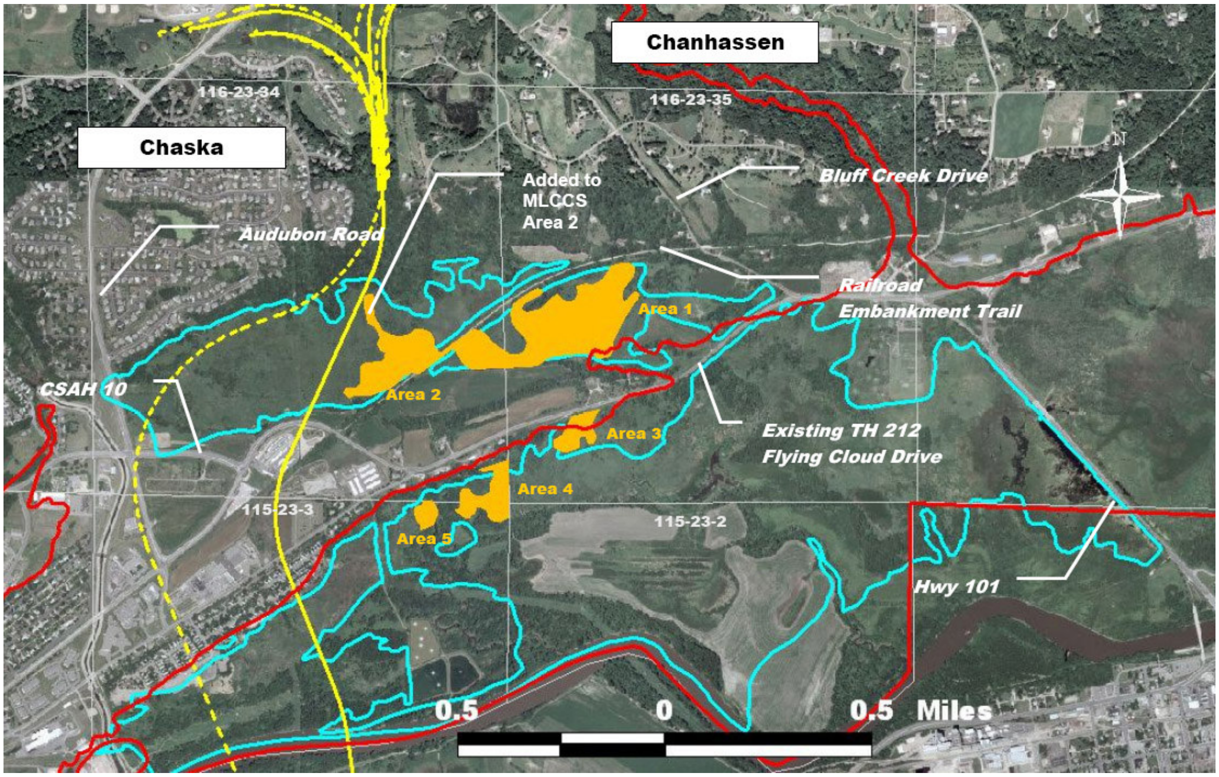
PHASE 1 CHARACTERIZATION
SEMINARY FEN WETLAND COMPLEX
TH 41 OVER THE MINNESOTA HIGHWAY PROJECT
Carver County, Minnesota



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Peterson
Environmental
Consulting, Inc.

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CARVER COUNTY, MINNESOTA
APRIL 24, 2006

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1 Executive Summary

Peterson Environmental Consulting, Inc. (PEC) was retained by the SRF Consulting Group, Inc. (SRF) to perform a Phase 1 characterization of the Seminary Calcareous Fen in support of a Tier 1 EIS being prepared to evaluate alternatives proposed for a new river crossing at Trunk Highway 41 (TH 41). For the purposes of the Phase 1 characterization, the "Seminary Fen Wetland Complex" (SFWC), which consists of two units of extensive peatland spread across four sections of the Minnesota River Valley in Carver County, was distinguished from the five calcareous fen components (CFC) of the SFWC (CFC-SFWC) as mapped under the Minnesota Land Cover Classification System (MLCCS). The study focused on the MLCCS calcareous fen components but also addressed characteristics of the entire SFWC.

This Phase 1 characterization of the Seminary Calcareous Fen:

- Provides essential background information on calcareous fen regulation in Minnesota and on the hydrology, soil, water chemistry, and vegetation characteristics used to identify calcareous fens in Minnesota,
- Discusses impacts known to adversely affect calcareous fens, focusing on those impacts associated with bridge construction,
- Places the Seminary Fen in a local and regional hydrogeological context necessary to understand calcareous fen function and characteristics,
- Assesses historic land use impacts to the Seminary Fen,
- Quantifies hydrology, soils, water chemistry, and vegetation calcareous fen criteria in the mapped calcareous fen components of the SFWC, and
- Provides recommendations for a Phase 2 assessment of potential impacts of Alternative Alignments E-1A and E-2, which will include discussion of potential impacts of TH 41 Alternative Alignments E-1A and E-2 to the calcareous fen components of the SFWC and to the SFWC itself.

Calcareous Fen Regulation and Definition

Calcareous fens are peat-accumulating wetlands dominated by distinct groundwater inflows and having specific chemical characteristics. Discharging groundwater is characterized as circum-neutral to alkaline with high concentrations of calcium and low dissolved oxygen content. The chemistry provides environments for specific and often rare hydrophytic plants (MR 8420.1020). Calcareous fens are protected and potential impacts regulated under Minnesota Statutes and Rules 103G.223, 8420.1010 to 8420.1070 and MPCA Rule 7050. Calcareous fens are formally defined and delineated based on the presence of specific hydrology, water chemistry, soils, and vegetation indicator criteria (Berglund 1995; revisions proposed in Leete et al., 2005). The primary differences between the 1995 and proposed 2005 criteria relate to vegetation. Both sets of vegetation criteria were used in this study. The "Seminary Fen" is formally listed as a calcareous fen under Minnesota Rule 7050.0180 Sub. 6b, B Carver County, Seminary Fen. It is currently listed as the only calcareous fen in Carver County.

Hydrogeologic Setting of the SFWC

The SFWC exists as a large North Unit adjacent to the north bluff of the Minnesota River and a South Unit that lies south of existing TH 212. The two units are separated by an upland terrace consisting of coarse textured glacial outwash. Several bluff top wetlands exist north of the SFWC at elevations approximately 200 to300 feet higher than the SFWC that could provide the hydraulic gradient driving groundwater discharge to the areas on the valley floor that are adjacent to the bluff. CFC Areas 1 and 2 are associated with groundwater discharge focused at the base of the bluff. Groundwater discharge to CFC Areas 1 and 2 can be through quaternary sediments (e.g. sand stringers in the till) and/or discharge from bedrock subcrops near the bottom of the bluff. During our investigation of CFC Area 2 a distinctive plant community outside of the MLCCS-designated fen was observed that would meet all calcareous fen criteria. This zone extended from the north-central boundary of the MLCCS unit north to near the base of the bluff. This area was added to CFC Area 2 based on the presence of all of the calcareous fen criteria, and is indicated in the figures that apply to CFC Area 2 in this report.

CFC Areas 3, 4, and 5 in the South Unit of the SFWC are approximately 15-to-20 feet lower in elevation than the southern portions of the North Unit of the SFWC. The presence of extensive spring heads and spring runs associated with the toeslope positions of the terrace and their distance from the base of the Minnesota River bluff suggest that the source of the discharging groundwater originates as recharge from losing reaches of the portion of Assumption Creek that flows on the terrace and groundwater recharge occurring at the northern edge of the terrace feature. The location and elevation of the discharge areas suggests a complex hydrology where groundwater discharges at and near the bottom of the bluff, becomes channeled surface flow in spring runs, diffuse surface flows and subsurface throughflow across and within the sloping peat aprons in the North Unit SFWC, recharges the groundwater system underlying the coarse textured terrace feature, and then discharges again as spring heads and spring runs in the Southern Unit of the SFWC.

The postglacial hydrogeology of the SFWC is complicated. Diffuse and focused groundwater discharge has resulted in paludification (peat accretion), and the formation of a large peatland that has a gradual slope to the south from the toe-of-slope positions at the bluff edge to the terrace feature that separates the North Unit of the SFWC from the South Unit of the SFWC. Similarly, peatlands to the south of the terrace feature also present a gradual slope from the south of the terrace feature to the active floodplain of the Minnesota River.

It is possible that a shallow post-glacial lake existed in the area for a period following glaciation. Natural drainage of this shallow lake resulting from downcutting of Assumption Creek providing an outlet to the east would have initiated the paludification process over much of the area. The result is a complex stratigraphy of thin-to-thick peat deposits accreting over fine-to-coarse textured calcareous marl, fine textured lacustrine sediment in low areas of the shallow lake, and coarse textured outwash sediments in elevated areas of the undulating lake bottom as indicated by an analysis of peat depths in the CFC-SFWC. The presence of a pre-glacial shallow lake characterized by the general presence of calcareous marl deposits and calcareous peat would result in virtually the entire wetland system being saturated with respect to calcium carbonate. Groundwater discharge would be more intense nearer the toe-of-slope positions at the base of the bluff and the terrace feature, and in areas where peat and lacustrine deposits are thin to the underlying sand. Groundwater discharge would be less intense in areas of thick peat over fine-textured lacustrine deposits. The distribution of the CFC-SFWC as highly calcareous fen features embedded in a surrounding carbonated wetland system could explain many of the calcareous fen features found in the SFWC.

Historic Land Use Impacts

Historic impacts to the SFWC were examined in aerial photos that date back to 1937. Because of their size and location in and near urbanizing areas, Minnesota Valley wetlands are particularly subject to various disturbances. While the CFC-SFWC are considered to be relatively pristine, the immediate area of the wetland and the adjacent bluffs have been impacted by fragmentation, municipal well withdrawals, bluff top urbanization and stormwater management, ditch and tile drainage, hydrologic alteration and surface water diversions, potential peat and/or mining of the underlying sediments, and limited industrial development. The Seminary Fen may, in fact, be maintained in the face of existing and historic disturbance by the sheer size of the wetland complex within which it is embedded, combined with the calcareous nature of the underlying sediments. Drainage impacts especially have affected the hydrology and plant community associated with a large, historic, calcareous-fen peat mound n CFC Area 1.

