Prepared for

LOWER MINNESOTA RIVER
WATERSHED DISTRICT

March 2024

Seminary Fen Stewardship Plan

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Prepared by

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Abbreviation	Reference
CCWMO	Carver County Watershed Management Organization
CGM	Cooperative Groundwater Monitoring
LMRWD	Lower Minnesota River Watershed District
MNDNR	Minnesota Department of Natural Resources
WMO	Watershed Management Organization
HVRA	High Value Resource Area
CAC	Citizen Advisory Committee
SFWC	Seminary Fen Wetland Complex
SNA	Scientific and Natural Area

INTRODUCTION

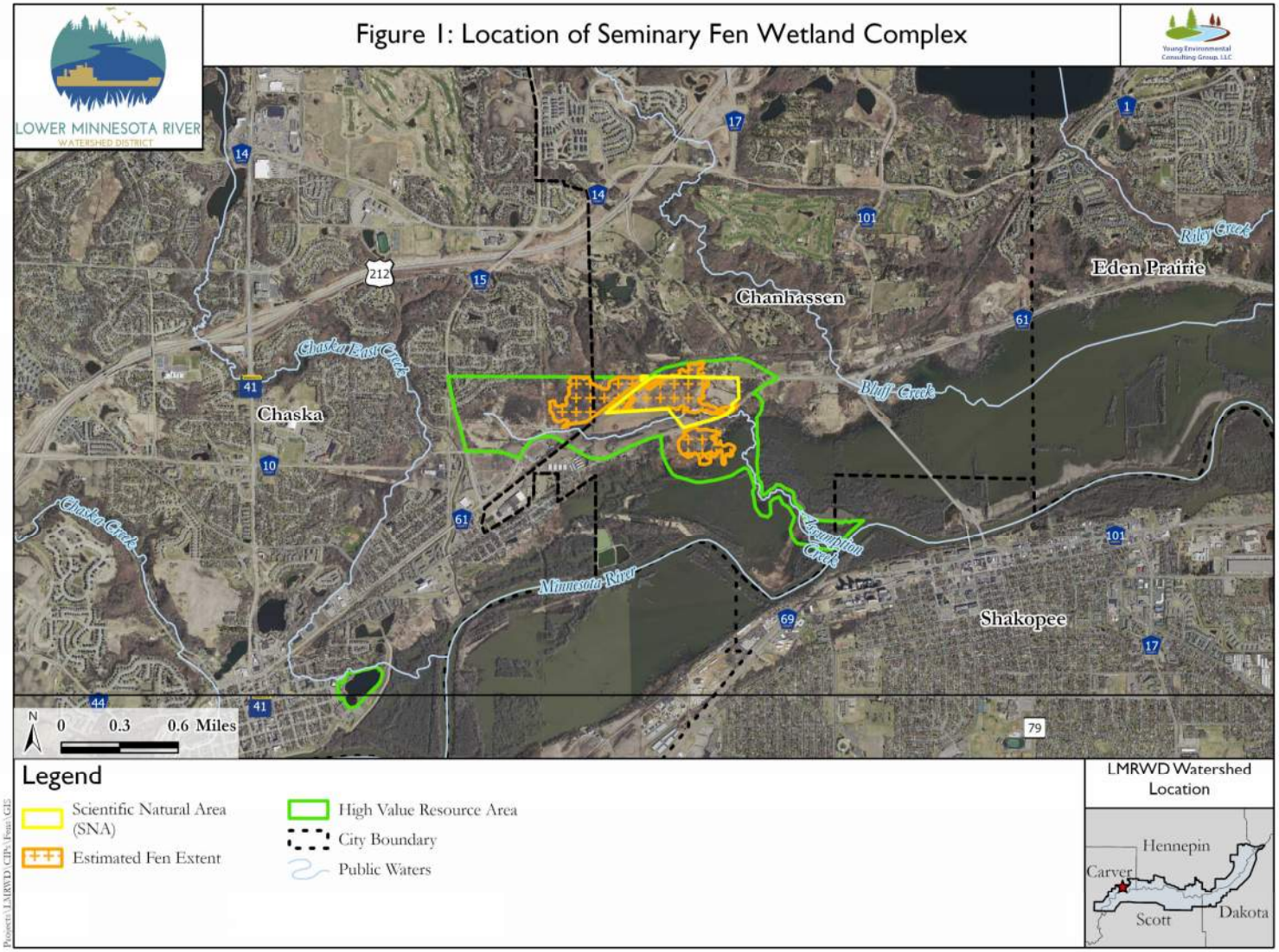
Seminary Fen is a collection of unique wetlands located in and around the Minnesota Department of Natural Resources' (MNDNR's) 73-acre Seminary Fen Scientific and Natural Area (SNA) on the north side of the Minnesota River in the cities of Chaska and Chanhassen in Carver County (Figure 1). As a group, these wetlands are identified as the Seminary Fen Wetland Complex (SFWC). This document uses "Seminary Fen" and "SFWC" interchangeably to describe the wetland complex. Seminary Fen is categorized as a calcareous fen, one of the rarest types of wetlands in the United States, characterized by a peat substrate and dependent on a constant supply of cold, oxygen-poor groundwater nearly saturated with calcium and magnesium bicarbonates. Fen ecosystems support unique plant communities that can contain rare and endangered plant species; vegetation surveys of Seminary Fen in 2021 identified several plants listed by the State of Minnesota as threatened or species of special concern. Assumption Creek runs through the southern part of the Seminary Fen SNA and likely receives baseflow upwelling from the same groundwater source as the fen.

Seminary Fen is located within one of the Lower Minnesota Watershed District's (LMRWD's) High Value Resource Areas (HVRAs), which require special consideration and adherence to protection standards as specified in the LMRWD's 2018 Comprehensive Watershed Management Plan (2018 Plan). The HVRAs are a management strategy, adopted as part of the 2018 Plan, that consists of managing areas directly draining into calcareous fens and trout waters through the formation of HVRA overlay districts. The goals of the 2018 Plan and the corresponding implementation of HVRA overlay districts are to understand, preserve, protect, and restore unique and high-value natural resources while critically evaluating projects that propose to alter them.

In 2021, Young Environmental prepared a Fens Sustainability Gaps Analysis for Carver, Dakota, and Scott Counties, Minnesota (Gaps Analysis) (Young Environmental, 2021) for the LMRWD that recommended the development of management plans for fens in the LMRWD. These plans would identify stewardship actions to protect and sustain the fens into the future. In response to the Gaps Analysis, this Seminary Fen Stewardship Plan (Stewardship Plan) has been prepared to identify stewardship and management actions, areas of additional study, and education and outreach opportunities for Seminary Fen. This Stewardship Plan represents the continued commitment to the LMRWD's goal to protect, enhance, and sustain the valuable resources, such as the Seminary Fen, that lie within its boundaries.

The Stewardship Plan's focus is to outline stewardship and management needs and suggests actions to protect, restore, and sustain Seminary Fen. Those stewardship needs and actions are presented early in the plan to highlight their importance. Information and data on Seminary Fen and the surrounding area, including data gathered since completion of the Gaps Analysis, are presented later in the plan. The Gaps Analysis includes additional detailed background information and data that informed the recommendations in this Stewardship Plan.

Figure 1. Location of the Seminary Fen Wetland Comple



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This Stewardship Plan is intended to create awareness of the value and uniqueness of Seminary Fen and guide future stewardship with the goal of creating collective commitment among stakeholders to protect the fen. Based on analyses of past fen studies, vegetation assessments, and groundwater monitoring data, this Stewardship Plan proposes data collection, resource investigation, and stewardship actions to be implemented by the MNDNR, the LMRWD, and other stakeholders to help protect and sustain Seminary Fen, including the following:

- Conducting vegetation surveys within the fen and developing and implementing programs to control nonnative, invasive species and propagate and reintroduce native species;
- Continuing groundwater monitoring efforts to build on the existing body of groundwater monitoring data, developing a more robust monitoring network by adding monitoring wells as needed, and continuing to collect groundwater quality data in the fen to improve understanding of the quality and sustainability of the groundwater supply;
- Identifying and assessing the impact of the existing drain tile network within the fen and decommissioning tiles that are negatively impacting the fen;
- Encouraging stakeholder engagement in protecting Seminary Fen by developing education and outreach materials and activities that inform stakeholders, encourage conservation, and provide public stewardship and engagement opportunities to raise awareness and understanding of these threatened ecosystems and encourage protection of Seminary Fen into the future.

This Stewardship Plan identifies stakeholders that can participate in the preservation and protection of Seminary Fen and recommends stewardship actions aimed at protecting and enhancing the fen ecosystem and mitigating risks of degradation.

STAKEHOLDER ENGAGEMENT

The MNDNR and LMRWD lead the planning and implementation of ongoing studies, stewardship actions, and education and outreach for Seminary Fen.

The MNDNR has management authority over the Seminary Fen SNA, including the associated monitoring well network. It has conducted several vegetation surveys, starting in 1990, that established the importance and viability of Seminary Fen, and it is responsible for licensing and allocating the use of groundwater and surface water resources. The MNDNR also manages the Cooperative Groundwater Monitoring Network, which provided the water-level information included in this report. In addition, the MNDNR Fisheries Department has conducted several fish assemblage and habitat assessments of Assumption Creek, which is closely connected to Seminary Fen.

The LMRWD is responsible for regulating development projects that occur within the Seminary Fen HVRA and surrounding areas within the district. It funds the Carver County Watershed Management Organization's (CCWMO's) monitoring efforts in Seminary Fen, and it is expected to be the primary coordinator of stakeholder education, outreach, and collaboration, and contribute to facilitating implementation of stewardship programs.

Developing collaborative relationships with stakeholders and other groups interested in studying, managing, and enhancing Seminary Fen is key to making informed management decisions and implementing actions

that will protect and sustain the fens. In addition to the MNDNR, LMRWD, and CCWMO, other stakeholders' collaboration will also be necessary for responsible development in areas surrounding the fen and groundwater recharge area, planning and implementation of stewardship actions, collecting and sharing Seminary Fen data, and tracking stewardship progress. These stakeholders include the Minnesota Pollution Control Agency, Minnesota Department of Transportation, Minnesota Department of Health, Minnesota Geological Survey, US Army Corps of Engineers, Metropolitan Council of the Twin Cities, City of Chanhassen, City of Chaska, National Audubon Society, Trout Unlimited, Minnesota Landscape Arboretum, Minnesota Native Plant Society, Science Museum of Minnesota, Great River Greening, private property owners in the vicinity of Seminary Fen, and prospective developers of nearby properties.

Many organizations and individuals are likely to support the protection and enhancement of Seminary Fen and its associated resources. However, many of those stakeholders may be unaware of the fen's unique ecosystem. Outreach efforts by the LMRWD could inspire interest and engender involvement and participation from previously uninvolved persons and groups.

Stakeholder engagement will also help inform adjacent landowners, developers, and responsible public entities about the importance of protecting Seminary Fen. The LMRWD can facilitate this engagement by developing education and outreach materials to encourage groundwater conservation and by providing opportunities for the public to be involved in restoring and protecting the fen. Such opportunities could include coordinating volunteer efforts to remove invasive, nonnative species as well as collaborating with MNDNR and the Minnesota Landscape Arboretum on plant propagation programs and seed collection for threatened and endangered species. It is imperative that education and outreach efforts highlight the sensitivity of the fen and the need to minimize human activity that would impact fen vegetation and habitat. When planning for stewardship actions within the fen, such as invasive vegetation control or groundwater monitoring, only actions that would result in minimal impact to the fen should be considered. Education and outreach efforts should focus on preserving and protecting the fen's sensitive habitat and should discourage activities that could detrimentally impact the fen ecosystem.

STEWARDSHIP OPPORTUNITIES

Since the Gaps Analysis was presented, some of its recommendations have been addressed and new opportunities have been identified (Young Environmental, 2021). After a thorough review of existing information and projections regarding the health of the fen, the MNDNR and the LMRWD will work with the existing and potential stakeholders outlined above to plan and implement continued monitoring, assessment, and actions to mitigate threats to fen health and enhance the fen ecosystem for future sustainability. Stewardship opportunities and actions are described below, and Table 1 outlines proposed stewardship opportunities, actions, timelines, and estimated costs.

