Use: Before or After Infestation

It is the MDA's recommendation that these BMPs be followed by those using pesticides in the Pine River watershed area in addition to complying with all mandatory and recommended use directions found on pesticide product labels, as well as herbicide-specific BMPs discussed above.

DNR Groundwater Protection Strategies

By statute DNR is required to accomplish two goals pertaining to groundwater.

DNR Goal 1: To ensure sustainable supplies of groundwater into the future

DNR Strategy 1: The DNR permits all groundwater users who require over 10,000 gallons of groundwater a day or one million gallons a year and reviews groundwater allocation permits every 5 years All permitted groundwater users are required to report volume of use annually to the DNR.

DNR Strategy 2: The DNR approves municipal water supply plans every 10 years for 360 communities serving over 1000 residents; future water supply plans will require planning for groundwater, demand reduction measures, and identification and monitoring of potential surface water feature impacts.

DNR Strategy 3: The DNR uses an improved well interference process that has greater consistency statewide to ensure allocation of groundwater appropriations within sustainable limits. The interferences process will prevent or resolve groundwater allocation issues, with first priority for water allocation to domestic water users.

DNR Strategy 4: The DNR encourages efficient groundwater use through voluntary conservation measures, including reuse, use of emerging technology to increase water conservation at the field or local level.

DNR Goal 2: To ensure that groundwater use does not degrade water quality or harm groundwater-dependent ecosystems

DNR Strategy 1: The DNR actively works with SWCD's to monitor the state's observation well system that monitors water levels.

DNR Strategy 2: The DNR protects key groundwater dependent surface water features, including trout streams and calcareous fens, through the development of thresholds. A statewide list of groundwater-dependent native plant communities is available through the DNR's Division of Ecological and Water Resources.

DNR Strategy 3: The DNR's Shoreland and Mississippi River Corridor Critical Areas rules encourage local protection of riparian vegetation that serves to slow the flow of surface water runoff and allow for pollutant-removal as the water infiltrates into the ground.

DNR Strategy 4: The DNR's many natural areas (Wildlife Management Areas, state forests, Scientific and Natural Areas, and state parks) serve to recharge groundwater.

DNR Strategy 5: The DNR and its conservation partners increase awareness about how land acquisition or conservation easements on private lands can protect groundwater recharge areas from inappropriate land uses.

DNR Strategy 6: The DNR supports local adoption of a groundwater overlay district or other local ordinances that prevent inappropriate land uses in groundwater recharge areas.

Site Level Strategies to Protect Groundwater-Dependent Native Plant Communities and Rare Species

Strategy 1: Efficient Groundwater Use

- If groundwater-dependent native plant communities with a conservation status rank of S1 or S2 or rare species exist, develop a co-monitored network of groundwater monitoring wells and native plant communities and/or rare species to assess changing groundwater conditions.
- Support public education about rare plant and animal species that are closely tied to groundwater. For example, incorporate high profile rare species or native plant communities into groundwater fact sheets for the public.

Strategy 2: Protection of Groundwater Recharge Areas

- Avoid conversion of County (tax forfeit) forest lands and DNR-managed Trust forest lands, to agriculture, highways, or urban development.
- Protect forested riparian areas at the water table interface by promoting Best Management Practices for timber harvesting across ownerships.
- Promote wetland conservation and restoration to support recharge areas with ground-water dependent native plant communities and rare species.
- Limit ditching and channelization that pulls water through the landscape in areas with ground-water dependent native plant communities and rare species.