Groundwater Hydrology

The hydrology of the CFC SFWC was assessed through an interpretation of surface water features characteristic of groundwater discharge combined with an assessment of hydrologic gradients in nested water table wells and piezometers established in representative areas of the CFC SFWC. Based on our observations and well nest data, virtually all of the SFWC both within and outside of the CFC SFWC would meet the hydrology criterion for calcareous fens that requires evidence of stable, upward groundwater flow and the presence of peat soils (Histosols) or mineral soils with peat surfaces. Small to substantial upward groundwater flow was observed in all areas examined. However, the highest upward gradients (approximately 4 feet of difference between the water table well and the nested piezometer) were observed associated with a component of high-quality calcareous fen in the northern part of CFC Area 1 (Well Nest 1A). Other well nests exhibited upward gradients to lesser degrees. A well nest installed in the terrace portion of Assumption Creek exhibited strong downward gradient, indicating the losing nature of Assumption Creek in the terrace reach and confirming the hypothesis that the terrace feature is the source of water discharging to CFC Areas 3, 4, and 5 that are south of the terrace and TH 212.

Field observations and interpretations of hydrographs in nested water table well and piezometers provide a general working hypothesis of groundwater flow in and around the SFWC that explains many of the important hydrologic features of the area. Salient features of the SFWC groundwater-flow model include the following:

1. Groundwater recharge occurs on bluff-top wetlands and uplands north of the bluff escarpment. Head gradients are large and can drive downward groundwater movement through unconsolidated glacial sediment as well as the underlying bedrock. Recharge could also occur in distant areas to the north of the SFWC. The SFWC lies at the mouth of a buried pre-glacial bedrock valley that extends north under both lakes Waconia and Minnetonka. Exact groundwater recharge areas and locations are not

known at this time, and will be examined under a Phase 2 investigation of potential impacts of bridge construction.

2. Groundwater discharge is primarily associated with spring heads and diffuse seepage areas at toe-of-slope positions at the base of the bluff and associated alluvial fans. The majority of the spring heads and seepage areas at toe-of-slope position are the result of high hydraulic gradients at these locations. Hydraulic gradients would decrease further south into the relatively flat, sloping peatland of the North Unit SFWC.
3. Localized zones of groundwater discharge are also associated with areas further from the base of the bluff that are shallow to sand or that do not contain fine textured substrates. The sandy substrate under the peat likely has undulating relief. It is also possible that fine-textured lacustrine sediments overlie areas in the sandy outwash. Peat in the area of the SFWC varies in thickness and substrate type. Seepage areas are more likely where peat is thin and fine-textured substrates are absent.
4. Groundwater throughflow dominates in the middle portions of the SFWC that are sloping peatlands with a gradient to the south. However, at any given point upward gradients are also observed. Groundwater flow occurs in three dimensions. In sloping peatlands with topographic gradients to the south, both lateral (throughflow) and upward (discharge) components to the flow directions were observed.
5. Groundwater recharge likely occurs at the northern edge of the terrace feature and in losing reaches of Assumption Creek. Assumption Creek has very complex hydrology and has been substantially affected by historic diversions and channelization. In its current configuration Assumption Creek headwaters lie within the north unit of the SFWC, where it has two main tributaries originating to the west and to the east of CFC Area 2, respectively. North of the railroad embankment the tributaries were observed to be perennial throughout the field season. However, once the tributaries join and flow under the railroad embankment, the streams becomes intermittent and loses water to the groundwater system. The data and field observations suggest that most of the water recharged on and flowing through the terrace feature resurfaces as groundwater seeps and spring heads at the toe-of-slope positions at the terraces southern edge, including CFC Areas 3, 4, and 5.

Water Chemistry

Our hypothesis of general calcareous groundwater discharge to the entire SFWC is confirmed by the chemical analyses of groundwater and surface water collected from water table wells, piezometers, spring heads, and spring runs. Virtually all surface water and groundwater samples satisfy the calcareous fen chemical criteria, and all of the SFWC water samples are saturated with respect to solid calcite. All samples are calcium-magnesium-bicarbonate dominated waters with neutral to alkaline pH values that are uniformly above pH 6.7. Total dissolved solids content is high ranging from 200 to 1200 mg/L, with the majority of the samples ranging from 500 to 1000 mg/L (Figure 4.16).

The data suggest that the discharging groundwater and surface flows originating as seeps, spring heads, and spring runs are saturated with respect to calcium carbonate, and remain saturated with respect to calcium carbonate as the water flows south through the system to the Minnesota River. As a result, the groundwater and surface water flows within the SFWC fulfill the water chemistry criteria for calcareous fens, and facilitate the presence of diverse, calciphile-dominated plant communities near points of focused groundwater discharge, and thinly distributed populations of calciphile plant communities in areas dominated by weak discharge and throughflow of calcareous groundwater.

A comparison of water chemistry between well nests indicates that the high-quality sloping fen adjacent to and south of he railroad embankment represented by Well Nest 1A had significantly different groundwater discharge chemistry when compared to all other sampling locations. The water collected from spring heads, spring runs, water table wells and piezometers associated with Well Nest 1A was higher in dissolved solids and had far greater concentrations of chloride, suggesting that the aquifer discharging to this location is different than the aquifers feeding the other CFC SFWC. The nature of this aquifer is unknown at this time, but may be the Franconia shale. Surface water and groundwater chemistry in the other areas examined were similar to each other in chemical constituents and carbonate chemistry and likely represent groundwater discharge from a different aquifer than that which discharges to the Well Nest 1A location.

<u>Soils</u>

The calcareous fen soil criteria were examined by describing representative soils within the CFC-SFWC and performing a loss-on-ignition laboratory analysis of the distribution of organic matter, calcium carbonate, and mineral material in samples collected incrementally from these representative soil profiles.

All of the soils collected within the CFC SFWC as well as all wetland soil profiles examined during walkover assessments of the SFWC would meet the calcareous fen soil criteria. All of the soils are histosols or have histic epipedons. Several profiles contain large quantities of marl (limnic sediments dominated by precipitated calcium carbonate) that represent calcite precipitation in spring heads and spring runs, and calcareous marl likely deposited during shallow-lake phases that may have occupied the area of the SFWC during early post-glaciation periods.

The majority of the SFWC soils were incorrectly mapped into the Blue Earth soil series (fine-silty, mixed, superactive, calcareous mesic Mollic Fluvaquents). Most of the soils examined would fall into the Houghton and Edwards soils series (euic, mesic Typic Haplosaprists and marly, euic, mesic Limnic Haplosaprists, respectively). Strongly expressed areas of calcareous fen consisting of dense and diverse populations of calciphiles were associated with Edwards soils that have strata of virtually pure calcium carbonate marl deposits interbedded with organic layers. Houghton soils consist of thick peat deposits that are neutral in pH and can have substantial amounts of calcium carbonate disseminated within the peat matrix, but lack marl/organic layer stratification. Calciphiles were observed in areas of Houghton soils, but were thinly distributed amongst the wetland plant communities.

A dynamic groundwater discharge/surface flow hydrologic system is indicated in areas with stratified marl/organic deposits (Edwards soils) that would be characterized by successive development and abandonment of spring heads, spring runs and flarks (broad, terrace-like surface flow features commonly associated with the flanks of sloping and mound-type calcareous fens). The Edwards soils associated with the high-quality calcareous fen plant communities in CFC Area 1 especially exhibit peat surfaces combined with complex stratification of marl and organic sediments in the sub-soil. An examination of the soils along a raised peat mound that is a significant physical feature of the entire SFWC indicated that the mound was historically high-quality calcareous fen that has been adversely affected by drainage. Edwards soils were observed along the flanks, with Houghton soils occupying the apex of the mound. The Houghton soils exhibited carbonate leaching in the soil surface that was likely the result of drainage observed as drain tile discharge on the flanks of the mound. Surface water well hydrographs (Well Nest 1B) indicate water-table fluctuation suggestive of tile drainage.

With two exceptions, soils present in CFC Areas 2, 3, 4, and 5 were Houghton soils that are thought to be more representative of mixed throughflow and discharge with calcareous groundwater. Some profiles contained substantial amounts of calcium carbonate disseminated within the peat matrix, but generally lacked the stratification associated with the high-quality calcareous fen areas. One profile in CFC Area 3 and one profile in CFC Area 5 exhibited marl/organic horizon stratification in the subsoil. However, the presence of thick overlying peat deposits suggests that the hydrology that resulted in the stratification is no longer active.

Moreover, soils in CFC Areas 4 and 5 exhibited alluvial strata and high mineral content in the peat that represent periodic inundation by Minnesota River floodwater. Both areas are well within the 100-year floodplain of the Minnesota River. Periodic flooding retards or prevents calcareous fen development and maintenance by disturbance, sediment burial, and the introduction of elevated nutrient levels in the sediments that favor plant species adapted to disturbance and high nutrient levels. These areas were dominated by rank, high-stature vegetation and lacked sufficient quantities of calciphiles to met the calcareous fen vegetation criteria. These areas, while being high quality fen wetlands, are not calcareous fens and were likely miss-mapped, with mapping based on evidence of groundwater discharge and the presence of peat soils.

Vegetation

Descriptions of vegetation were prepared from qualitative and quantitative surveys of the SFWC. Several rare and protected plant species, and species with a high affinity for calcareous fens have been previously documented. During the present study, the following species were observed: *Carex sterilis*, *Cladium mariscoides*, *Cypripedium candidum*, *Eleocharis rostellata*, *Scleria verticillata*, and *Triglochin palustris*.

Numerous locations of calcareous fen were found in Area 1. That area supports a diversity of different plant communities, many of which represent the variation possible in calcareous fen vegetation. Notably, short sedge calcareous fen communities on tufa (thin to thick deposits of calcium carbonate precipitated at the soil surface) and tall sedge calcareous fen communities on peat are both significantly present. Despite the presence of calcareous fen plant communities, the area has suffered extensive ecological disturbance. Without proper management, the unique fen habitats and associated species may be further degraded or lost. However, this disturbance presents many opportunities for restoration of calcareous fen habitats. Area 1 satisfied 1995 and proposed 2005 vegetation criteria using vascular plants and bryophytes. Invasive species such as *Phalaris arundinacea*, *Phragmites australis*, *Rhamnus cathartica*, and *Rhamnus frangula* all pose biotic threats to the fen communities. Erosion and past drainage post abiotic threats.

Area 2 satisfied calcareous fen criteria for both vascular plants and bryophytes. This area, however, does not support the diversity of calcareous fen plant species or communities as seen in Area 1. Tall sedge calcareous fen communities are found that intergrade into other wetland communities such as emergent marsh, shrub carr, and wet meadow. *Phragmites australis* and unchecked shrub growth poses an ecological threat in this area.

Area 3 is similar to Area 2 in satisfying vascular plant criteria for calcareous fens and supporting tall sedge fen communities. Short sedge fen communities are lacking as with Area 2. The area failed to meet the proposed bryophyte criteria for calcareous fens. Invasive species, shrub growth and anthropogenic disturbance (in the form of a radio tower and associate facilities) pose ongoing threats to the integrity of the plant communities.