Vegetation Assessment

The vegetation relevés recommended in the Gaps Analysis were completed in June and August 2021. These assessments identified previously unknown thriving communities in Seminary Fen, suggesting that future vegetation assessments could identify other previously overlooked or undiscovered fen vegetation communities. Continuing vegetation assessments are recommended at five-year intervals using the existing relevé plots. Additional plots should be considered as necessary and feasible.

Vegetation Management

There are several methods to consider for managing invasive, nonnative species. These include hand pulling, digging, spot herbicide treatments, and controlled burns. Controlled burns in fens add the risk that a peat fire could be started, which would be difficult to control and could destroy parts of the fen. New techniques and protocols for identifying and managing invasive species, such as the use of drones, are currently being developed, and opportunities to work with stakeholders to apply and refine these evolving techniques should be considered in lieu of riskier management strategies. Development of a vegetation management program is recommended to address threats from invasive, nonnative species. Such a program should identify vegetation management needs, identify volunteer groups and experienced vegetation management personnel to implement management actions, and use and develop vegetation control techniques to minimize disturbance and damage to native plant species and the fen ecosystem.

Fen Vegetation Indicators

Development of additional fen indicators would help expand the toolbox used by practitioners, making identification of fens more efficient and informing ongoing stewardship needs. Vascular plants are assessed using the relevé method, and plants unique to the fen environment are given point values that are added to achieve a score characterizing the wetland as a calcareous fen. Other indicators may be equally or more effective at identifying calcareous fens and could potentially be identified cheaply and easily. Bryophytes, including mosses, liverworts, and hornworts, have been suggested as useful fen indicators (Janssens, 2014) because they may not require the season-specific, paired site visits needed when using vascular plants as fen indicators. House (2021) suggests that bryophytes are a good indicator of the health of a calcareous fen. However, there is a paucity of technical experts and resources to pursue investigating bryophytes as a tool for fen characterization. Identifying other indicators will require research into various fen floral and faunal characteristics, which could be funded by research organizations and conducted by teaching staff and students at nearby scholastic institutions or by state or federal agencies with a relevant mandate and sufficient funding.

Groundwater Elevation Monitoring

The primary contributor to fen health appears to be the sustained flow of calcium-enriched groundwater from beneath. There are several fens in the LMRWD in varying conditions, but the healthiest appear to have the most reliable supplies of groundwater (Young Environmental, 2021). Seminary Fen's sustainability depends on this continuous supply of upwelling groundwater. Therefore, it is important to continue monitoring groundwater levels with existing wells and regularly evaluate whether additional wells are needed. Continued operation of automated recorders provides more detail and better resolution of groundwater levels as they change over time. The MNDNR must continue to coordinate with existing and potential users of the groundwater that sustains Seminary Fen to prevent overallocation and maintain groundwater levels and conditions to sustain a healthy fen ecosystem.

Groundwater Quality Monitoring

Young Environmental (2021) noted that minimal water chemistry data were available to describe the groundwater quality beneath Seminary Fen, except to verify that the water chemistry was consistent with the

calcium- and magnesium-bicarbonate waters associated with calcareous fens. Young Environmental (2021) recommended routine sampling to better describe water quality and identify trends. The MNDNR initiated routine sampling of groundwater chemistry from selected wells after the 2021 analysis; this will provide information about ionic strength and the proportions of ions comprising the water supplying the fen, establish a baseline, and quantify the variability of chemicals in the water. The information will also document changes in water chemistry related to land use in the presumed groundwater recharge area and near the SFWC. Sampling a pair of shallow and deep wells is suggested, with the shallow well completed in the peat layer and the deeper well completed in the sand and gravel aquifer beneath the peat layer. Peat deposits provide a highly organic, minimally transmissive medium, whereas sand and gravel provide a mineral-rich, more transmissive medium, so the water chemistry in each environment may have characteristically distinct differences.

The annual sample collection should be accompanied by field measurements of water temperature, specific conductance, pH, and dissolved oxygen. These measurements should be used to determine whether sampled water is representative of the aquifer chemistry by documenting three consistent readings before samples are collected. Because peat has low transmissivity, insufficient water may be withdrawn to achieve these three-reading criteria before collecting the water chemistry samples. Collected samples should be field-filtered, preserved, and laboratory analyzed for dissolved major-ion concentrations and concentrations of nutrients, including dissolved phosphorus and nitrogen species, alkalinity, and dissolved organic carbon.

Age-dating indicators should also be sampled annually from the deep well until the age of the water supplying the SFWC is clearly understood. Recent groundwater is more likely than old groundwater to have recent manmade contaminants, such as pesticides, nitrate nitrogen, and chloride salts, because these chemicals could have been applied to or released on the landscape when the groundwater recharged the aquifer. A variety of tools are available to age-date the water, and it will be necessary to evaluate which is most appropriate for SFWC groundwaters. Tritium analyses are indicative of water recharged in the 1950s and 1960s, chlorofluorocarbons indicate waters recharged in the 1930s through the 1980s, and sulfur hexafluoride indicates water recharged since about 1965. Other tests can be used to refine these numbers or age-date water that was recharged decades or centuries earlier. Because each test can be expensive, and some indicators are difficult to collect and analyze, selecting a different indicator for sampling each year is prudent to develop results that confirm or refute previous findings.

Assumption Creek

Stewardship of Seminary Fen should include consideration of the adjacent Assumption Creek trout stream. Although Assumption Creek does not presently appear to support a trout population, it seems to have the needed habitat characteristics. Water draining from Seminary Fen provides sustained flow to much of the creek. The creek may also protect Seminary Fen by carrying potentially detrimental runoff from upland areas around and away from the fen. Improved understanding of the connection of Seminary Fen and Assumption Creek and holistic management of these resources is important to their sustainability.

Stakeholder Collaboration, Education, and Outreach

Partnerships with interested stakeholders will help broaden support and increase understanding of the value of calcareous fens, which is needed to support Seminary Fen's stewardship. A broadened base of support

will also enhance opportunities to secure needed funding. Potential opportunities include securing grants while promoting volunteer opportunities to help manage invasive, nonnative species.

Opportunities to work with the Minnesota Landscape Arboretum, local universities, state and federal agencies, and other entities should be considered to assess the vulnerabilities of native fen flora to chemicals that may be in the area. Opportunities also exist for collaboration with local, state, federal, and nonprofit agencies, as well as landowners adjacent to Seminary Fen.

Stewardship Strategies Table

Table 1 provides recommendations for various stewardship strategies to protect, enhance, and manage Seminary Fen. The lead agency in most of these efforts is the MNDNR, because it manages the Seminary Fen SNA and has responsibility and authority for many of the resources related to Seminary Fen. The timelines shown may need to be adjusted as information is gathered and programs and implementation of actions are planned.

Table 1. Seminary Fen Stewardship Strategies

Item	Stewardship Strategy	Category	Responsible Agencies	Additional Considerations	Proposed Action Year			
					2024	2025	2026	2027
1	Conduct plant surveys every five years using existing relevé plots.	Vegetation	MNDNR and LMRWD	Utilize vegetation plots established in the 2021 relevé and identify additional locations for vegetation plots to best inform actions and locations of stewardship opportunities.			Repeat Survey	
2	Develop and implement a nonnative, invasive species management program to identify and map nonnative, invasive species and implement actions to control them in Seminary Fen.	Vegetation	MNDNR and LMRWD	Identify stakeholders to implement control measures, including volunteer groups and vegetation professionals. Consider using drones and field verification to map nonnative, invasive species. Coordinate with drain tile assessment work to determine whether a nexus exists between drain tile location and invasive species locations and abundance.	Develop and Implement Plan			
3	Develop a native species propagation program to collect seeds and replant threatened and endangered fen species in strategic locations to provide ecosystem uplift.	Vegetation	MNDNR and LMRWD	Coordinate with SNA management, Minnesota Landscape Arboretum, and other stakeholders to develop this program. Initial efforts would focus on public lands and could be scaled later to include private lands. The goal of this strategy is to enhance Seminary Fen and develop tools and methods for restoring and enhancing fen ecosystems on a broad scale, not just at Seminary Fen.	Collaboration			
4	Continue research and validation of tools and methods to identify fen species and indicators of fen vigor.	Vegetation	MNDNR	Studies of bryophytes as fen indicators are on hold because too few experts are available. Identify and assess additional methods to expand the current fen assessment and identification toolbox.	Collaboration			
5	Continue monitoring the existing well network in Seminary Fen.	Groundwater	MNDNR, LMRWD, and CCWMO	See Item 7	Ongoing Monitoring			
6	Expand efforts to monitor two wells each year for water quality and age-dating parameters, including nutrients and major ions.	Groundwater	MNDNR, LMRWD, and CCWMO	The MNDNR is currently doing this work, but it could be scaled up by collecting extra samples and analyzing them for additional constituents. Wells can be rotated yearly. This will help assess the need for more robust water-quality monitoring in future years.			Data Assessment	
7	Evaluate and enhance the monitoring well network annually to identify additional needs, including adding new wells, removing redundant wells, or additional water quality monitoring parameters.	Groundwater	MNDNR, LMRWD, and CCWMO	This strategy requires ongoing collaboration between MNDNR, LMRWD, and CCWMO to validate data and to plan for future improvements to the monitoring program.	Ongoing Evaluation			

Item	Stewardship Strategy	Category	Responsible Agencies	Additional Considerations	Proposed Action Year			
					2024	2025	2026	2027
8	Initiate a project to assess the drain tile system and decommission tiles where doing so would lead to improved fen health. Confirm locations of mapped drain tiles, assess tile conditions, assess drain tile impact on the fen and Assumption Creek, and prioritize decommissioning of drain tiles that are negatively impacting fen health.	Groundwater and Hydrology	LMRWD and MNDNR	Coordinate with Seminary Fen SNA management to identify appropriate methods of tile assessment and decommissioning. This project should focus on tiles where decommissioning would bring about the greatest benefit. Initial efforts may require monitoring or follow-up to determine benefit, need for additional actions, and implementation of a broader drain tile decommissioning effort. This may be combined with invasives mapping to use drones and further assess connections between drain tiles and invasive species abundance.	Evaluate and Map Tile Network	Implement		
9	Identify opportunities for stormwater infiltration in groundwater recharge areas upgradient of the fen.	Groundwater and Hydrology	LMRWD	Work with municipalities and developers to promote low-impact development techniques that increase infiltration of clean stormwater, which will enhance groundwater recharge.	Ongoing Evaluation		Ongoing Evaluation	
10	Track weather, precipitation, and longer-term changes in climate to assess how fen health is impacted by climatological changes and to inform future fen management decisions.	Climate	LMRWD and MNDNR	Include assessment of climatological data when evaluating groundwater monitoring and vegetation data. This will help identify and assess trends and inform fen management needs and stewardship opportunities.		Groundwater Elevation Assessment		
11	Develop education and outreach materials and support ongoing efforts to inform stakeholders about ongoing stewardship actions and the importance of protecting and enhancing Seminary Fen.	Education and Outreach	LMRWD	This will require support and guidance from SNA managers and ongoing collaboration with stakeholders. Materials can be modified to reach a variety of audiences.	Ongoing Support			
12	Map and assess characteristics of properties adjacent to Seminary Fen and pursue acquisition of properties where fen areas exist.	Property Acquisition	MNDNR and LMRWD	MNDNR will be responsible for ultimate ownership of fen properties because of its ability to accept ownership of properties adjacent to existing MNDNR lands. The MNDNR can do the mapping, but it may need assistance engaging with landowners. The private property to the northeast of the SNA where fen Site E was identified is a notably valuable resource.	Property Assessment			
13	Identify funding opportunities to enable the long-term management of invasive, nonnative species; plant and animal surveys; groundwater monitoring; drain tile assessment and management; and land acquisition.	Funding	MNDNR and LMRWD	Significant funding will be needed to implement and manage stewardship actions and expand public ownership of Seminary Fen. Ongoing collaboration among stakeholders will be instrumental in identifying and securing funding to sustain and enhance the fen.	Ongoing Collaboration			

Item	Stewardship Strategy	Category	Responsible Agencies	Additional Considerations	Proposed Action Year			
					2024	2025	2026	2027
14	Improve tracking and entry of data collected by various entities for permits, water use, pumping, and monitoring. The provided data need to be reviewed and entered into a centralized database. The system should include feedback to assure data quality and consistency.	Data Management	MNDNR	This should be initiated as a test effort focused on data relating to Seminary Fen that could later be scaled into a statewide program to provide high-quality, streamlined data useful to resource managers.	Ongoing Collaboration			
15	Determine interest in studying faunal populations in Seminary Fen to help better understand the fen ecosystem and how it supports faunal species.	Wildlife	LMRWD	Coordinate with potential stakeholders, such as the US Fish and Wildlife Service or the Minnesota River Valley Audubon Chapter. European research has suggested that some non-plant species, including insects and arachnids, are uniquely adapted to the fen ecosystem.		Ongoing Collaboration		Ongoing Collaboration

ENVIRONMENTAL SETTING

Fens in Minnesota have been protected since 1991 by the state's Wetland Conservation Act. They cannot be drained, filled, altered, or degraded and are recognized as an environment for rare plant species, including the white lady's-slipper. Seminary Fen contains a trout stream, eight species of state-listed rare plants, and important wildlife habitat (MPCA, 2022).