Areas 4 and 5 failed to meet vascular plant criteria for calcareous fens. The plant communities resembled riparian forest and emergent marsh ecosystems more than calcareous fens. The sites are apparently subject to periodic flooding from the Minnesota River, and deposition of sediments and nutrients may prevent development of calcareous fen characteristics. Areas 4 and 5, in combination, did meet the proposed bryophyte criterion for calcareous fens, in contrast to the vascular plant results.

Potential Impacts of TH 41 Alternative Alignments E-1A and E-2

Both alternative alignments E-1A and E-2 are located to the west of the SFWC CFC Area 1, which is hydrologically separated from the alternatives by the railroad embankment. Because of the hydrologic separation produced by the railroad embankment, proximity of the calcareous fen to the bluff base that would be the focus of groundwater discharge, and the distance from both of the alternative alignments, it is our opinion that Phase 1 information indicates that it is unlikely that either alternative would have a substantial impact on CFC Area 1.

However, there is the potential for substantial direct impacts to CFC Area 2, and potential indirect impacts to CFC Areas 3, 4, and 5. CFC Area 2 is within 100 feet of alignment E-2. Alternative alignment E-1A is located within the western portion of the north unit of the SFWC and follows the bluff line where groundwater discharge results in spring heads and spring runs that flow to a confluence with the westerly flowing tributary of Assumption Creek to the north of the railroad embankment. Surface flows join to form Assumption Creek that subsequently flows across the terrace feature. The Assumption Creek piezometer data indicate that the losing portion of Assumption Creek provides much of the groundwater feeding CFC Area 3, 4, and 5.

Recommendations for Phase 2 Assessment of Potential Impacts

The Phase 2 assessment should concentrate on the overall regional hydrology of the SFWC to investigate potential impacts on all of the areas that meet the calcareous fen criteria in Leete et al. (2005). However, the Phase 1 assessment suggests that CFC Area 1 will not likely be affected by either alternative alignment E-1A or E-2.

1. A more detailed review of the western portion of the north unit SFWC needs to be performed to ensure that no outliers of calcareous fen exist in the area.

2. A detailed plant community inventory of ecotopes within a specific distance of the E-1A and E-2 alignments should be performed under Phase 2 (e.g. 500 feet either side of the applicable alternative).

3. Impacts need to be assessed in the context of specific construction procedures and proposed features of the alignments, including span width, length, construction methods, timing for specific procedures and total length of time expected for completion, location of staging areas, fill pads, pier placement and dewatering requirements, and erosion control methods.

4. An assessment of the location and environmental characteristics of the areas directly impacted that would need to be mitigated should be performed.

5. An assessment of temporary impacts will need to be evaluated in the context of the proposed construction methods.

6. The direct, long-term impacts of shading and winter salting need to be determined for post-construction road operation, especially on the portions of CFC Area 2 that are adjacent to proposed alignment E-2.

7. The potential for salt movement and impacts to plant communities should be assessed in a hydrogeologic context for the entire SFWC. Particular attention should be paid to potential effects on calciphile communities by road salt-contaminated groundwater that resurfaces at the numerous spring heads in Areas 3-5.

The direction the Phase 2 assessment takes will be dependent upon the availability of appropriate literature that can be applied to the specific setting of the SFWC and the proposed alternative alignments. The Phase 2 assessment should evaluate potential impacts based on the existing literature refined with additional field work applicable to the specific alignment alternative.

2 Introduction

Peterson Environmental Consulting, Inc. (PEC) was retained by the SRF Consulting Group, Inc. (SRF) to provide scoping and environmental assessment support to characterize the Seminary Calcareous Fen in support of a Tier 1 EIS being prepared to evaluate alternatives proposed for a realignment of Trunk Highway 41 (TH 41). The "TH 41 Over the Minnesota River" Tier 1 EIS is being prepared by SRF on behalf of the Minnesota Department of Transportation (MnDOT), the project sponsor.

Calcareous fens are protected under Minnesota Statutes and Rules 103G.223, 8420.1010 to 8420.1070 and MPCA Rule 7050. Calcareous fens are peat-accumulating wetlands dominated by distinct groundwater inflows and having specific chemical characteristics. The water is characterized as circum-neutral to alkaline with high concentrations of calcium and low dissolved oxygen content. The chemistry provides environments for specific and often rare hydrophytic plants (MR 8420.1020). Detailed discussion of fen characteristics are provided in Amon et al. (2002) and Bedford and Godwin (2003).

A "tiered" two-step environmental review process (as permitted by the National Environmental Policy Act (NEPA) regulations and by Minnesota Rule 4410.4000) is being utilized for the proposed project in order to identify a preferred alignment. Two TH 41 Tier 1 alternative alignments have been identified that lie just west of the Seminary Fen. Both alternatives involve high traffic-volume bridge construction over the Minnesota River. This report specifically provides baseline information characterizing the Seminary Calcareous Fen in support of the TH 41 alternatives analysis. A Phase 2 report identifying potential impacts to the Seminary Fen that could result from construction of the applicable alternatives will be prepared in support of the Tier 1 alternatives selection process subsequent to this initial characterization.

Interim results have been used to design minor adjustments to the alignments to minimize impacts. Once all potential alternative alignments have been reduced to one that acceptably minimizes impacts to both the human and natural environment, a Tier 2 EIS assessment will be prepared for the selected alternative at a time closer to project construction, which may or may not involve either of the alternatives potentially affecting the Seminary Fen.

2.1 Summary Description of the Proposed Action

MnDOT proposes to construct a new river crossing between TH 169 in Scott County and the proposed realignment of TH 212 ("New TH 212") in Carver County in the vicinity of existing TH 41. The total length of the project corridor is approximately three miles. The project is proposed in order to (1) reduce congestion by increasing river crossing capacity; (2) improve connectivity, specifically providing a free-flowing high volume principal arterial connection between TH 169 and New TH 212 (two high-priority interregional corridors); and, (3) provide a facility above the 100-year floodplain to avoid closures due to seasonal flooding.

The proposed project is not currently programmed for construction within the next 20 years. However, there is a need to preserve right of way in the corridor that best meets project objectives as soon as possible since the rapid development of the study area will further limit available options for increasing corridor capacity in the future.

2.2 TH 41 Alignments Potentially Impacting the Seminary Fen

Six alternative alignments are being evaluated under the Tier 1 EIS; however, two alignments initially proposed by MnDOT in the final Tier 1 EIS scoping decision document (MnDOT, 2005) are located near and have the potential to impact the calcareous fen components of the Seminary Fen Wetland Complex (**Figure 2.1**). Areas designated as Calcareous Fen by the Minnesota Land Cover Classification System (MLCCS, MnDNR Staff et al., 2004) are provided in Figure 2.1 for reference and are discussed further in Section 3.4. National Wetlands Inventory polygons in which the calcareous fen components are embedded are also provided for reference and to illustrate the size of the wetland systems involved.

NOTE: During our 2005 field investigations we added an area that met all calcareous fen criteria to the CFC Area 2 MLCCS polygon. This additional area appears as a narrow "finger" that extends from the north central boundary of the original MLCCS polygon to the northwest. This area is identified in Figure 2.1 and all applicable figures in the Results section.

Alternative alignment E-1A crosses the Minnesota River south of the junction of Audubon Road and TH 212, briefly parallels Audubon Road and then diverges to the east near the junction of Audubon Road and CSAH 10. The alignment then curves to the northeast, parallels the bluff of the Minnesota River, and then curves to the north and follows a deeply dissected drainageway (coulee) up the bluff face to the junction with the new TH 212 interchange. The route traverses the northwestern periphery of the Seminary Fen Wetland Complex, but is west of the calcareous components of the wetland complex that have been mapped under the MLCCS (Figure 2.1).

Alternative alignment E-2 lies to the east of alternative E-1A and takes a more direct route traversing northeast through the Seminary Fen Wetland Complex west of the MLCCS-designated calcareous fen components (Figure 2.1). Alternative E-2 lies immediately west of the westernmost portion of the designated calcareous fen components.

2.3 Potential Issues with the Delineation of Regulated Calcareous Fens

Section 3.1 provides the basic regulatory framework for calcareous fen regulation in Minnesota, Section 3.2 describes the criteria to identify calcareous fens in detail, and Section 3.4 describes in detail the hydrogeologic setting of the calcareous fen components of the Seminary Fen Wetland Complex.

The areas designated as calcareous fen under the MLCCS and the Minnesota County Biological Survey (MCBS; MnDNR Staff, 1998) are embedded in a much larger, more extensive wetland complex. Leete et al. (2005) indicate:

> "[T]he habitat for the calcareous fen plant community is often larger than the area within a wetland complex that the calcareous fen currently occupies……Thus the boundaries of the calcareous fen must be defined as the boundaries of that part of the wetland that meets the soils and/or hydrology criteria." (Leete et al., 2005, Page 1)

This definition of calcareous fen boundaries, while presenting few problems with isolated calcareous fens that are not extensive, provides significant problems when considering extensive wetlands in the

Minnesota River Valley such as those found in the area of the Seminary Fen. The Blue Earth and related soils that dominate the wetlands in the area are calcareous and typically meet the soils criteria, and the groundwater hydrology is dominated by calcareous groundwater discharge that is typical of the hydrogeologic setting. The criteria and guidance in Leete et al. (2005) have not been formally accepted as the official criteria and guidance governing fen identification and delineation.

For the purposes of the present report, we will distinguish between the "Seminary Fen Wetland Complex" (SFWC) which consists of two units of extensive peatland spread across four sections of the Minnesota River Valley in Carver County, from the five calcareous fen components of the SFWC (CFC-SFWC) as mapped under the MLCCS. The northern unit (North Unit SFWC) extends from Audubon road east to the eastern limits of the wetland system just west of Bluff Creek Drive, and north from the toe of the bluff south to TH 212. The southern unit (South Unit SFWC) extends from TH 212 south to the Minnesota River and west from the Chaska Creek diversion east to TH 101 (Figure 2.1).

The contiguous wetland that includes the CFC-SFWC total over 800 acres. In contrast, the five MLCCS calcareous fen polygons total just over 56 acres. A more detailed analysis of the entire SFWC is beyond the scope of the Phase 1 effort, and would be a subject for a Phase 2 examination under the guidance of the MnDNR and MnDOT to determine the extent of the SFWC that would be regulated as calcareous fen under Minnesota Rules and the draft criteria and guidance provided in Leete et al. (2005).