Seminary Fen is located on the north side of the Minnesota River in Carver County, mostly in the city of Chanhassen and partly in the city of Chaska (Figure 1). Residential development has occurred north and upgradient of the fen, with some agriculture and road rights-of-way nearby. Part of Seminary Fen is protected as a 73-acre SNA managed by the MNDNR, whereas other areas remain under private ownership. More information about the site conditions can be found in Young Environmental (2021).

Seminary Fen is in the Minnesota River Valley, which was carved into the land surface when Glacial River Warren drained Glacial Lake Agassiz following the last period of glaciation. Almendinger and Leete (1998) estimated that nearby fens are over 10,000 years old. During the early 1900s, the fen was substantially altered when drain tiles were installed to divert water from the fen to the Mudcura Sanitarium Spa (Olson, 2002). The spa, which opened in 1909, was a thriving business with 27 bedrooms that operated for several decades until its popularity declined in the 1940s. In 1951, a group of Franciscans were deeded the property, and they operated it as the Assumption Seminary and College. The buildings were abandoned in 1970, and the property then changed hands many times until the structure burned down in 1997 in a suspicious fire (Gould, 2022). The MNDNR acquired the property as part of the Seminary Fen SNA in 2008. Remnants of the historic spa and related structures are still visible; however, much of the historical damage to Seminary Fen has been mitigated, except for drainage tiles that may be affecting the hydrology (Young Environmental, 2021).

SOILS

Calcareous fens develop in unusual settings where cool, mineral-rich upwelling groundwater keeps the soil surface continuously wet, allowing for the formation of peat. In these areas, saturated soils obstruct the flow of oxygen from the atmosphere, slowing the rate of decomposition and creating an accumulation of layers of partially decayed vegetation and saturated soils like mucks or peats. The pH of the soils can range from neutral to strongly alkaline, exceeding pH 6.6. The soils are typically rich in calcium bicarbonates, with tufa that looks like gritty chalk, sometimes identified as marls.

According to the USDA Soils Map (USDA , 2021), Seminary Fen is characterized as a combination of mucky silt loam, with some sandy loam and loam making up the fringes of the site. The mucky silt loam, which encompasses most of the site, is classified as having a moderate to very slow runoff rate.

This mucky silt loam is referred to as the Blue Earth series and consists of deep, poorly drained soils. However, these soil infiltration and drainage characteristics are inconsequential in the fen environment, because the source of water comes from beneath.

CLIMATE

Climate information from the past helps us understand the conditions that gave rise to the fen's current vegetation and other presently observable characteristics. Predictions about the climate may help identify

stressors that could threaten fen sustainability. The following information on climate is summarized from Appendix D of Young Environmental (2021).

Climate records for the Minnesota River Valley began in 1895. The average low temperatures in the area have been increasing since then, and there have been fewer extreme cold temperature events. The records also show that average high temperatures have remained consistent; however, long-term climate predictions suggest that summers will continue to get hotter with longer growing seasons. Other identified trends include an increase in intense and heavy precipitation events.

Research cited by Young Environmental (2021) suggests that, in the future, the growing season will be longer and winters will be warmer. Summer storms are expected to be more intense and provide more rainfall. It is not known how changes in precipitation might affect the fen, which is reliant on upwelling groundwater. Extreme runoff events might cut channels through the fen, which could impact vegetation. Rising temperatures could favor warm-climate plants, including invasives, while being detrimental to the native fen plants that evolved in a cooler temperature regime. This would disrupt the fen ecosystem. Concern also exists that a warmer climate could allow invasive species to outcompete native species and allow pests to emerge earlier in the season, which could further disrupt the fen ecosystem.

HYDROLOGY

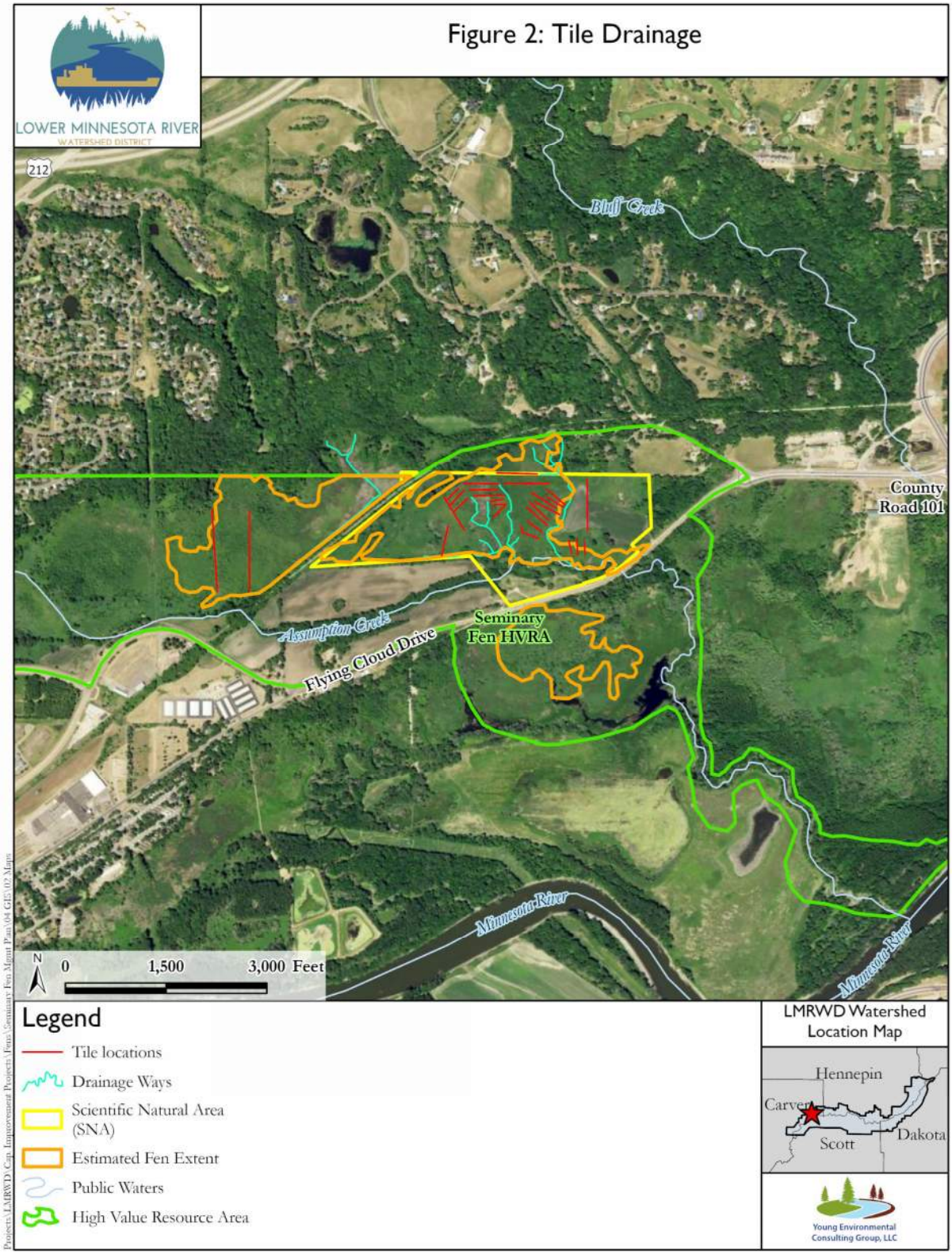
The hydrology of the SFWC is a complex association between upwelling calcium- and magnesium-rich groundwater, unique plant communities, climate, and surface water. Aerial photographs (Figure 1) show the fen's association with Assumption Creek, which forms the southern limit of the largest part of the SFWC and the SNA. Assumption Creek, a designated trout stream (MNDNR, 2021), is being assessed separately, but it is an important component of the SFWC hydrology. Assessment of Assumption Creek hydrology shows Seminary Fen provides sustaining flow to the creek (Wetterlin, 2013).

Seminary Fen and the water that sustains it have been altered by agricultural encroachments, redirection of water to the spa, roadways, railways, and upgradient development that may have changed recharge characteristics. The Gaps Analysis (Young Environmental, 2021) provides detailed information about the wells located in the SFWC and how water levels show annual fluctuations of more than six feet in some years before 2014. It is unknown why these fluctuations occurred or why they stopped after 2014, but we suspect the cause was pumping from nearby large-capacity wells.

Drainage tiles in Seminary Fen pose a threat to fen habitat. Figure 2 shows the suspected location of drainage tiles within Seminary Fen based on contrasting patterns observed in aerial photographs and knowledge of the fen hydrology. Hydrographers have observed that the tiles continue to drain parts of the fen. The fen may have reached equilibrium with much of the tile network, but the tile outlets concentrate and increase flow velocities, which cuts channels in the fen vegetation mat. Channeling erodes vegetation and can create open water that is not conducive to fen vegetation habitat. However, removing the tiles could seriously damage the fen by re-disturbing the fen surface and creating new channels. Recovery of the fen could take years or decades. A potential remedy is to have people walk the suspected tile lines and physically break the tiles with a heavy hand-held device like a mallet or ice chisel to prevent them from conveying water. These early-design drain tiles are made of terra cotta or other clay-based material and break easily. This strategy of breaking the tiles in place would allow them to endure as a reminder of the history surrounding the fen, while also preventing the unnatural conveyance of water. A drain tile management

strategy should be developed to better understand the impact of the tiles on the fen and identify the least impactful methods for decommissioning tiles that are detrimental to the fen ecosystem.

Figure 2. Seminary Fen Tile Drainage



The SFWC is potentially threatened by water laden with fertilizers and other chemicals from nearby agricultural fields or lawns, as well as road runoff, which can contain pollutants that negatively affect water quality and plants in the fen. The vegetation in the fen can also be affected by changes in drainage. However, presently there do not appear to be any direct connections that would allow surface runoff to enter the fen. The repurposed railway along the north edge forms a barrier to most upgradient surface runoff, directing water that does not infiltrate toward Assumption Creek.

GROUNDWATER

Groundwater is integral to the viability of Seminary Fen. Multiple groups, including the Carver County Soil and Water Conservation District, CCWMO, and Metropolitan Council Environmental Services, have been collaborating with the MNDNR and LMRWD for several years to monitor groundwater levels associated with the SFWC. The following sections summarize historical and current groundwater information for the SFWC.

Historical Groundwater Data

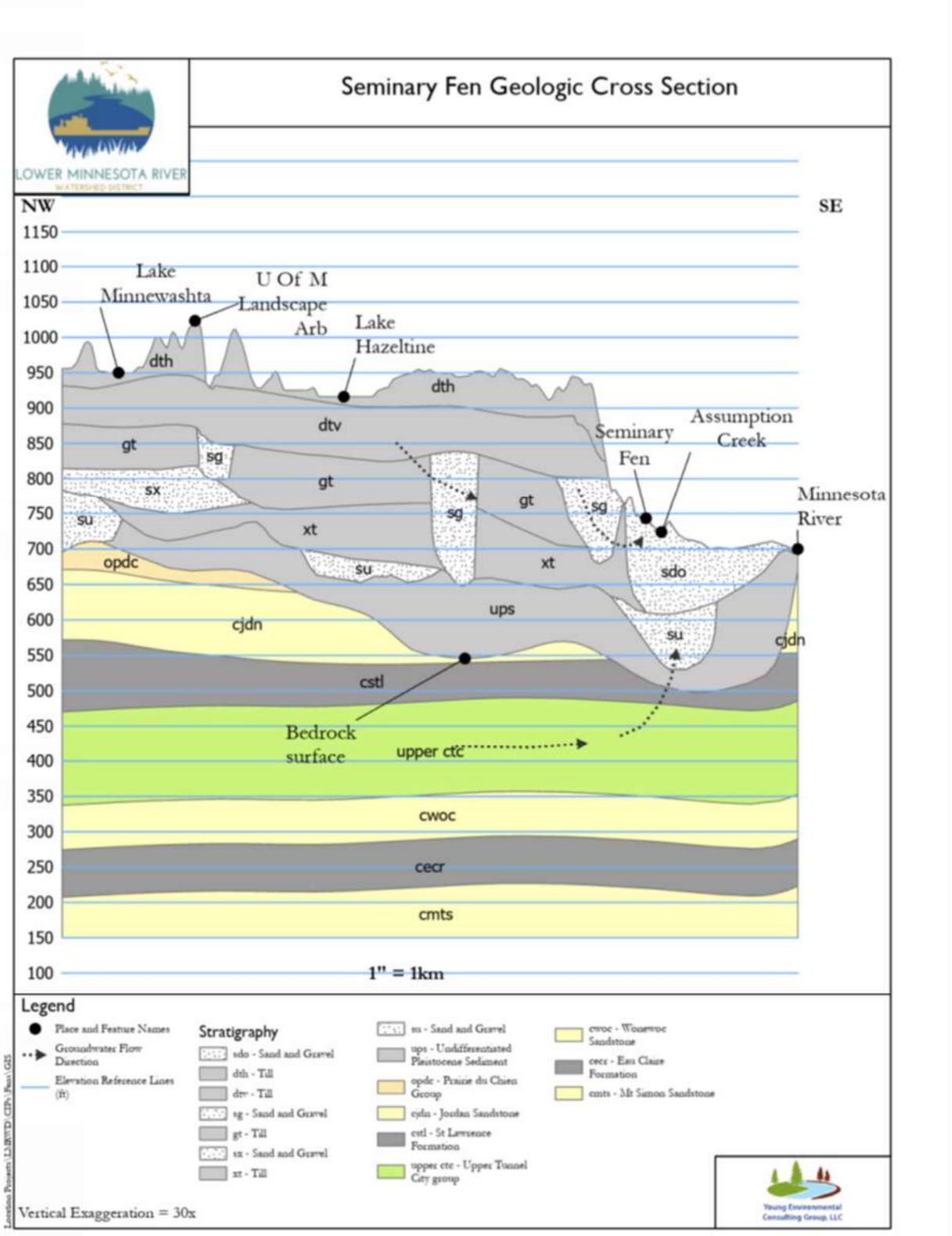
Information reported by Young Environmental (2021) provides details about the groundwater data collected for the SFWC. Although there are no clear trends in recent groundwater levels, longer-term assessments suggest a decline in groundwater levels starting in the early 2000s, when local communities began relying on groundwater instead of surface water for their water needs (MPCA, 2021; Freshwater Society, 2013).

Hydrogeology

Figure 3 shows the aquifers that supply groundwater to the SFWC. Water recharged on the upland bluffs infiltrates multiple layered aquifers that flow toward the Minnesota River. The deeply incised Minnesota River Valley exposes many of these aquifers, resulting in springs and seeps that discharge at various levels and feed Seminary Fen, Assumption Creek, and other water features above the river level. The water table is not shown but is slightly below the ground surface.

Figure 3 also illustrates the extent and thicknesses of aquifers and aquitards in the area, groundwater flow directions, and helps define groundwater recharge and discharge areas. Seminary Fen is fed by groundwater discharging from a shallow local aquifer named sg, and from the deeper Upper Tunnel City regional aquifer.

Figure 3. Geologic Cross Section Showing Hydrogeology Associated with Seminary Fen



The following background information is modified from Berg (2021) and Petersen (2009): Aquifers consist of coarser-grained sediment or porous and permeable bedrock that holds and transmits abundant water. Aquitards consist of fine-grained sediment or bedrock that slows water movement and creates confining layers. Groundwater flow is initially downward, then lateral toward creeks and rivers. In many areas recharge to the deeper aquifers can take hundreds to thousands of years, where there is no focused recharge through interconnected buried sand and gravel aquifers.

During the Pleistocene Epoch, multiple sequences of sand and gravel were deposited by meltwater from the ice lobes through successive advances and retreats. The sand and gravel bodies form aquifers confined by aquitards that formed from unsorted sediment and glacial till deposited directly by the ice and from bedded sediments of clay, silt, and fine-grained sand deposited in ponds and lakes. These till units tend to be more laterally extensive than the buried sand and gravel layers.

The upper light-gray aquitards and stippled aquifer layers shown on the cross section in Figure 3 represent alternating layers of older sand, gravel, and fine-grained deposits from successive glacial advances as mapped in Bauer's county geologic atlas (2009). The naming convention for the buried sand and gravel aquifers was based on the underlying till unit described in this Part A atlas.

The shallowest buried sand and gravel aquifer, labelled sg, is shown on the Figure 3 cross section as partially exposed to the surface along the edge of the Minnesota River valley. This partial exposure allows surface water to infiltrate and discharge locally to the nearby Seminary Fen area. Figure 4 is a recharge and pollution sensitivity map of the sg aquifer (Peterson, 2009). The warm colors indicate that a portion of the sg aquifer near Seminary Fen provides some local recharge to the area.

The lower colored and medium-gray layers of Figure 4 represent bedrock aquifers and aquitards. The bedrock formations of the area are part of regionally extensive, gently dipping layers of Paleozoic sandstone, shale, and carbonate rock that range from 30 to 300 feet in thickness. An enhanced-permeability zone exists in the uppermost 50 feet of the shallow bedrock surface and in bedrock valleys where bedrock and glacial sediment are in contact (Runkle et al., 2006). This contact zone developed when the bedrock surface was exposed at the land surface. Fractures in the bedrock generally increase the yield from aquifers but may compromise the protective character of aquitards.

Cambrian-aged formations are primarily siliciclastic sandstones and siltstones that include, in ascending order from oldest to youngest, the Mt. Simon Sandstone, Eau Claire Formation, Wonewoc Sandstone, Tunnel City Group, St. Lawrence Formation, and Jordan Sandstone. In the Seminary Fen area, the upper part of the Tunnel City Aquifer is overlain by a thin portion of the St. Lawrence, which would normally be an aquitard. However, the St. Lawrence is fractured and permeable at this location, which allows groundwater from the underlying Upper Tunnel City aquifer to discharge through the overlying sand and gravel to Seminary Fen and the Minnesota River valley (Figure 5).

There does not appear to be a local recharge area for the Upper Tunnel City aquifer because it is beneath thick layers of glacial and bedrock aquitards in the area. Recharge may be occurring in areas many miles upgradient of Seminary Fen in adjacent Hennepin County.

Figure 4. Groundwater Recharge of the sg Sand and Gravel Aquifer

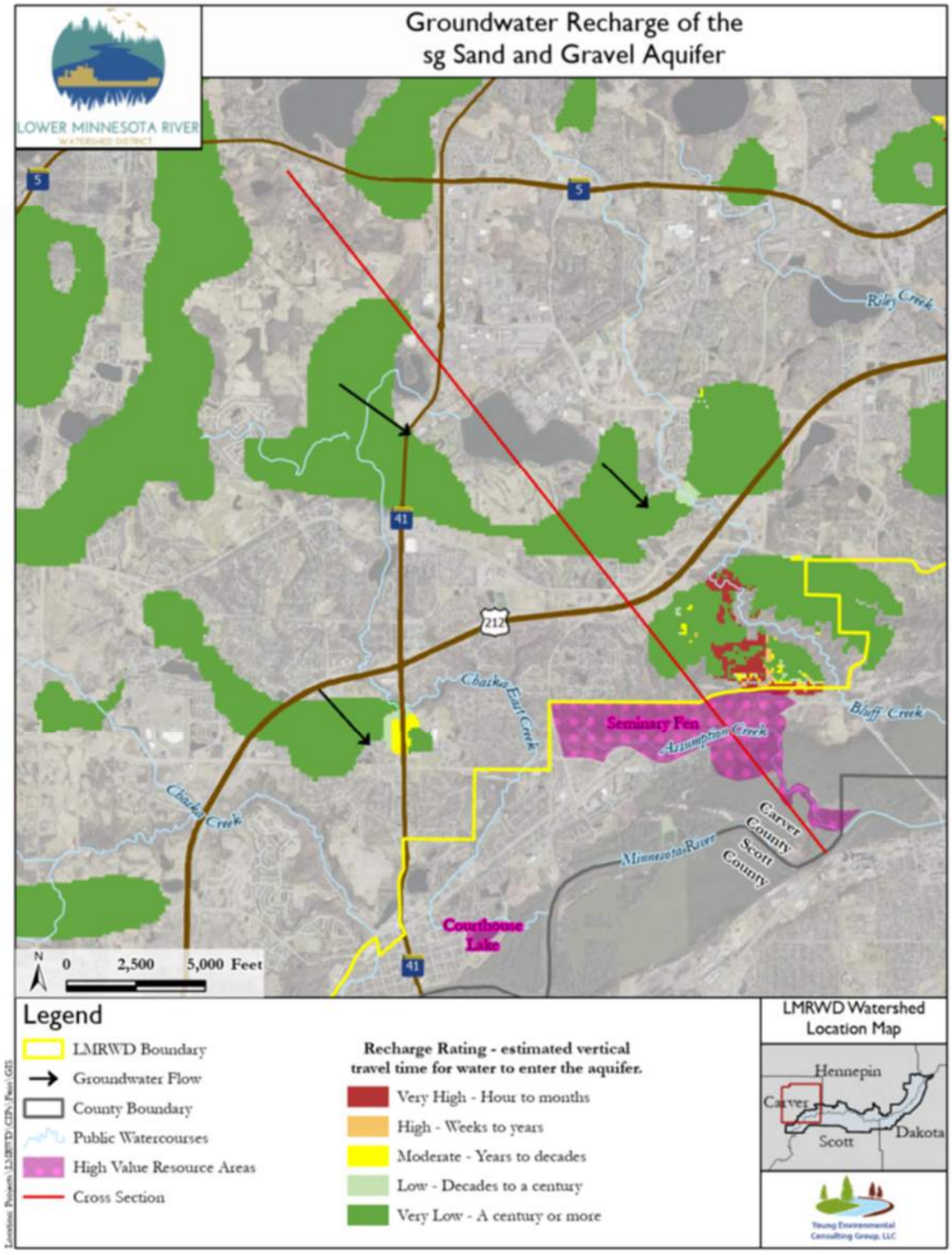
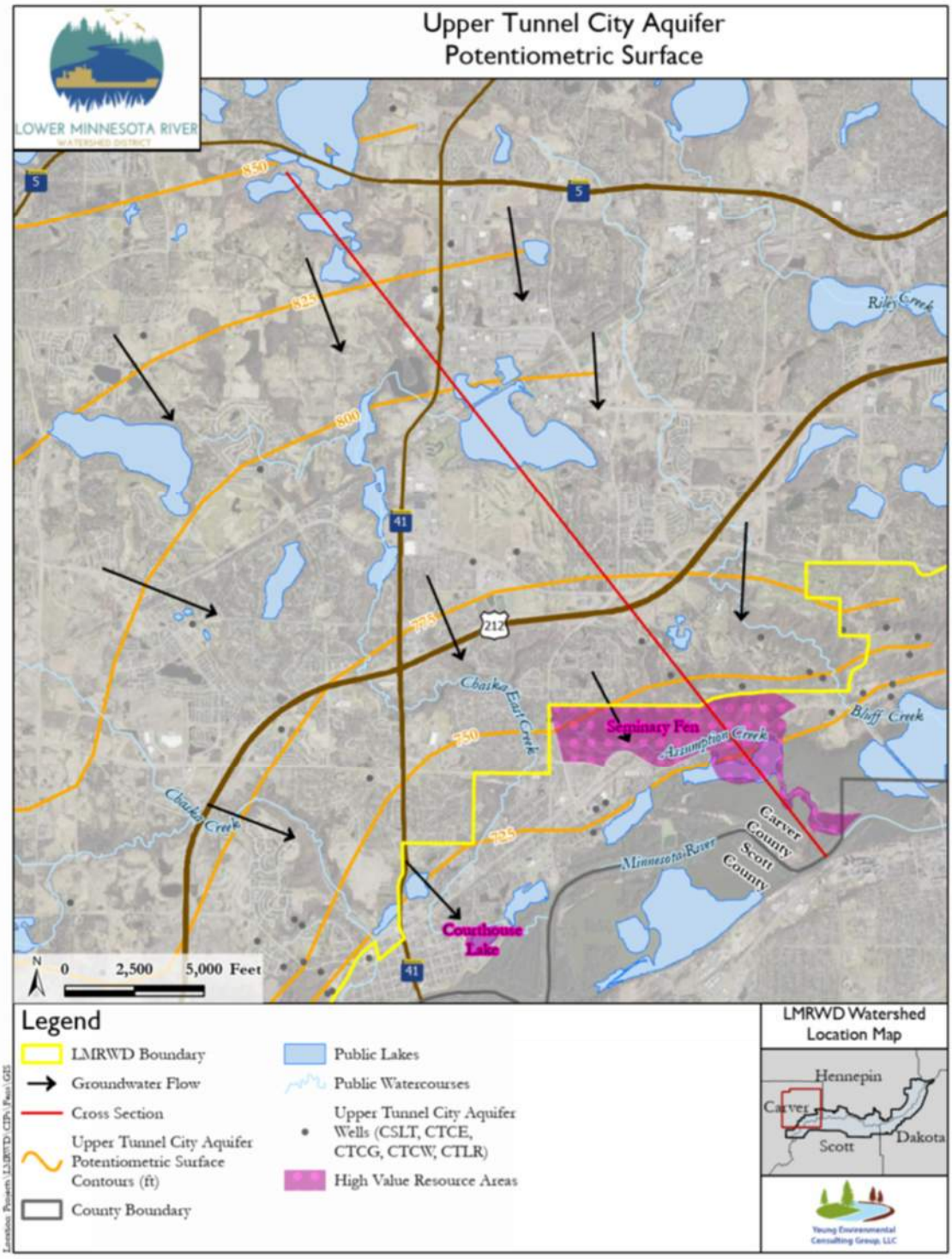