3 Background

The SFWC is generally located in Sections 34 and 35, T116N R23W near the towns of Chaska and Chanhassen, Carver County, Minnesota (Figure 2.1). Though formally identified as a protected calcareous fen, insufficient information on the criteria used to identify and delineate calcareous fens in Minnesota exists for the CFC-SFWC. This information is necessary to evaluate the extent and character of the protected resource subject to potential impacts of bridge construction and roadway operation.

PEC and SRF invited the input of recognized Minnesota calcareous fen experts in the development of a scope that would result in a more complete knowledge of the soil, hydrology, geochemical, and floristic characteristics of the Seminary Fen in support of the TH 41 Tier 1 EIS. Several Technical Working Group meetings were held to facilitate scope development and to provide interim results. Our work focused on the delineated CFC-SFWC. Work completing the tasks of the resulting scope is presented in this report.

3.1 Calcareous Fens as a Regulated Resource in Minnesota

Calcareous fens are a uniquely protected wetland resource in Minnesota. Wetlands are generally regulated under the 1991 Minnesota Wetlands Conservation Act administered by the Board of Water and Soil resources (BWSR), and under Section 404 of the Clean Water Act by the US Army Corps of Engineers (USACE). Other regulatory agencies, such as the MnDNR, are also involved in wetland regulation; dredge and fill impacts to wetlands are a relatively common occurrence and are subject to a permit process requiring compensatory mitigation. Impacts are generally considered only within the delineated wetland boundary for most wetlands. The MnDNR also regulates wetlands on their protected waters inventory (PWI). Only Assumption Creek and portions of the wetlands associated with Seminary Fen that are south of TH 212 are considered MnDNR protected waters (PWW 222 and PWW 223).

However, calcareous fens are recognized and regulated as “Outstanding Resource Waters” in Minnesota. Any activity that has the potential to degrade or adversely affect calcareous fens is a regulated activity permitted only under a fen management plan approved by the commissioner of the MnDNR.

The CFC-SFWC have been identified as an “Outstanding Resource Water” protected under Minnesota Statutes and Rules 103G.223, 8420.1010 to 8420.1070 and MPCA Rule 7050.

3.1.1 Calcareous Fen Regulations that Apply to the TH 41 Project

3.1.1.1 MR 8420.1010 Identifying Calcareous Fens

Because the state regulates activities with the potential to impact calcareous fens, the calcareous fen resource must be characterized sufficiently to identify for project proponents where regulated calcareous fens exist. Thus the state required the development of technical criteria for identifying and delineating calcareous fens in Minnesota. Two documents apply and are described along with the applicable calcareous fen identification criteria in Section 3.2.

3.1.1.2 MR 8420.1030 Procedures to List Calcareous Fens

The responsibility of defining, listing, and noticing regulated calcareous fens falls to the Commissioner of the DNR. The "Seminary Fen" is formally listed as a calcareous fen under Minnesota Rule 7050.0180 Sub. 6b, B Carver County, Seminary Fen. It is currently listed as the only calcareous fen in Carver County. Sufficient plant data have been gathered to award the CFC-SFWC a calciphile plant score (described below in Section 3.2.1.4) of 156 points (Leete et al., 2005), though the location and specific plant species are not provided.

3.1.1.3 MR 8420.1040 Management Plans

> "[C]alcareous fens may not be drained or filled or otherwise altered or degraded except as provided for in a management plan approved by the commissioner. The commissioner will provide technical assistance to landowners or project sponsors in the development of management plans." (MR 8420.1040)

Because of their dependence on groundwater discharge from aquifers of often unknown extent and character, calcareous fens can be subject to hydrologic impacts from project areas sometimes far distant from the fen area itself, especially if the impacts result in temporary or permanent alterations to the groundwater system feeding the fen. It is primarily because of this dependence on aquifer maintenance that calcareous fen management plans were developed. Fen management plans are a required component of any project with the potential to impact groundwater and surface water flows within and adjacent to calcareous fens. A frequently large adjacent area will need to be examined to address several complex hydrologic-impact issues that could extend well beyond the calcareous fen boundary.

3.2 Calcareous Fen Identification and Description in Minnesota

Berglund (1995) has been in use for the last 10 years to formally identify calcareous fens regulated in Minnesota. More recently Leete et al. (2005) refined and updated the technical criteria in Berglund (1995). Both documents were based on an examination of soil, hydrology, chemistry, and vegetation characteristics that differentiated known calcareous fens from other wetlands. The 2005 criteria are virtually identical in soil, hydrology and chemistry parameters, with the exception that dissolved oxygen criteria were dropped. Significant changes were made to the vegetation criteria by revising sampling methods, updating and regionalizing the indicator plant species list, and adding a list of bryophyte calcareous fen indicator species.

Leete et al. (2005) is in the public comment process and draft calcareous fen criteria have not been formally adopted. However, Leete et al. (2005) provide detailed data comparing and refining calcareous fen criteria that can be used to distinguish calcareous fens from non-calcareous fen wetlands. The calcareous fen technical criteria of Berglund (1995) and Leete et al. (2005) were used to evaluate soil, hydrology, geochemical, and vegetation characteristics of the Seminary Fen.

3.2.1 Technical Calcareous Fen Criteria: Hydrology

With respect to the hydrology criterion, Leete et al, (2005) state:

> "[A]n area meets the hydrology technical criterion when the hydrology is characterized by having stable, typically upwelling groundwater inflows sufficient to maintain saturation for the development of a histosol or histic epipedon soil." (P. 31)

Discussion

The hydrologic criterion is specific by itself but is supported by the presence of organic peat soils that require persistent water saturation to form. The hydrologic criterion is met when the surface saturation is dominated by upwelling groundwater. Field evidence of upwelling groundwater includes:

- The presence of spring heads and spring runs reflecting focused groundwater discharge from underlying aquifers.
- The presence of diffuse overland flow a few millimeters deep indicating seepage from the underlying aquifers, and
- The presence of "quaking ground" that is kept turgid by hydrostatic pressures from underlying aquifer discharge.

More formal determination of the hydrologic criterion consists of installing wells and piezometers to determine groundwater flow directions and gradients. Shallow water-table wells are screened to the surface and reflect the actual water table. Piezometers are screened at specific depths to determine the energy (pressure) of the water at that specific depth. Since water flows from areas with high pressure to areas with low pressures, upwelling groundwater is indicated by the presence of water levels in piezometers that are above the ground surface or the level of the surface water table, thus satisfying the hydrologic criterion. Monitoring well pairs (or well nests) will indicate the dynamic nature of the discharge. When spatially distributed throughout the fen, data from well nests can indicate water flow in three dimensions.

Calcareous fens require relatively stable upwelling of groundwater with minimal variation in water levels. Water levels at a given site that vary between recharge (indicated by piezometer water levels below the ground surface), and discharge (indicated by piezometer levels above the ground surface) are not typical of undisturbed calcareous fens.

3.2.2 Technical Calcareous Fen Criteria: Water Chemistry

With respect to the water chemistry criterion, Leete et al, (2005) state:

> "[A]n area meets the water chemistry criteria when the following conditions are met: pH of 6.7 or more; calcium of 30 mg/L or more, alkalinity of 1.65 meq/L or more; and specific conductance of 500 uS/cm or more." (P. 31)

Discussion

Calcareous fens are dependent upon specific groundwater chemistry that reflects the presence of solid calcium carbonate in the aquifer feeding the fen. Such water is said to be "saturated" with calcium carbonate and will have relatively stable chemistry characterized by minimum values of dissolved calcium (Ca^{2+}), alkalinity (HCO_3^-) and total dissolved solids (TDS) content because the water will have picked up dissolved ions as it travels through the groundwater flow system. Because pure water is an effective insulator, water with dissolved solids conducts electricity dependent upon the amount of dissolved solids. Groundwater will dissolve minerals as it moves through the aquifer and will have an elevated and distinctive electrical conductivity (EC) measured in various units of conductance (e.g.

criteria units of uS/cm). Dissolved calcium and bicarbonate ions in addition to other dissolved ions in groundwater will yield the minimum EC and calcium values that characterize fen water chemistry.

Leete et al. (2005) indicate that there may be a relationship between dissolved calcium and magnesium (alkaline earth cations) and the base cations such as sodium and potassium. They also suggest that there may be a relationship between alkalinity (primarily bicarbonate) and the other major anions of sulfate and chloride. However, in their comparison between these chemical ratios in fens and non-fens, the relationship was not significant and would likely not assist in discriminating calcareous fens from other wetlands.

An additional chemistry criterion provided in Berglund (1995) was that the groundwater be anaerobic (relatively free of oxygen). Dissolved oxygen is difficult to measure under field conditions for several reasons. However, low dissolved oxygen values are a property of virtually all saturated wetland sediments containing organic matter. Because of the difficulty of field determining oxygen content, the dissolved oxygen criteria was dropped as a recommended chemistry technical criterion in Leete et al. (2005).

Summary of Calcium Carbonate Equilibrium Geochemistry as Applied to the Calcareous Fen Environment

Calcium carbonate is ubiquitous in the Des Moines lobe till that occupies the bluff tops above the Seminary Fen, and is also present in the underlying bedrock. Calcium carbonate is one of the strongest buffers in nature, resulting in very stable pH ranges that are near neutral (~ pH 7). A brief statement of the geochemistry of calcium carbonate can provide some insight into the nature of calcareous fens. Detailed assessments of carbonate chemical equilibria are in and Garrels and Christ (1965), Lindsay (1979) and Arndt and Richardson (1992).

1. The solubility of calcium carbonate is significantly affected by dissolved CO_2. Higher levels of dissolved CO_2 in groundwater promote increased dissolution of calcium carbonate.

   Effect: High plant/animal respiration rates in aquifer recharge areas result in “aggressive” groundwater high in CO_2 that can dissolve greater quantities of calcium carbonate than would be dissolved in areas with lower biological activity. When this groundwater discharges and outgases CO_2, substantially greater amounts of solid calcium carbonate precipitate. This property has implications for the nature of the groundwater recharge areas for the aquifers that feed the Seminary Fen.

2. The solubility of calcium carbonate is temperature dependent. Cold water dissolves more calcium carbonate than warm water.

   Effect: Cold discharging groundwater that is saturated with calcium carbonate will hold more dissolved calcium carbonate, and will precipitate even more calcium carbonate as the water warms up subsequent to discharge at the soil surface.

3. Calcite-saturated groundwater, while frequently thought to be “nutrient rich” has characteristics that actually reduce the availability of several plant nutrients, especially phosphorus and nitrogen (Boyer and Wheeler, 1989; Bedford and Godwin, 2003; Moorehouse 2004).