Figure 5. Upper Tunnel City Aquifer Potentiometric Surface

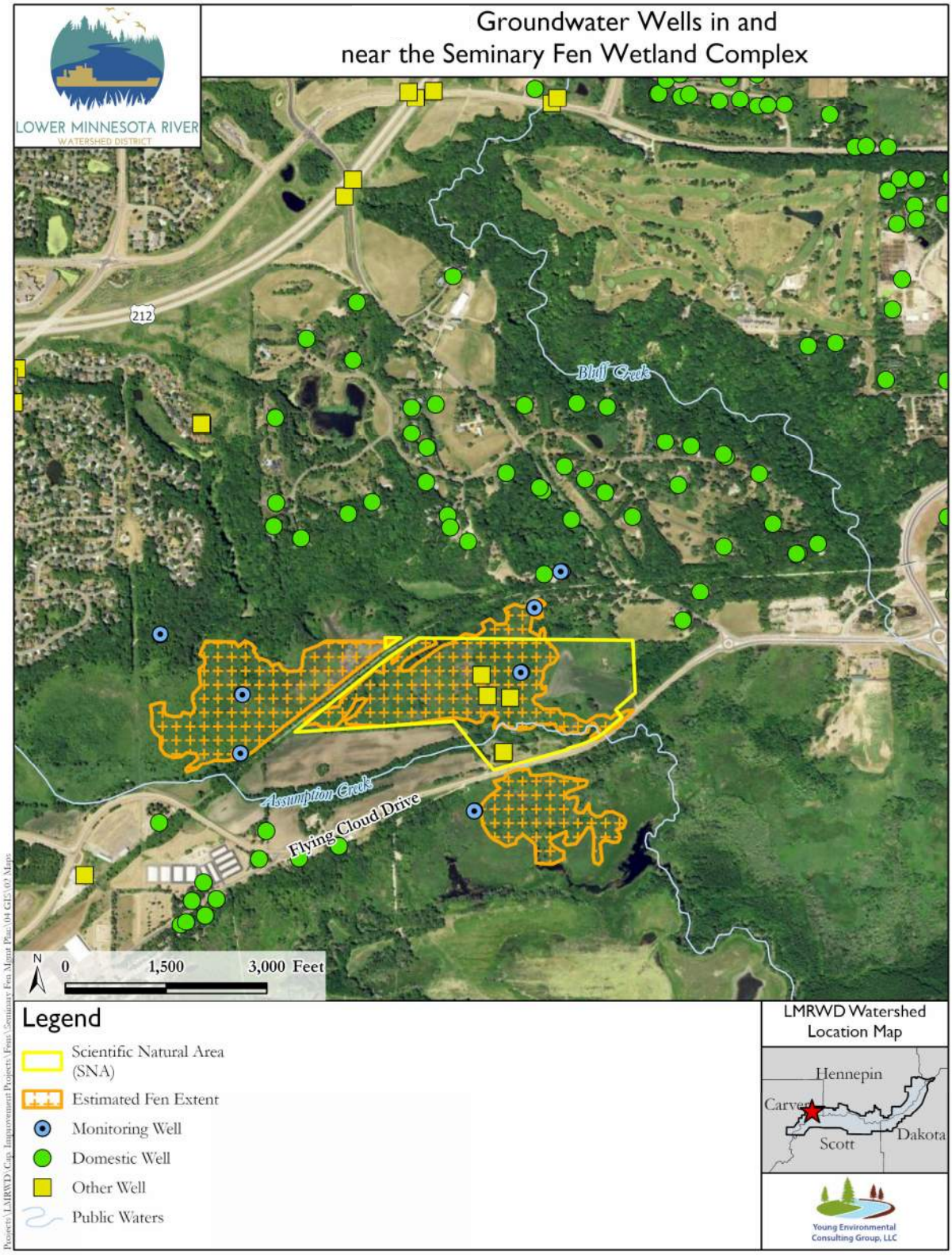


The locations of active groundwater wells in and near the SFWC are shown in Figure 6. The wells associated with monitoring the SFWC are categorized as "monitoring wells" and "other wells." Monitoring wells are used to assess ambient groundwater levels and may be used for water-quality sampling. They can be paired with deep wells, which are completed at a greater depth, to measure the upward pressure of the water. The density of monitoring wells is reduced, and fewer wells are monitored than was described in the report by Young Environmental (2021) because unreliable and redundant wells were removed or sealed to protect the fen and the underlying groundwater. Two monitoring wells northeast of the SNA that are subject to flooding will be sealed and discontinued. The remaining wells are considered adequate to monitor water levels in the SFWC (Andrews, 2022).

Most of the wells outside the SFWC shown in Figure 6 are categorized as domestic wells that supply water to homes and farms. Although the withdrawal of water for domestic use may be considered consumptive, the water may be returned to the groundwater if the homes using it are equipped with subsurface sewage treatment systems. If wastewater is piped away for treatment elsewhere, it is removed from the groundwater system.

Notably missing from Figure 6 are the large, high-capacity public-supply wells that provide water to many communities in the area. These wells withdraw thousands of gallons of water per day for the surrounding communities. This use is typically consumptive because the wastewater is pumped for treatment and discharged elsewhere. Pumpage from these wells is monitored by the MNDNR to prevent over-allocation of the limited groundwater supply and to protect the viability of competing resources. Nearby irrigation wells beyond the northern edge of Figure 6 (MWI, 2022) are also missing from the figure but would be visible on a larger scale.

Figure 6. Groundwater Wells in and near the Seminary Fen Wetland Complex (MWI, 2022)

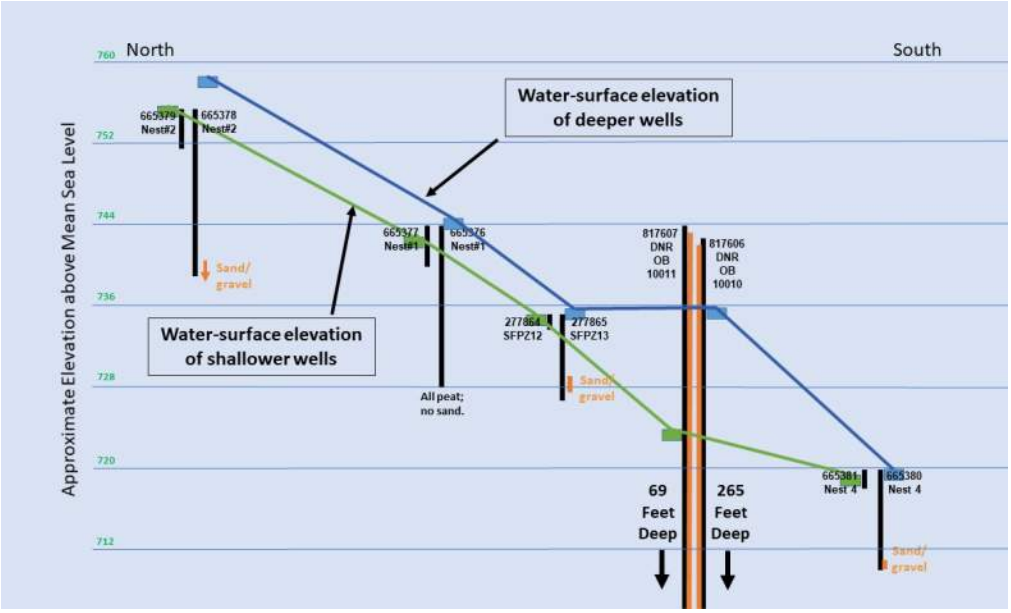


Groundwater Monitoring

Groundwater levels are monitored by CCWMO staff at dedicated wells completed and screened at selected depths in representative aquifers in and adjacent to the SFWC. The LMRWD supports this ongoing effort and the MNDNR oversees it. Most wells are equipped with a water-level measuring device and a recorder, and recordings are downloaded and checked with manual field water-level measurements monthly. These recordings are then adjusted to compensate for instrument drift if needed and uploaded for storage and public dissemination on the Cooperative Groundwater Monitoring website operated by the MNDNR (2022a).

Young Environmental compiled manual water level measurements and well information taken in late 2021 from selected paired wells roughly aligned in a north-to-south direction to produce the cross section of groundwater levels shown in Figure 7. Each well is represented by a black vertical line that extends from the land surface to the completed depth of the well. Most of the shallow wells, which range in depth from one to four feet, are completed and screened in the peat deposits. These are paired with deeper wells that are usually completed and screened in or near a more transmissive underlying material, such as sand or gravel, which may be continuous with the underlying aquifer but sometimes may be isolated lenses of sand or gravel. Two observation wells installed in sand and gravel deposits adjacent to the fen and in line with the monitoring well transect were included in this graphic, although they were both completed at a much greater depth in the aquifer. Figure 7 also includes a pair of wells that are on the south side of Flying Cloud Drive (CSAH 61) but in a wetland that displays some fen-like characteristics.

Figure 7. Cross Section of Seminary Fen Showing Selected Groundwater Level Data



The cross section shows that the water levels, which represent the potentiometric surface of the groundwater, are generally higher than the land surface and often higher than the top of the well casing, causing water to flow out of the well. The deep wells consistently have a potentiometric surface that is about four feet higher than the shallow wells. This results from the strong upward gradient of groundwater from deep to shallow that forces water to the surface, creating the consistently water-saturated land surface

needed to sustain the fen ecosystem. The interwoven vegetation overlying the peat apparently forms a tight surface that keeps a dome-shaped lid on the upwelling groundwater, creating an isostatic equilibrium. It is uncertain how long the fen vegetation would survive if this positive groundwater flow were interrupted by overallocation and over-pumping of the finite groundwater supply or other actions that would lower the water level. Young Environmental (2021) discussed other fens in the LMRWD that might have been irreparably damaged by water levels that dropped below the level of the fen surface, either by diversion of water elsewhere or because channels were cut into the fen, draining away the water.

Wuolo et al. (2022) completed a study of groundwater hydrology in the vicinity of the SFWC to assess present hydrologic conditions and determine whether the groundwater levels show any trends. This study included runs of a previously developed regional groundwater flow model to incorporate variations in precipitation and changes in nearby groundwater withdrawals to further elucidate water level trends. This study concluded that groundwater levels have been stable over the past 15 years and that pumping and changes in precipitation-derived regional recharge have not affected water levels. Pumping high-capacity wells in the area also does not appear to adversely affect water levels in Seminary Fen. However, the study cautioned that continued development in the area could result in the withdrawal of large amounts of groundwater, which might cause a decline in Seminary Fen's water levels.

WILDLIFE

European and domestic fen research has provided information about the communities of fauna that may find refuge in fens (Broads Authority, n.d.; Stokmane & Cera, 2018; Willis, 2008). Generally, fen ecosystems are understudied; however, they can include unique invertebrate populations, including insects, spiders, and snails, as well as vertebrate populations of amphibians, voles, mice, and lemmings, which provide a food source for predatory species, including snakes and birds. In addition, the generally open, diverse vegetation of fens often attracts small insects and swarms that can provide food for insectivorous birds, bats, and other insects. A researcher documenting spider populations at fens in Latvia suggested several species are unique to the fens studied (Stokmane & Cera, 2018).

Migratory bird species attract bird enthusiasts to areas associated with Seminary Fen in spring and summer. The National Audubon Society has designated the Lower Minnesota River Valley, including the SFWC and other natural resources, as an Important Bird Area (IBA; Audubon Society, 2022). Over 260 species have been documented throughout the IBA, with 100 species nesting. However, the avian population is threatened by power lines, agriculture and urban development, feral and introduced species, and invasive and nonnative species. The use of mosquito control chemicals is also speculated to have a significant impact on the amount of biodiversity (especially migrating swallows) in wetlands because of the loss of a food source (Westerberg et al., 2011).

Because of its relatively sparse cover and forage, large animals are not common in the SFWC; small mammals, such as shrews, voles, and rabbits, are more likely to inhabit the area. Frogs and toads are more adapted to this environment than turtles, lizards, and snakes, and insects, including mosquitoes, damselflies, dragonflies, and deerflies, inhabit the fens in abundance (MNDNR, 2022b).

THREATENED AND ENDANGERED SPECIES

The MNDNR, through the Minnesota Endangered Species Statute (State of Minnesota, 2022), and the US Fish and Wildlife Service, through the federal Endangered Species Act of 1973 plus amendments (USFWS, 2020), administer laws designed to protect threatened and endangered species from going extinct. Losing even a single species can alter the rest of the ecosystem. From potentially providing cures to diseases to maintaining natural ecosystems to improving overall quality of life, the benefits of preserving threatened and endangered species are incalculable (The National Wildlife Federation, 2022).

In Minnesota, three distinctions exist for imperiled species: endangered, threatened, and species of special concern (State of Minnesota, 2022). Endangered species are threatened with extinction throughout all or a significant portion of their range. Threatened species will likely become endangered within the foreseeable future throughout all or a significant portion of their range. Special concern species are those that are uncommon in Minnesota or have unique or highly specific habitat requirements and deserve careful monitoring.

Two federally listed endangered species have been observed near the SFWC, but it is not apparent that the fens are a critical part of their habitat. The rusty-patched bumblebee has been listed as endangered because its habitat has been fragmented and degraded as prairies and grasslands have been converted to developed areas or agriculture (USFWS, 2019). The increase in pesticide use and monoculture farming have also contributed to the decline of this pollinator species. The northern long-eared bat is a threatened species on the federal list that has been observed in the Minnesota Valley National Wildlife Refuge near the SFWC (NRRI, 2018). The decline of this bat species is attributed to white-nose syndrome, although road construction, large tree removals, mining, and wind turbines are also contributing factors (USFWS, 2015).

Calcareous fens are known to have diverse populations of wetland plants, many of which are threatened or endangered in Minnesota. Table **2** lists the plant species of concern commonly found in calcareous fens.

Table 2. Plant Species of Concern Found in Calcareous Fens

Common Name	Scientific Name	Classification
Hairy fimbry	*Fimbristylis puberula*	State endangered
Sterile sedge	*Carex sterilis*	State threatened
Hair-like beak rush	*Rhynchospora capillacea*	State threatened
Beaked spikerush	*Eleocharis rostellata*	State threatened
Whorled nutrush	*Scleria verticillata*	State threatened
Cut-leaf water parsnip	*Berula erecta*	State threatened
Edible valerian	*Valeriana edulis*	State threatened
Twig rush	*Cladium mariscoides*	State special concern

Common Name	Scientific Name	Classification
Small white lady's-slipper	*Cypripedium candidum*	State special concern
Wild sweet william	*Phlox maculata*	State special concern

VEGETATION

Fen plant communities are assessed using relevés that focus primarily on vascular plants, particularly documenting the presence and abundance of fen-indicator plants. However, some researchers suggest that other fen indicator plants, such as bryophytes, which include mosses, liverworts, and hornworts, would provide a more robust and reproducible indicator of fen health (Janssens, 2014).

Prior to 2021, the most recent documented vascular-plant-based vegetation survey was conducted in 1995, so the Gaps Analysis recommended completing a new survey, given that the vegetation in the fen might have changed in response to environmental influences. Young Environmental collaborated with Barr Engineering to complete a vegetation survey of the SFWC during June and August of 2021. These relevés documented the occurrence and distribution of vascular plants within five 100-square-meter (10 meter by 10 meter) plots throughout the SFWC, as established by the assessment team for subsequent monitoring and reassessment. Locations were selected using guidance from the MNDNR and placed in high-quality areas of the plant community.

Figure 6 shows the location of the relevé plots in and near the Seminary Fen SNA. Within the selected plots, vegetation identifications and estimates of the percent area occupied by each species within the plot were recorded. The percent area was assigned to a cover class using the DNR's relevé method (MBS et al., 2013) using a regionalized list of vascular plant calciphiles, or plants that thrive in calcium-rich environments, to determine whether the wetland community met the technical criteria for a calcareous fen based on its vegetation. The same method was used for all five plots in June and again in August. Replicate relevés were conducted in early and late summer to aid in identification of plants that seasonally express unique identifying morphometric characteristics. Plot locations were determined with a global positioning system, and permanent markers were installed to assure the same plots were evaluated during subsequent visits. Plant species were assigned values (high, medium, or low) for being characteristic of a calcareous fen.

The vegetation surveys confirmed that the SFWC meets the criteria for a southeastern Minnesota native calcareous fen plant community in the MNDNR plant community classification system (MNDNR, 2022c).

Figure 8. Location of Vascular Plant Relevés in and near the Seminary Fen Scientific Natural Area (Tix & Anderson, 2021)

Of the five plots, only one, Site A, was identified as barely meeting the criteria to qualify as a calcareous fen. This plot is located north of the railway on land owned by the City of Chaska. It received the minimum number of points, 50, to be considered a calcareous fen. No state threatened or endangered species were found in the plot, but it did include six calcareous fen indicator species:

- Fringed brome (*Bromus ciliates)*
- Porcupine sedge (*Carex hystericina)*
- Inland sedge (*Carex interior*)
- Prairie sedge (*Carex prairea*)
- Sage-leaved willow (*Salix candida*)
- Northern bog aster (*Symphyotrichum boreale*)

This plot had extensive patches of willows and red osier dogwood shrubs, and many patches of trees. The shrubs and trees in this plot caused a decline in native species by altering and degrading the habitat and competing with the native species.

Site B is near site A and is located on the north side of the railway on land owned by the City of Chaska. It received 105 points, having nine calcareous fen indicator species and one state threatened species. The nine indicator species include the following:

- Fringed brome (*Bromus ciliates)*
- Spring cress *(Cardamine bulbosa)*

- Water sedge (*Carex aquatilis)*
- Porcupine sedge (*Carex hystericina)*
- Prairie sedge (*Carex prairea*)
- Sterile sedge (*Carex sterilis*)
- Kalm's lobelia (*Lobelia kalmia*)
- Sage-leaved willow (*Salix candida*)
- Northern bog aster (*Symphyotrichum boreale*)

Sterile sedge (*Carex sterilis*) is listed as a threatened species in Minnesota. It is highly susceptible to changes in hydrology. Biologists conducting the relevé noted that this plot had a linear low area that appeared to have a subtle seepage channel. This area was fully vegetated and wetter and springier than the rest of the plot. Site B has extensive patches of willows and red osier dogwood shrubs and many patches of trees, like site A, with several large patches of reed grasses.

Site C is south of CSAH 61 in the DNR-owned Raquet Wildlife Management Area. It received 125 points, having nine calcareous fen indicator species and two threatened species. The indicator species found at Site C include the following:

- Fringed brome (*Bromus ciliates)*
- Spring cress (*Cardamine bulbosa*)
- Porcupine sedge (*Carex hystericina*)
- Inland sedge (*Carex interior*)
- Prairie sedge (*Carex prairea*)
- Sterile sedge (*Carex sterilis*)
- Beaked spikerush (*Eleocharis rostellata*)
- Kalm's lobelia (*Lobelia kalmia*)
- Northern bog aster (*Symphyotrichum boreale*)

The two threatened plants, sterile sedge and the beaked spikerush, were observed at Site C. The plant community in this plot has also been invaded by extensive patches of reed canary grass (*Phragmites australis* subsp. *australis)* and cattails (*Typha* spp.).

This site is prone to flooding from the Minnesota River, which may have implications for the resiliency of these fragile ecosystems. Flooding alters the exchange of airborne gases, such as oxygen and carbon dioxide; affects the turgidity of plant cells that are adapted to air instead of water; and excludes direct sunlight by reflection, refraction, and attenuation. In addition, flooding may interfere with important plant life stages, including pollination and seed dispersal, and it carries sediments and other waterborne contaminants that

exclude sunlight and deposit on foliage. The waterborne contaminants include the seeds of potentially invasive plants that could further alter the native plant community.

Site D is within the Seminary Fen SNA and is owned by the MNDNR. Its vegetation relevé earned a point value of 190, having 10 calcareous fen indicator species and four state threatened species. The indicator species include the following:

- Stream parsnip (*Berula erecta*)
- Fringed brome *(Bromus ciliatus*)
- Porcupine sedge (*Carex hystericina*)
- Prairie sedge (*Carex prairea*)
- Sterile sedge (*Carex sterilis*)
- Beaked spikerush (*Eleocharis rostellata*)
- Kalm's lobelia (*Lobelia kalmia*)
- American grass of Parnassus (*Parnassia glauca*)
- Whorled nutrush (*Scleria verticillata*)
- Seaside arrowgrass (*Triglochin maritima*)

The state threatened species include the following:

- Stream parsnip was observed in several seepage channels to the south and west of the Site D plot. There are several large populations growing within the flowing water of the channels; none were within the relevé plot.
- There were about 50 sterile sedge plants within the relevé plot.
- Beaked spikerush was observed in an area just south of the relevé plot in a small population of about 40 individual stems.
- Low nutrush (*Scleria verticillate*) was observed in an area with distinctively low stature just south of the relevé plot and included a small population of about 50 individual stems.

Site E scored 245 calcareous fen indicator points, the highest number for the sites assessed. It is located on private property northeast of the SNA. Thirteen indicator species and six state-listed plants were identified:

- Stream parsnip (*Berula erecta)*
- Spring cress *(Cardamine bulbosa)*
- Porcupine sedge (*Carex hystericina)*
- Prairie sedge *(Carex prairea)*
- Sterile sedge (*Carex sterilis*)

- Smooth sawgrass (*Cladium mariscoides)*
- Beaked spikerush *(Eleocharis rostellata*)
- Kalm's lobelia (*Lobelia kalmia*)
- American grass of Parnassus (*Parnassia glauca*)
- Needle beaksedge (*Rhynchospora capillacea*)
- Low nutrush *(Scleria verticillata*)
- Northern bog aster *(Symphyotrichum boreale*)
- Seaside arrowgrass (*Triglochin maritima*)

The state listed species include the following:

- The threatened stream parsnip was observed in a seepage channel to the west of the Site E plot and included a large population growing within the flowing water of the channels. Only about 10 plants were within the relevé plot.
- Smooth sawgrass, a species of special concern, was growing within the plot and included about 100 stems. Additional patches were observed to the southwest.
- A large population of the threatened sterile sedge was identified within the relevé plot and was abundant within the surrounding area.
- The threatened beaked spikerush was a dominant species within the plot and in the vicinity. This large population is a defining characteristic of the vegetation near Site E.
- Low nutrush is considered threatened and occurs in a small patch within the plot and in several additional patches to the west and south. The population exceeded 1,000 plants.
- Needle beaksedge is a threatened species that was observed in a small patch to the west of the Site E plot. About 20 plants were observed, with multiple stems each.