   Effect: Plants in calcareous fens are adapted to <u>nutrient poor environments</u> in the immediate area of discharge. Europe has extensive literature on calcareous fens, which they consider “species rich” and “nutrient poor.”

These unique chemical properties of calcite have implications for calcareous fen development, location, and maintenance.

- The recharge areas should be characterized by high biological activity, resulting in elevated dissolved CO_2 that can aggressively dissolve more calcium carbonate as the water flows through the aquifer.
- Elevated dissolved calcium carbonate amounts will persist along the groundwater flow path to the area of discharge.
- The aquifer water will be cold, permitting even more dissolution of calcium carbonate.
- When the groundwater discharges, the water warms and the dissolved CO_2 out-gasses from the water, resulting in the precipitation of large amounts of carbonate near the discharge area until equilibrium with the atmospheric conditions is obtained.
- Once this equilibrium is obtained, no more calcium carbonate will precipitate unless the water evaporates.
- The equilibrium process takes time, and areas of strongly expressed calcareous fen features are usually located in close proximity to zones of strong groundwater discharge. Plants are frequently found associated with specific zones that are distributed around the point of discharge.
- Areas more distant may be weakly calcareous, but will not have the extremely high amounts of solid calcium carbonate as those found near the points of active groundwater discharge (see also Bowles et al., 2005). Areas distant from active discharge zones may lack the vegetation criteria as well.

3.2.3 Technical Calcareous Fen Criteria: Soils

With respect to the soils criterion, Leete et al, (2005) state:

> "[A]n area meets the soils technical criteria when the soils are characterized by the presence of either a histosol or a histic epipedon (as defined in Soil Survey Staff, 2003). Calcium carbonate precipitates, such as tufa deposits, may frequently be associated with calcareous fens and high carbonate content in this case is not indicative of a mineral soil." (P. 31)

Discussion

The established soils criteria require the presence of a histic epipedon, defined as a surface layer that meets certain criteria for organic matter content. A histic epipedon generally consists of a dominance of organic matter, and may include minor amounts of mineral material. Histic epipedons require virtually continuous water saturation to form. Anaerobic conditions resulting from water saturation reduce the rates of decomposition of organic matter, allowing organic matter to accrete (build up) at the surface. By formal definition, histosols must be continuously saturated for 30 or more days during the growing season. In natural conditions histosols are typically wet for the entire growing season. There are also additional depth and organic matter criteria to characterize histosols (Soil Survey Staff, 2003, Chapter 2, Definition of Organic Soils).

Soils in calcareous fens should be near neutral pH and will typically contain minor-to significant amounts of solid calcium carbonate, indicated in the field by treating the soil with a weak solution of hydrochloric acid and noting if the soil foams. The presence of foam indicates that calcium carbonate is dissolving in acid to CO_2 and calcium ions. Laboratory analysis quantifies the amount of calcium carbonate present in the soil. Soils in calcareous fens frequently present substantial deposits of almost pure calcium carbonate at or near the soil surface because evapotranspiration is more intense at the soil surface. Such deposits, called "tufa," are frequently observed in areas of maximum groundwater seepage to the soil surface of calcareous fens.

Calcareous fens are dynamic ecologic systems that are subject to growth (peat mound accretion) and vary in the location and intensity of groundwater discharge over time. The authors of this report frequently observed soil layers consisting of virtually pure calcium carbonate within the soil profile in areas of CFC-SFWC. These lenses of carbonate may represent abandoned spring heads and spring runs that historically precipitated calcium carbonate at the surface, but were subsequently abandoned and covered with new peat deposits. Another form of calcium carbonate is called "marl" and is recognized as a soil horizon characteristic of certain shallow lake (limnic) environments. Many soils within and near calcareous fens with a history of post-glacial shallow lake formation contain or are underlain by marl deposits.

3.2.4 Technical Calcareous Fen Criteria: Vegetation

Minnesota DNR staff have developed a regionalized list of vascular plant calciphiles and a statewide list of bryophyte calciphiles indicative of calcareous fens in the state as reported in Leete et al. (2005). With respect to the vegetation criterion, Leete et al, (2005) state:

> "[A]n area meets the calcareous fen vegetative criterion when, under normal circumstances, the area has a natural community index of 50 or more by summing the appropriate regional index values of vascular plant plus the bryophyte calcareous fen indicator species. Where both bryophyte and vascular plant data are available and the sites latitude is greater than 47 degrees, the natural community index must exceed 80. Plot size and shape are dependent upon the professional judgment of field personnel.
>
> Note: if a site has calcareous fen soil, hydrology, and water chemistry but the calciphile point total ranges from 30 to 50, the area will be considered to meet calcareous fen criteria. If a disturbed site has calcareous fen soil, hydrology, and water chemistry but a calciphile point total of less than 30, the disturbed area may have the potential to support a calcareous fen plant community." (P. 31)

Discussion

Many of the plants specific to calcareous fens are state-listed as threatened or endangered because they are rarely found outside of the calcareous fen environment. The specific reason for the adapted nature of calciphiles has not been investigated in detail. However, their specific adaptation to calcareous environments is thought to result from their ability to withstand continuously saturated, nutrient poor, anaerobic environments that other plants cannot tolerate (Bedford and Godwin, 2003: Moorehouse, 2004).

Berglund (1995) indicates that the vegetation of calcareous fens is composed of a number if individual species (the flora) which may be present in the fen for a variety of reasons:

- Those that respond solely to either the hydrological, soil/water chemistry, and/or microhabitat conditions. These plants would tend to be specific, strong indicators of calcareous fens.

- Those that have a broad range of ecological tolerance and are there in spite of the unique attributes of the environment,
- Those that are there by chance, and
- Those that respond to more than one of the above factors.

Statistical methods were used in Berglund (1995) to develop a list of 27 calciphile plants with varying degrees of fidelity to the calcareous fen environment. The list was further subdivided into vascular calciphile indicator classes of “strong” (25 calciphile points), “moderate” (5 calciphile points), and “weak” (1 calciphile point).

Under the Berglund (1995) Technical Vegetation Criteria, an area meets calcareous fen vegetative criteria when, under normal circumstances, either:

1. 50 Percent Cover Method: More than 50 % of the composition of the dominant species from all strata are calciphiles from any of the indicator classes.
2. When the area has a natural community index of 50 or more by summing the index values of the 27 calcareous fen indicator species. Plot size and shape are dependent upon the professional judgment of field personnel. Identification plots may be large (400 square meters or larger) whereas delineation plots or other techniques may be smaller to provide more definite margin boundaries.

Leete et al. (2005) criticized the floristic inventory method provided in Berglund (1995) for a number of reasons, including:

1. Method 1 was semi-quantitative, ambiguous and not clearly defined in the original document, giving rise to a number of interpretations of how to apply the 50% cover method to plots used to characterize the vegetative composition.
2. Method 2 was qualitative more than quantitative, and again did not clearly specify the methods to be used, nor did the text specify how to determine plot size and shape. Presumably it related specifically to the calcareous fen ecotope, which required a determination of the limits of the ecotope prior to the inventory to determine if the ecotope was indeed calcareous fen, a circular argument.
3. In order to adequately characterize the calcareous fen, more than one sampling would be necessary to identify plants that flower and senesce at different times.

Leete et al. (2005) provided new vegetation criteria that were based on Method 2 of Berglund (1995). They based their criteria on a detailed plant community inventory of several known calcareous fens compared to non-fen wetlands. They strengthened the method for determining the vegetation criterion by (1) regionalizing the calciphile indicator status into Northwest, Minnesota Valley, Southeast, and Southwest regions, and (2) including mosses (bryophytes) that appeared to have fidelities to the calcareous fen environment similar to those of the herbaceous calciphile indicators. Because bryophytes are evergreen, their inclusion in the vegetation technical criteria has the added advantage of permitting interim sampling during fall, winter, and spring when herbaceous plants are difficult or impossible to identify.

3.3 Sensitivity of Calcareous Fens to Impacts

Calcareous fens are often found as embedded discharge areas within a larger wetland complex. This is particularly true of calcareous fens that have been identified in the Minnesota River Valley where extensive wetlands are located in backswamp areas distant from the river, and in depressions and abandoned channels within the broad valley floor. Such wetlands contain focused areas of calcareous groundwater discharge originating as recharge in the extensive uplands adjacent to the bluff top. The resulting high hydraulic gradients between bluff top recharge areas and discharge areas on the valley floor produce numerous seepage areas, spring heads and spring runs that are generally associated with areas adjacent to and near the valley bluffs. Groundwater flow to these discharge features can be through calcareous glacial sediments derived from Des Moines Lobe till, as well as underlying calcareous bedrock (Almendinger and Leete, 1998b).

Because of their size and location in and near urbanizing areas, Minnesota Valley wetlands are particularly subject to various disturbances. While the CFC-SFWC are considered to be relatively pristine, the immediate area of the wetland and the adjacent bluffs have been impacted by fragmentation, municipal well withdrawals, bluff top urbanization and stormwater management, ditch and tile drainage, hydrologic alteration and surface water diversions, potential mining of the peat and/or underlying sediments, and limited industrial development. These impacts are discussed in Section 3.4.3 which presents an aerial photo history of the immediate area. The Seminary Fen may, in fact, be maintained in the face of existing and historic disturbance by the sheer size of the wetland complex within which it is embedded, combined with the calcareous nature of the underlying sediments.

3.3.1 Direct and Indirect Impacts to Calcareous Fen Hydrology

Impacts that temporarily or permanently alter the established hydrologic equilibrium between recharge and discharge in the supporting groundwater aquifer can adversely affect fens because the unusual hydrologic stability is altered.

3.3.1.1 Direct and Indirect Water Appropriations

Appropriations from the aquifer feeding the fen can result in a loss of groundwater volume, a reduction in flow rate, and a change in the magnitude of groundwater flow regimes operating at regional, sub-regional, and local scales (Wassen and Barendregt, 1992). The reduction in water inputs correlates to a reduction in storage and/or the amount of water discharging at the fen location, and a potential lowering of watertables associated with the fen combined with a reduction in the extent of the continuously saturated area. Groundwater appropriations could result in long term impacts such as those associated with municipal and local domestic well development (Rural Utilities Service, 1998; Barr Engineering Company, 1994, Schot and Van der Wal, 1992) and temporary impacts from dewatering in support of construction projects that need to rapidly lower local water tables (Almendinger and Leete, 1998a).

An indirect form of groundwater appropriation is urbanization and stormwater management that results in increased runoff and reduced recharge in the developed area, reducing the volume of discharge water available to the fen (Schot and Van der Wal, 1992). Urbanization and residential development in the Rochester, Minnesota area has recently caused concern because of the impact that surface water management has on the aquifers feeding the many fens associated with groundwater discharge from the edge of the Decorah Shale. Several developments in the Rochester Area are now developing Fen Management Plans to accommodate the unique calcareous fen hydrology into their surface and subsurface water management plans.