The unexpected richness of fen vegetation at relevé Site E suggests an urgent need to engage with the owner of that property regarding long-term protection of the property. If the owner is not willing to sell, there may be an opportunity to work with them on a plan to protect the site.

The vegetation assessment shows a diverse population of native vegetation throughout the wetland complex, indicating that most of the fen ecosystem is healthy (Tix & Anderson, 2021). However, there is evidence of invasive species encroachment. Buckthorn has been identified as the most invasive of the species; it is aggressive and has the potential to shade out the native species, leading to loss of ground cover and erosion and drainage of the peat, resulting in habitat loss. Other invasive species throughout the fen include various reed grasses and cattails. Some of the woody vegetation species, including aspen, dogwood, and willows, are native to Minnesota but not to the fen ecosystem. Without proper management, the native vegetation in the fen community could be overwhelmed by invasive species.

LAND USE

The land in and around the SFWC is composed of fertile soils derived from sediments eroded from upland soils and fine sediments deposited whenever the Minnesota River floods. Saturated soils from shallow or upwelling groundwater were often quaky and unstable for most uses, whereas nearby drier, gently sloping land was often farmed and sparsely settled. Summarized below are the historical and planned land uses for the area surrounding the SFWC.

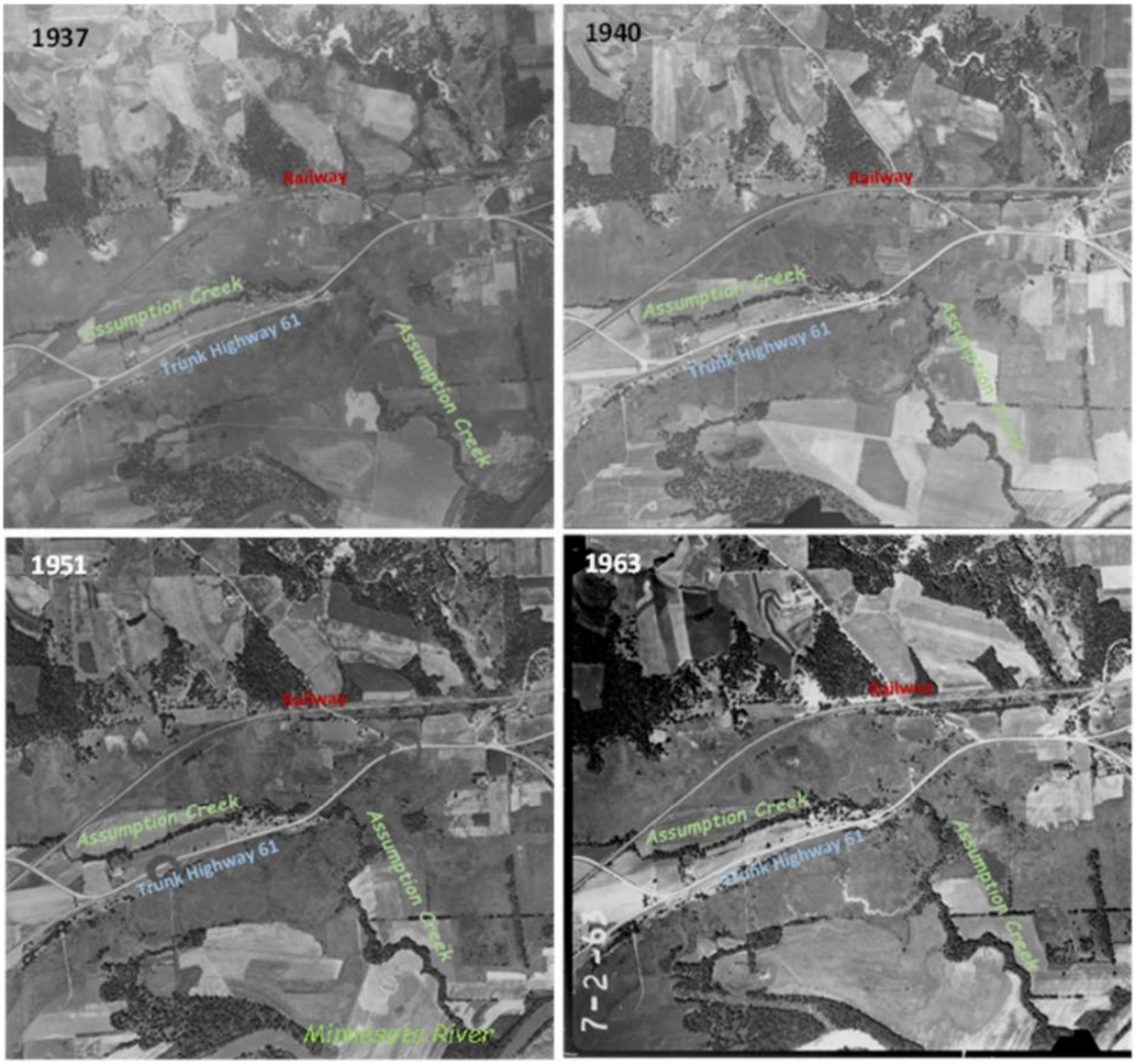
Historical

MHAPO photographs in Figure 9 were taken in July or August in 1937, 1940, 1951, and 1963. They each have several features in common that can help the reader orient between the different images. The bluffs to the north show a changing mosaic of varying patterns of farmland. The steep slopes below the bluffs are mostly forested and feature varying alluvial fans, showing where runoff from upland areas carried sediments and eroded gullies that deposited material onto the wetlands at the base of the bluffs. A railway runs along the base of the bluffs to the east and angles southwest to cross CSAH 61 to the west. CSAH 61 runs left (southwest) to the right (northeast) across the middle of each image. Assumption Creek begins where small streams to the west meet and pass beneath the railway. The creek parallels CSAH 61 as it flows to the east before turning south beneath the highway and onto the Minnesota River floodplain. It then meanders across the floodplain before joining the river near the southeast corner of the photographs. Most of the SFWC is nestled between the railway and CSAH 61. Assumption Creek constitutes much of the southern border of the main part of Seminary Fen.

Figure 9 shows a series of aerial photographs of the area encompassing the SFWC that were taken starting more than 80 years ago. These images were downloaded from Minnesota Historical Aerial Photographs Online (MHAPO), managed by the University of Minnesota Libraries (MHAPO, 2015). They show the progression of land use and land cover in and around the SFWC. Each image was cropped from images that covered a larger area than the SFWC and usually centered on different coordinates. The most recent images from the MHAPO in this area were taken nearly 60 years ago in the early 1960s. More recent images were copied from aerial photography provided by Google Earth (Google, 2021).

MHAPO photographs in Figure 9 were taken in July or August in 1937, 1940, 1951, and 1963. They each have several features in common that can help the reader orient between the different images. The bluffs to the north show a changing mosaic of varying patterns of farmland. The steep slopes below the bluffs are mostly forested and feature varying alluvial fans, showing where runoff from upland areas carried sediments and eroded gullies that deposited material onto the wetlands at the base of the bluffs. A railway runs along the base of the bluffs to the east and angles southwest to cross CSAH 61 to the west. CSAH 61 runs left (southwest) to the right (northeast) across the middle of each image. Assumption Creek begins where small streams to the west meet and pass beneath the railway. The creek parallels CSAH 61 as it flows to the east before turning south beneath the highway and onto the Minnesota River floodplain. It then meanders across the floodplain before joining the river near the southeast corner of the photographs. Most of the SFWC is nestled between the railway and CSAH 61. Assumption Creek constitutes much of the southern border of the main part of Seminary Fen.

Figure 9. Historical Aerial Photographs of Seminary Fen and Related Features



This sequence of photographs suggests the land use changed little during the years depicted. They all show the large structure between CSAH 61 and Assumption Creek, at the apex of the inverted V-shaped driveway, which housed the Mudcura Sanitarium Spa and associated outbuildings. The alluvial fans of sediment where the bluffs meet the wetlands appear to change over time, suggesting that continued upland and gully erosion are impinging on the wetlands, although they do not directly affect the SFWC. The 1951 photograph vaguely shows a pinnately arranged series of dark lines on the fen that form a network pointing toward the main building of the spa. These lines probably show the trace of the drain tiles installed to drain water from the fen to the spa.

Recent and Planned

The 2021 aerial image in Figure 10 shows substantial changes in some areas around the SFWC. The farmland to the north has been almost entirely converted into low- and medium-density residential housing. The alluvial fans are no longer apparent, suggesting erosion has subsided. The inverted V-shaped driveway remains, but the structures that housed and supported the Mudcura Sanitarium Spa and the Assumption Seminary have been removed.

The SFWC is situated in a mixture of agricultural, residential, and industrial land. A goal of Carver County is to direct development to the cities to allow agriculture to remain the principal land use in the county. The county's 2020 Comprehensive Plan lays out natural environment goals, including protection of the calcareous fens.

Much of the existing land use adjacent to the SFWC shown in Figure 11 consists of parks and open space. The data used to generate the land use maps for this report were obtained from the Minnesota Geospatial Commons, which provided data compiled by the Metropolitan Council of the Twin Cities (GISDataMN, 2022). Considerable amounts of land around the SNA are designated as undeveloped and agricultural land, generally in private ownership.

The planned land use around Seminary Fen shown in Figure 12 proposes the elimination of undeveloped land around the SFWC to the north of CSAH 61 in favor of low- and medium-density residential land uses. Agriculture may replace the park, recreational, and undeveloped land south of CSAH 61, possibly because this area is subject to flooding from the Minnesota River.

Figure 10. Year 2021 Aerial Imagery of Seminary Fen

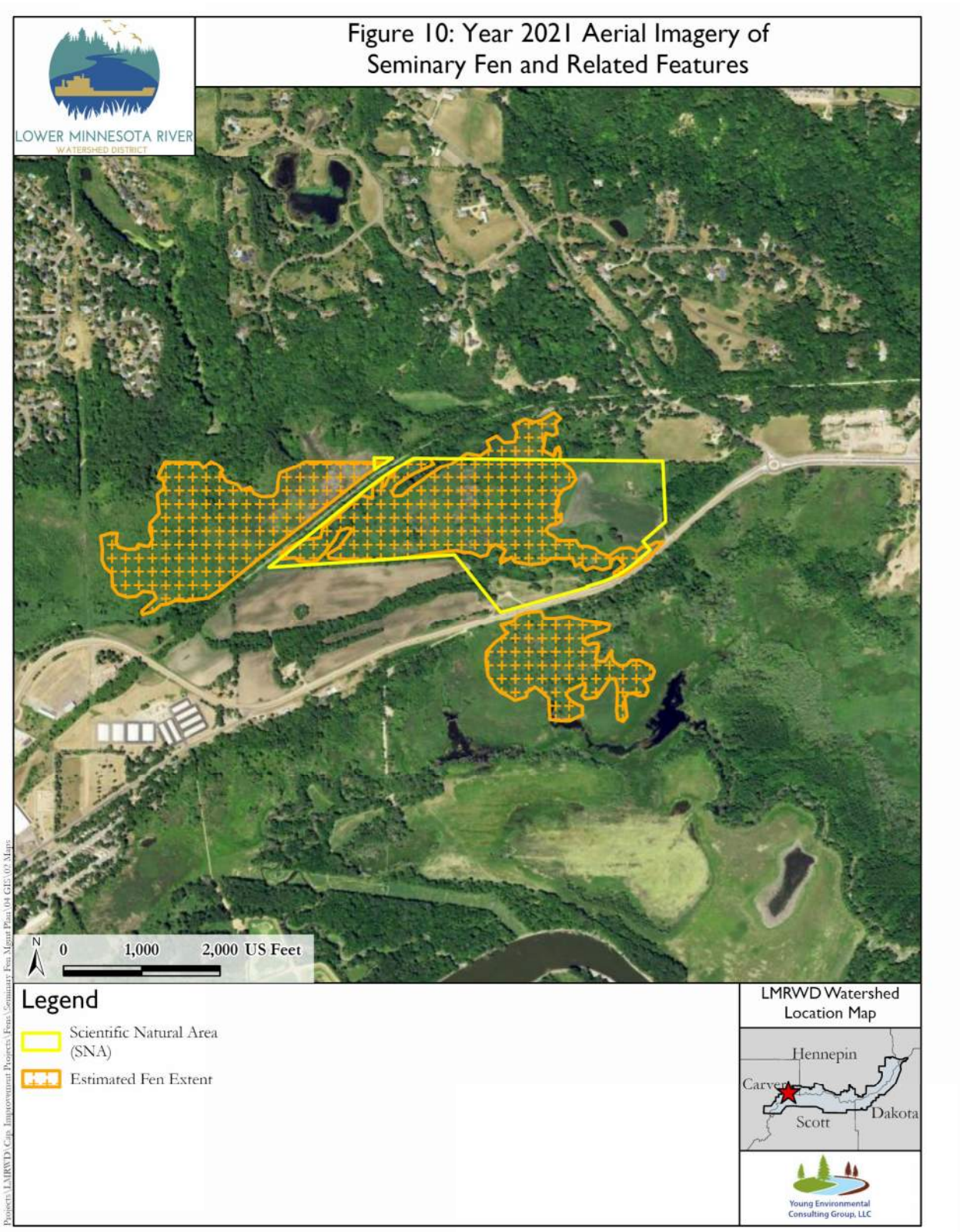


Figure 11. Seminary Fen 2020 Land Use

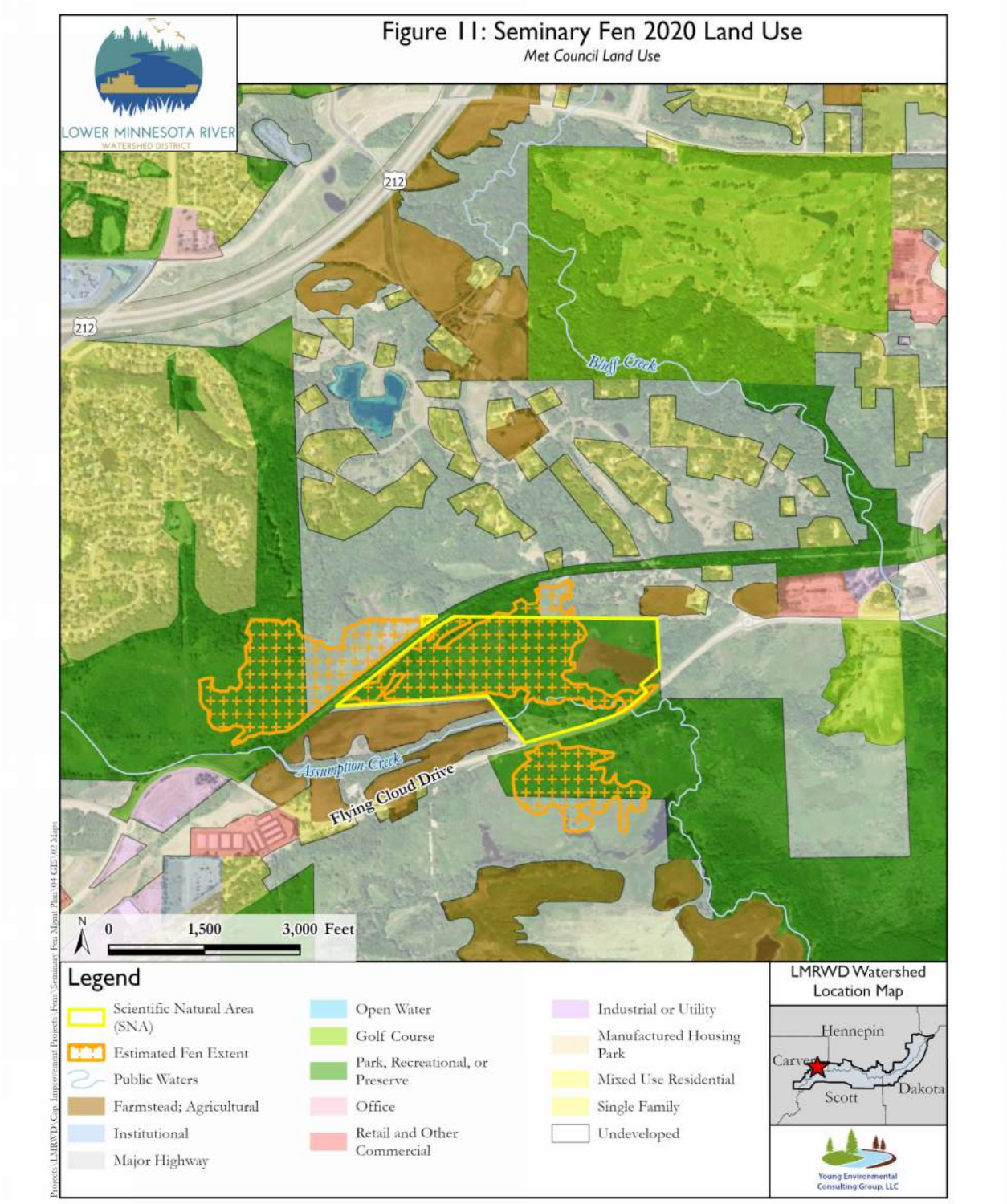
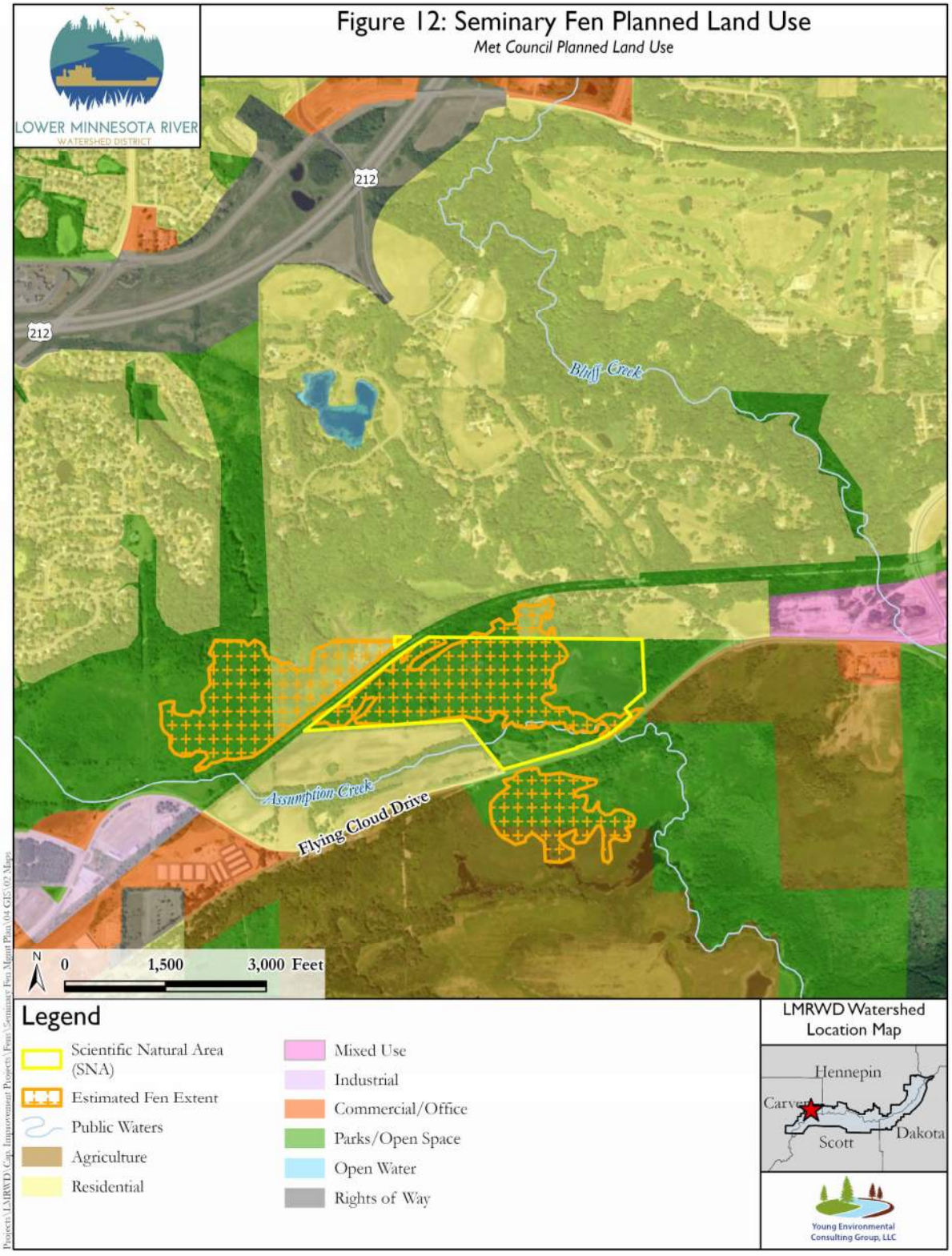


Figure 12. Planned Land Use



The proposed residential development may not have a direct effect on the SNA, but indirect effects should be considered. More people living nearby may increase exploration of these fragile and unique ecosystems, which could result in degradation. In addition, much of the land proposed for residential development is wetland, some of which may harbor previously undiscovered fen communities that should be assessed before development.

Residential and other development may require substantial dewatering to establish solid foundations. This dewatering, even if temporary or seasonal, has been shown to have prolonged effects on fen health and sustainability (Young Environmental, 2021). Residential developments that include below-grade basements may require sustained dewatering using individual drainage and pumping systems.

Improved understanding of the value of the SFWC and of the buffer provided by surrounding lands may foster an increased effort to protect those resources. Planned developments may be altered to add protection to the SNA and adjacent areas. The MNDNR, other agencies, and nongovernment conservation organizations continue to pursue opportunities to acquire additional property for inclusion and protection as part of the SNA or other protected lands. The vegetation assessment conducted in 2021 established Site E on private property north of the SNA as a particularly rich assemblage of previously unidentified fen flora. Although its privately owned location may be afforded some protection by the current property owner, an effort to protect Site E and a surrounding buffer as part of the SNA or other protected status might be prudent.

Because the SFWC relies on the sustained flow of upwelling groundwater, the land use in areas on the upland bluffs where groundwater is believed to recharge the groundwater supply is relevant to the long-term health of the fen. The sequence of historic to recent aerial photographs shows a transition from agricultural to residential land use, and it is expected to remain residential. It is uncommon to transition beyond residential neighborhoods to another type of land use.

The SFWC is an ecologically significant, dynamic ecosystem that interacts with other nearby ecosystems. The SFWC's wetland habitat connections to nearby resources have been affected by roads, altered land uses, and other habitat changes. These features can create barriers for birds, amphibians, fish, aquatic invertebrates, and wetland plants, as described by Johnson and Walz (2013). These are important considerations because there may be a need to restore or maintain these connections.

CONCLUSIONS

Estimated to be nearly 10,000 years old, the SFWC is the culmination of climatological and evolutionary forces that resulted in a unique ecosystem engendered by the accumulation of poorly decomposed peat present today. The recent pressures of changing land use and competition for groundwater have measurably stressed the ecosystem. Recently conducted vegetation assessments identified indicators that confirm the presence of a healthy calcareous fen plant community. The results of these assessments show healthy fen communities are present in places that had not been previously assessed. The fen areas that are not protected by the SNA established to protect the fen should be considered for additional protection. Other areas with fen vegetation periodically subject to flooding, suggest the fen community has some resilience to inundation.

The recent vegetation assessments summarized in this report and related observations identify an incursion of invasive, nonnative species that could disrupt the existing vegetation and the fen ecosystem. Many of the invasive plants, including reed grasses and shrubs like buckthorn, shade the native plants, depriving them of sunlight and interfering with life-cycle functions. Aggressive efforts to control invasive plants are needed to protect the fen community.

A well-managed groundwater-level data-collection network helps monitor the SFWC to determine whether it continues to be supplied with the water needed to sustain its ecosystem. However, our growing understanding of fens has many gaps that should be addressed. The quality and sustainability of water supplying the fen need to be maintained, and competition for the finite groundwater supply remains a threat.

There are many opportunities to study Seminary Fen resources and compare their attributes to those of other fens in the Lower Minnesota River Valley. Although vegetation relevés are a useful tool for identifying fens, learning about, and defining other features that characterize fens would benefit fen sustainability.

Natural resource managers are making important contributions to our understanding of fens by supporting important data collection programs and resource investigations. Educational institutions, environmental organizations, nonprofit organizations, and other stakeholders can support or conduct research that enhances understanding of these threatened ecosystems. New and creative approaches to understanding and characterizing the fen and its associated resources could help foster additional opportunities for study and provide broader protections for fens and similarly rare and threatened resources.

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