Some dewatering will likely be necessary to set bridge piers and pier footings during construction of either alternative E-1A or E-2. The effects of the dewatering on adjacent discharge wetlands, including nearby CFC-SFWC would depend upon the depth to which the sediments need to be dewatered, the length of time dewatering is necessary, and the proximity of the area of concern. The creation of time-distance-drawdown graphs associated with dewatering activities can describe the potential impacts associated with dewatering activities under the alternatives, and can predict the potential effects on adjacent sensitive wetland resources that are dependent on groundwater discharge. If either alternative E-1A or E-2 are chosen as the preferred alternative, bridge-pier placement and the associated dewater activities will have to be carefully chosen to avoid or minimize potential impacts to nearby CFC SFWC.

3.3.1.2 Agricultural Drainage

Calcareous fens are frequently associated with productive agricultural land in adjacent areas. Many of these areas have an extensive history of surface ditching and subsurface tiling constructed and installed to render adjacent wetlands agriculturally productive for hayland and cropping. Lowered watertables are the result of increased hydraulic gradients between the water table surface and the water level in the ditch or tile line (Moorhouse, 2004).

Drainage can also be a natural occurrence in calcareous fens (Miner and Ketterling, 2003). Because calcareous fens frequently have positive relief and are characterized by the presence of spring heads and spring runs, down-cutting of spring runs through calcareous fen peat can have a natural effect similar to ditch drainage (Miner and Ketterling, 2003). Vegetation in affected areas frequently includes invasive plants that are tolerant to the lowered watertables adjacent to the down-cutting ditch or natural drainageway. Buckthorn invasion subsequent to natural headward erosion into fen areas was directly observed in one of the most important areas within the SFWC and will be discussed later.

While the immediate area of the Seminary Fen and associated wetlands has been significantly impacted by ditch and tile drainage, no ditch or tile drainage is expected as a result of the construction of any of the TH 41 alternatives. However, the presence of ditch and tile drainage, as well as headward erosion of natural spring runs provides a restoration opportunity for the affected areas.

3.3.1.3 Mining

Calcareous fens are frequently associated with highly conductive aquifers that consist of unconsolidated sand and gravel deposits (Amon et al., 2002). Such deposits are in high demand, especially near urban and developing areas where sand and gravel deposits are at a premium. The mining of these deposits can have a dramatic effect if aquifer recharge/discharge hydrology is affected, either by aquifer truncation or dewatering activities. Mining has been associated with adverse effects on the Ottawa fen in LeSueur County, Minnesota (Lynch and Leete, Undated Fact Sheet) and the Savage Fen in Scott County (Minnesota Department of Natural Resources, 1998).

Cut and fill activities associated with the construction of the TH 41 bridge crossing through the western portions of the SFWC up the coulee to the bluff top can simulate the effects of mining on altering hydrology. Care will need to be taken so that the hydrology of potential aquifers that feed portion of the SFWC is not adversely affected by truncation or disturbance.

3.3.2 Impacts to Soils

Hydrologic alterations that result in water table reductions can alter the surface hydrology of peat soils and influence their chemical and physical characteristics (Almendinger and Leete, 1998a; Parent and Ilnicki, 2002; Moorehouse, 2004). Affected soils can consolidate and increase bulk density through dewatering and increased aerobic decomposition. Dewatering peat soil surfaces can change the structure of surface peat and result in increased levels of aerobic decomposition affecting soil chemistry and nutrient availability to plants.

The structural change is one from a nearly continuously saturated, essentially massive unstructured condition to a more granular peat structure called “Moorsh” peat (Parent and Ilnicki, 2002). Moorsh peat surfaces have higher infiltration rates which can accelerate the leaching process. Persistent watertable declines can change a non-leaching environment to a leaching environment in peat soil surfaces, resulting in a change in soil chemistry. Calcium carbonate can be leached from the soil surface increasing the availability of phosphorus and nitrogen. Increased peat decomposition in the aerated peat surface can also result in the release of these and additional plant nutrients sequestered in the peat, favoring the invasion of plants that are not adapted to the nutrient poor calcareous fen environment. The altered hydrology and surface chemistry in areas hydrologically altered to drier conditions has been shown to result in a persistent change in plant community composition from a low-stature calcareous plant community to one dominated by rank, high stature invasive shrubs and herbaceous vegetation such as buckthorn (*Rhamnus cathartica, R. frangula*), reed canary grass (*Phalaris arundinacea*), and common reed grass (*Phragmites australis*) (Moorehouse, 2004, Eggers 1995, Wisconsin Coastal Management Program, 2005, MnDNR Staff, 1998b).

Direct impacts to the groundwater discharge hydrology associated with the SFWC are expected to be temporary as a result of dewatering necessary for bridge-pier installation. However, impacts to near surface lateral flows through the peat could result from construction pads and associated temporary construction roads. If localized groundwater flows are reduced over a long-term, the associated reduction in water tables could result in impacts to soils producing an environment favorable for invasive plants.

3.3.2.1 Sedimentation

Because of the occurrence of some Minnesota Valley fens near steeply sloping bluff escarpments, erosion of steeply sloping areas has been a natural occurrence in toe-slope positions and in alluvial fans downslope of steeply down-cutting drainageways. However, historic agricultural use, deforestation of steep slopes, and recent urbanization has accelerated erosion. Nearby fens can be adversely affected when sediment covers the affected areas or affects surface runoff patterns (J. Leete, MnDNR Minneapolis, Pers. Comm.)

The routes of both alternative alignments E-1A and E-2 follow a steeply sloping coulee on the north bluff that is actively down-cutting and is characterized by erosive sediments (Figure 2.1). Construction of either alternative creates the potential for eroded sediments to be transported downslope to areas within the SFWC and adjacent to CFC-SFWC Area 2.

3.3.2.2 Erosion and Drainage

Dewatered peat soils are particularly subject to water erosion. In sloping areas where peat soils are dewatered, erosion following intense precipitation events can develop drainageways that can further channel water, resulting in incised drainageways that will further dewater the adjacent peat resulting in alterations to the local hydrology, soil, plant nutrient status, and eventually the vegetation community (Moorehouse, 2004; discussed below in Section 3.3.4). Preferential flow patterns could be introduced into the microtopography that would direct and channel diffuse flows. This could possibly result in erosion of the peat given the positive relief and topographic gradients that characterize the sloping peatlands of the SFWC.

3.3.3 Direct and Indirect Impacts to Groundwater Chemistry

As discussed in Sections 3.3.1 and 3.3.2, alteration to the hydrology and soils in calcareous fens can change the chemistry and hydrology of the peat surface and potentially alter the composition of the adapted plant community (Schot and Van der Wal, 1992; Parent and Ilnicki, 2002). Direct impacts to aquifer chemistry by contamination of the undisturbed aquifer from stormwater and winter salting and deicing of nearby roads mixing with the water of the undisturbed aquifer can also substantially alter the chemistry of aquifer water. Surface water management can introduce chlorides and other nutrients that alter rhizosphere chemistry and can affect calciphile health (Panno et al., 1999; Richburg et al., 2001). The hydrology of the SFWC is dynamic and surface water flow and subsurface groundwater flow may be rapid through conductive unconsolidated glacial aquifers resulting in potential salt contamination of discharge areas distant from the contaminant source.

3.3.4 Direct and Indirect Impacts to Plant Communities

The short stature plant community associated with calcareous fens is generally open to full sun and adapted to distinct groundwater chemistry and hydrology as described above. Anthropogenic alterations to the undisturbed hydrology, soil, and water chemistry characteristics can have a substantial impact on plant communities. Drainage facilitates invasion by plants that would be adapted to drier conditions in the surface peat and even temporary reductions in the surface water table elevation should be avoided. In general, a reduction in watertable persistence and depth releases nutrients and converts “species rich, nutrient poor” fen environments to “species poor and nutrient rich” environments (Bedford and Godwin, 2003; Moorehouse, 2004). Invasion by reed canary grass, giant reed grass, buckthorns, and various dogwoods (*Cornus* spp.) and willows (*Salix* spp.) are particular concerns in Minnesota Valley fens. The invasion of calcareous fens by various shrubs can crowd out shade-intolerant plant species, including the calciphiles that are a defining characteristic of calcareous fens. Historically, fire may have reduced natural invasion by shrubs adapted to wet conditions (Spieles et al., 1999). Drainage and the lack of fire may have accelerated shrub invasion into the western portions of the North Unit SFWC especially.

Reed canary grass is adapted to physically and hydrologically disturbed sites and is a common component of disturbed areas on the Seminary Fen and other calcareous fens in the lower Minnesota Valley (J. Leete, Pers. Comm., field observations). Because reed canary grass is tolerant of freezing temperatures and begins to grow very early in the spring, it can out-compete many other species and commonly forms monotypic stands (Lyons, 1998).

Similarly, common reed is a particular problem for fens in the Minnesota River Valley. The USACE has documented invasion of portions of the Savage Fen in the city of Savage Minnesota by *Phragmites australis* that was initiated by localized disturbance resulting from road construction (Eggers, 1995). Both Phragmites and reed canary grass have been shown to dramatically reduce species diversity in affected fens (Kercher et al., .2004, Wisconsin Coastal Management Program, 2005, Richburg et al., 2001).

Buckthorns are common invaders of drained peatlands. Because of their canopy characteristics, buckthorns can shade out much, if not all of the understory of the plant communities they invade. Both buckthorn species are adapted to calcareous environments, and will invade areas that have been subject to persistent dewatering (Converse, 1984). Invasion by glossy buckthorn (*R. frangula)* especially is fostered by hydrologic manipulation and persistent declines in water table depth in wetlands.

Disturbance from temporary construction road, access points, bridge piers and footings can result in the introduction of invasive plants that can act as a seed source for invasion into sensitive adjacent areas. Temporary or permanent reductions in water tables resulting from bridge construction may also provide conditions favorable to the introduction of invasive species.

3.4 Environmental Setting of the Seminary Fen

3.4.1 Plant Community and Wetland Characteristics

Four Geographic Information System (GIS) resources are available that provide general context information on native plant communities and wetland characteristics.

- The Minnesota Land Cover Classification System (MLCCS) is a cover type mapping system that does not rank communities by quality, but identifies them by their vegetative community/cover type.
- The Minnesota County Biological Survey (MCBS, MnDNR Staff 1998a) similarly identified and mapped plant communities by their vegetative type in the area of the SFWC. The MCBS located higher quality native plant communities using aerial photo interpretation followed by a field survey of selected sites.
- The MCBS also identified natural areas that they inventoried based on their biodiversity significance, focusing on areas with varying levels of native biodiversity that may contain high quality native plant communities, rare plants, rare animals, and/or animal aggregations. A biodiversity significance rank is assigned on the basis of the number of rare species, the quality of the native plant communities, size of the site, and context within the landscape. MCBS Sites that are found to be disturbed are retained in the layer and are given the Biodiversity Significance rank of "Below."

- The National Wetlands Inventory (NWI) is based on aerial photo interpretation and identifies wetlands by their Cowardin (1992) classification that provides information on wetland type, vegetation, hydraulic regime, and disturbance.

3.4.1.1 Minnesota Land Cover Classification and the MCBS Plant Community Inventory

MLCCS and MCBS mapping generally identify the CFC-SFWC as distinct areas (**Figure 3.1**) classified as Calcareous Seepage Fen, Prairie Subtype, Southeast Section (Minnesota Department of Natural Resources Natural Heritage Program Staff, 1993) or the equivalent OPp93: Prairie Extremely Rich Fen, Calcareous Fen, Southeastern Type (Minnesota Department of Natural Resources, 2005).

Both the MLCCS and MCBS polygons identifying CFC-SFWC vary considerably in the aerial extent of the calcareous fen components. The CBS indicates three distinct units, whereas the MLCCS identifies five distinct units (Figure 3.2). For the purposes of the present study, the authors confined a detailed analysis of hydrology, soils, water chemistry, and vegetation to the more extensive MLCCS-identified calcareous fen areas (Figure 3.1).

- Area 1 consists of the MLCCS polygon that lies between the railroad embankment and TH 212.
- Area 2 is the MLCCS polygon that lies to the north of the railroad embankment.
- Areas 3, 4, and 5 lie south of TH 212 and are numbered sequentially from east to west.

The project botanist observed areas outside of the MLCCS-calcareous fen polygons through walkovers to characterize the vegetation and to generally look for calcareous fen outliers. Our field investigations, discussed below, indicate that SFWC CFC Areas 4 and 5 would not meet calcareous fen vegetation criteria and are not calcareous fens. Our Phase 1 analysis assumed that a more detailed analysis of potential CFC-SFWC directly related to alternative alignments E-1A or E-2 would occur under Phase 2.

3.4.1.2 The National Wetlands Inventory

The National Wetlands Inventory (**Figure 3.2**) places the CFC-SFWC into the following Cowardin (1992) classifications:

- Area 1 is identified as a palustrine wetland dominated by persistent herbaceous vegetation with a saturated hydrologic regime and affected by drainage (PEMBd).
- The majority of Area 2 is designated as a palustrine wetland dominated by persistent herbaceous vegetation and woody shrubs (a shrub-carr) with a saturated hydrologic regime and affected by drainage (PEM/SSBd). A very small portion to the south of Area 2 is designated as forested wetland with emergent herbaceous vegetation components that is seasonally flooded and affected by drainage (PFO1/EMCd)
- Most of Area 3 is considered upland. A small portion to the west is considered a palustrine wetland dominated by a seasonally flooded shrub-carr (PEM/SS1C).

- Most of Area 4 is considered a palustrine wetland dominated by a seasonally flooded shrub-carr (PEM/SS1C). A small portion to the west is considered a seasonally flooded forested wetland (PFO1C).
- Area 5 is equally divided between a seasonally flooded forested wetland (PFO1C) and a seasonally flooded emergent marsh dominated by emergent herbaceous vegetation (PEM1C).

The majority of both alternative alignments E-1A and E-2 traverse a shrub-carr affected by drainage (PEM/SS1Bd). Alignment E-1A also traverses a small portion of temporarily flooded palustrine emergent marsh (PEMA) at the wetland's far western reach (Figure 3.2).

3.4.1.3 MCBS Classification of Areas with Outstanding Biodiversity Significance

The MCBS identifies the North Unit SFWC that contains CFC-SFWC as well as the steeply sloping coulee that is planned as the route for both alternative alignments to reach the bluff top as an area of "Outstanding Biodiversity Significance" (**Figure 3.3**). Alignment E-1A traverses the northern edge of the unit, whereas alternative alignment E-2 takes a more direct route through the unit. Fragmentation may be an issue because of the units CBS ranking as an area with outstanding biodiversity significance.

MLCCS and MCBS mapping identify components of calcareous fen south of TH 212 as "High Biodiversity Significance." Both alternative alignments E-1A and E-2 avoid direct impacts to this unit, instead traversing a western unit identified as having low (below ranking) biological diversity (**Figure 3.3**).

3.4.2 Hydrogeologic Setting

Calcareous fens occur where there is an uninterrupted discharge of mineral rich water at the surface that is neither ponded nor flows away, and where surface water inputs (rainfall, runoff) are minor compared to groundwater input (Almendinger and Leete, 1998b). In the Lower Minnesota River Valley, such conditions occur where the surface slopes intersect groundwater bearing layers, or where permeable formations penetrate confining beds overlying aquifers with above surface hydraulic heads.

Geomorphology and bedrock stratigraphy are important components of calcareous fen hydrology. Previous work on the Savage Fen made extensive use of geological cross-sections provided in the Scott County Geologic Atlas to evaluate the hydrogeologic setting of the fen (Barr engineering Company, 1994; MnDNR Staff, 1998b). However, a county geologic atlas is not available for Carver County, Minnesota in the area of the SFWC. Geology and stratigraphy were evaluated by extrapolation from bedrock sections provided in nearby Scott and Hennepin counties (Balaban and Swingen, 1982; Balaban, 1989, respectively), combined with data provided in the County Well Index (CWI; Minnesota Geological Survey, 2004) and the Carver County Water Management Plan (Moline, 2001).

3.4.2.1 Geology and Geomorphology

A topographic map and a shaded relief map for the Seminary fen area are provided in **Figure 3.4**. An interpolated geologic cross section with bedrock information is provided in **Figure 3.5**. These resources are subject to updating when more hydrogeologic information becomes available.

Bedrock Geology

During the Wisconsin glaciation, the Minnesota River Valley was occupied by Glacial River Warren, a major drainageway for Glacial Lake Agassiz. The SFWC has formed on the northern edge of the broad valley of the underfit Minnesota River in an apparent cutbank location created by erosion from Glacial River Warren (Figure 3.4). Vast amounts of Lake Agassiz water flowed through the Minnesota River Valley, resulting in deep incision of the valley into the surrounding calcareous Des Moines lobe till and the underlying bedrock sequences, dominated from top to bottom, by the calcareous Prairie du Chien group, the Jordan Sandstone, the fine grained St. Lawrence formation, and the Franconia formation (Balaban, 1989).

It is likely that the Prairie du Chien group is the first bedrock aquifer that lies under the till that forms the northern bluffs of the Minnesota River valley (Balaban, 1989). However, Glacial River Warren incised itself through the Prairie du Chien and underlying geological formations, leaving these formations exposed as subcrops under the bluffs and Glacial River Warren sediments in the area of the SFWC. The Prairie du Chien formation consists of a sandy calcareous dolomite that is underlain in places by the Jordan Sandstone (Figure 3.5). Both units are unconfined and permeable. The Prairie du Chien and Jordan aquifers are underlain by the St. Lawrence and Franconia formations. The St. Lawrence formation is generally considered an aquitard or confining layers to the underlying permeable Franconia shale unit (MnDNR Staff, 1998b) (Figure 3.5).

The northern and southern units of the SFWC lie at an elevations of approximately 740 to750 fASL and 720 fASL, respectively, based on ground surface elevations collected at well sites presented in this report. Depth to bedrock on the floor of the Minnesota River Valley in the area of the Seminary Fen wetland complex is unknown, but is likely on the order of 50 to well over 150 feet based on similarly situated portions of Minnesota River Valley in western Hennepin county that have depth to bedrock data (Balaban, 1989). An examination of County Well Index records for wells on the bluff near the SFWC indicates that the first bedrock aquifers contacted in wells completed in bedrock on and near the northern bluff is the Prairie du Chien group at elevation of approximately 650 to 700 fASL. Assuming a relatively flat orientation for the Prairie du Chien aquifer, this would put the first bedrock aquifer contact at an elevation below the land surface of either the northern or southern units of the SFWC.

However, bedrock subcrops would be expected near the surface at the foot of the bluff, suggesting that groundwater discharge through the calcareous bedrock aquifer could act as a source for groundwater feeding the fens near the bluff in the North Unit SFWC. Groundwater discharge through the Prairie du Chien and Jordan aquifers was proposed as a source of calcareous discharging groundwater for the Savage Fen (Barr Engineering Company, 1994; MnDNR Staff, 1998b). However, CWI records did not indicate any contact with the Jordan Sandstone aquifer, suggesting that the Jordan aquifer is absent or discontinuous in the immediate area of the SFWC. The CWI data further indicate several wells in the area with the St. Lawrence/Franconia as the first bedrock contacted.

A complicating factor is that the area of the SFWC lies above a deeply incised, relatively narrow pre-glacial bedrock valley where the overlying Prairie du Chien and Jordan sandstone aquifers have been removed, thus a complex sequence of bedrock exposures is possible in the area. The first bedrock under the Des Moines lobe till covering the till plain and the northern bluffs of the Minnesota River could be either the Prairie du Chien/Jordan formations, or possibly the St. Lawrence/Franconia formation. All of the bedrock sequences save the St. Lawrence formation are considered aquifers. The St. Lawrence formation is a fine grained aquitard and confines the underlying Franconia shale that is permeable and may serve as a source of calcareous groundwater.

An assessment of well records within the Minnesota River Valley that are near the SFWC further indicates that sand and gravel deposits cover the floor of the valley to depths greater than 100 feet, consistent with the Hennepin County depth to bedrock data.

Surface Geology and Geomorphology

The areas on the till plain above the northern bluff of the Minnesota River Valley have a rolling topography characterized by numerous wetlands and lakes (Figure 3.4). When connected by drainageways, the drainage is poorly integrated forming classic "deranged" drainage patterns associated with a youthful till landscape. Elevations on the till plain above the SFWC range in elevation from 950 to just under 1000 fASL, providing approximately 300 vertical feet of relief from the elevated position of the till plain to the valley of the Minnesota River (Figure 3.5). Glacial till consists of calcareous Des Moines Lobe till sediments deposited during the Mankato substage of Wisconsin glaciation (Edwards, 1968).

The northern bluff the Minnesota River Valley is similarly composed of calcareous Des Moines lobe till. The bluff is steeply sloping and likely originated as a cut bank of Glacial River Warren. No bedrock outcrops were observed along the bluff, further suggesting that bedrock eroded by Glacial River Warren is till covered and deeper than the elevation of the Minnesota River Valley floor. The toe of the bluff consists of relatively thick deposits of local alluvium and colluvium derived by mass wasting and erosion of the bluffs themselves. Steep coulees are present that dissect the bluffs and lead runoff water through intermittent streams to the valley floor. Extensive alluvial fans associated with upland soils extend from the mouth of the coulees into the North Unit SFWC in several areas. Blanket-type peatland ("peat aprons," Almendinger and Leete 1998a) is located downslope of the alluvial material and slopes gently down to the terrace feature that intervenes between the north and south units of the SFWC. The peatland is generally at an elevation of 750 fASL to the north, and 740 fASL at the south boundary near the terrace feature, providing for surface drainage and diffuse surface flow to the south. The peat is underlain by coarse textured sediments deposited by Glacial River Warren and by fine-textured Holocene sediments likely deposited in a shallow lake environment. Based on data provided in the present report, peat thickness and depth to the underlying lacustrine and sandy outwash sediments is variable in the northern unit of the SFWC.

The SFWC is divided into two units by the intervening terrace feature that forms the southern boundary of the northern unit (Figure 3.4, Figure 3.5). The southern unit extends from the terrace to current floodplain of the Minnesota River. SFWC CFC Areas 1 and 2 are associated with the northern unit and are elevated 15-to-20 feet above Areas 3, 4, and 5 that are located to the south of the terrace unit (Figure 3.5). The current course of Assumption Creek has its headwaters as spring heads and spring runs originating near the bluff toe-slope in the northern unit of the SFWC.

Areas of the current floodplain of the Minnesota River that lie downslope of the terrace feature are dominated by silty Holocene sediment deposited across that active floodplain during flooding events of the Minnesota River.

3.4.2.2 Summary and Implications of Important Hydrogeologic Features

The hydrogeologic setting of the Seminary Fen wetland complex is similar to that described for the Fort Snelling fen in Almendinger and Leete (1998b). Important hydrogeologic characteristics for the formation, maintenance and support of the calcareous fen components of the Seminary Fen wetland complex include the following:

1. Glacial till deposits on the till plain elevated approximately 300 feet above the valley floor consist of calcareous sediments that can act as a source of calcium carbonate for infiltrating rainwater. The presence of numerous undrained wetlands and lakes on the till plain indicates that the water table is high, and would not be isolated from the groundwater system that discharges to the SFWC. Groundwater with a lengthy flow path through the till and intertill lenses of coarser sediments will be saturated with respect to calcium carbonate and will precipitate calcium carbonate when the water is subsequently discharged to wetlands on the valley floor. Recharge occurring in wetland areas will ensure that the percolating groundwater has a high partial pressure of CO_2 and will be able to dissolve considerable quantities of calcium carbonate.

2. Very steep slopes and high relief are associated with the northern bluff of the Minnesota River Valley. The presence of 300 vertical feet of gradient between the till plain and the SFWC itself provides for large hydraulic gradients that produce extensive areas of focused and diffuse groundwater discharge.

3. Glacial till deposits are probably underlain by the calcareous Franconia formation in the buried pre-glacial valley that lies north of the SFWC. The Franconia formation can serve as a source of calcareous groundwater similar to that of unconsolidated calcareous glacial sediments. Because the bedrock aquifers are relatively permeable (MnDNR Staff, 1998b), the high hydraulic gradients produced by recharge in the uplands above the bluff can result in the discharge of substantial amounts of groundwater through the underlying bedrock. Where the depth to the bedrock aquifer subcrop is thin and overlying sediments are permeable, focused discharge can result in calcareous seepage areas and spring heads.

4. The toe of the bluff slope is dominated by alluvial deposits originating as sediments eroded from the bluff. These sediments are relatively coarse textured, are at an elevation of several feet above the wetland itself, and can provide for localized groundwater discharge in areas where these alluvial deposits are recharged by precipitation or by runoff from the steep adjacent slopes.

5. Alluvial fans extending into the Seminary Fen wetland complex are associated with deeply incised, actively eroding coulees. These alluvial fans can extend from the mouth of the coulees well into the wetlands occupying the valley floor. The alluvial fans receive large amounts of surface water from the coulees during rain events. This water rapidly infiltrates the soil and can similarly act as a potential discharge water source for the wetlands that are downgradient.

6. A coarse-textured terrace deposit of unknown origin lies between the northernmost and southernmost CFC-SFWC. Because the northernmost unit is elevated approximately 10 to 15 feet above the southern unit (Figure 3.5), surface water from the northern unit can recharge the groundwater under the terrace, which can subsequently discharge to the southern unit. Because the recharging

groundwater from the northern unit is calcareous, the areas south of the terrace receiving discharge are likely to be calcareous as well.

3.4.2.3 Soils

Upland and wetland soils associated with the area of the SFWC are grouped by their geomorphic setting and provided in **Figure 3.6**.

Soils of the Bluff Top

Soils on the bluff top consist of the well-drained Lester (fine-loamy, mixed, superactive mesic Mollic Hapludalfs), Kilkenny (fine, smectitic mesic Oxyaquic Vertic Hapludalfs), and Rasset (coarse-loamy, mixed, superactive mesic Typic Argiudolls) soil series that formed in calcareous Des Moines lobe till and local outwash deposited during the Wisconsin glaciation. Interspersed within the upland soils are the poorly and very poorly drained Glencoe (fine loamy, mixed, superactive, mesic Cumulic Endoaquolls), Hamel (fine-loamy, mixed, superactive mesic Typic Argiaquolls), and Klossner (loamy, mixed, euic Terric Haolosaprists) series that developed in locally deposited alluvium over till in wetlands. These wetland soils can provide focused areas of groundwater recharge that maintain elevated watertables in the area of the wetlands represented by these soils and ensure the presence of groundwater high in CO_2 content that can "aggressively" dissolve calcium carbonate. Recharge can also occur in the upland soils as well, but to lesser degrees. It is probable that the local watertables on the top of the bluffs that are away from the bluff edge are maintained at or at most several feet below the elevations of the bluff top itself providing large hydraulic gradients between the recharge areas and the discharge areas on the valley floor (Figure 3.5).

Bluff Soils

Soils on the bluff itself similarly consist of the Lester, Kilkenny, and Rasset soil series in steep slope classes (e.g. 18-40%). In these slope classes the soils are eroded easily and provide large quantities of calcareous slope-wash alluvium and colluvium to the toe-slope positions at the base of the bluff.

Soils at the Base of the Bluffs

Soils at the base of the bluff consist primarily of the Terril (fine loamy, mixed, superactive, mesic Cumulic Hapludolls) and Minneiska (coarse loamy, mixed, superactive (calcareous), mesic Mollic Udifluvents) series that formed in the alluvial and colluvial sediments eroded from the bluff and associated, deeply dissected coulees. These soils tend to be coarser textured as a result of their being deposited by moving water, and form alluvial fans at the mouth of the coulees, and narrow alluvial terraces at the base of the bluff. In locations where the alluvial soils are elevated above the wetlands and peatlands downslope, it is likely that runoff from the bluffs and the associated coulees will infiltrate these soils, producing a groundwater mound that will result in localized groundwater discharge to the wetland soils that are downslope.

Soils within the SFWC and CFC-SFWC

Soils within the SFWC itself including all of the calcareous fen components (Areas 1-5, Figure 3.6) are mapped into the very poorly drained Blue Earth (fine-silty, mixed, superactive, calcareous mesic Mollic Fluvaquents) soil series that formed in calcareous coprogenous earth in postglacial lakes and floodplains.

The presence of Blue Earth soils as the dominant map unit strongly suggests that the SFWC and the included calcareous fen components may have formed in a shallow, post-glacial lake that would be characterized by large inflows of calcareous groundwater. Precipitation of calcium carbonate in this shallow lake setting produced limnic sediment known as "marl" which consists of varying amounts of organic sediments mixed in with precipitated calcium carbonate (Schnurrenberger et al., 2003). Marl deposits typically form in shallow lakes dominated by calcareous groundwater inflows and with short residence times (McDonough, 2001; Drummond et al., 1995).

At some point after glaciation, the lake levels declined, resulting in the formation of organic peat of varying thickness over marly limnic material and the underlying coarse-textured outwash sediments. In low areas of the original mineral surface, the peat is thick to the underlying sediment. In higher areas within the abandoned lake, the peat thickness can be thin to the underlying sediments. Marl formation may also occur outside of the lacustrine environment and is associated with complex, dynamic depositional environments in calcareous fens that are characterized by recessions and transgressions of peat aprons growing and being eroded over long periods of time (Miner and Kettering, 2003). Both terrestrial and limnic marl formation processes are likely in some areas of the CFC-SFWC. In any event, the widespread presence of underlying, calcareous marly sediments virtually ensures that the organic histosols that form will be dominantly calcareous in nature.

Two other peat soils were observed within the SFWC and its calcareous fen components that depend upon the thickness of the peat and the texture and nature of the underlying sediments. Muskego soils (coprogenous, euic, mesic Limnic Haplosaprists) are similar to the Blue Earth soils but have a thicker peat surface. Houghton soils (euic, mesic Typic Haplosaprists) are entirely peat to depths greater than 51 inches. All of the peat soils present within the SFWC are near neutral in pH and can have varying amounts of free calcium carbonate within the soil profile.

Most of the soils described in the CFC-SFWC do not fall into the soil series that are recognized in Carver County. Two new, tentative soil series are recognized that are specific to a calcareous fen environment. These soils are the Edwards and Edselton soil series (both soils are classified as marly, euic, mesic Limnic Haplosaprists). The Edselton soil series consists of peat over marl over sandy sediment, whereas the Edwards soil series consists of peat over marl to 5-feet. Most of the soil examined in the CFC-SFWC would be mapped into the Edwards soil series.

Terrace Soils

The sandy terrace feature that intervenes between the north and south units of the SFWC is dominated by sandy and loamy soils that formed in sandy glacial outwash sediments. Based on the landscape position and the observation of extensive areas of groundwater discharge on the southern edge of the terrace, it is probable that the coarse-textured sediments are not underlain by finer textured material. The terrace apparently provides for relatively unimpeded groundwater flow through its length in the area of the SFWC.

Terrace sols consist primarily of the following soil series: Estherville (sandy, mixed, mesic Typic Hapludolls), Hawick (sandy, mixed, mesic Entic Hapludolls), Minneiska (coarse-loamy, mixed (calcareous), mesic Mollic Udifluvents), and Sparta (sandy, mixed, mesic Entic Hapludolls).

Floodplain soils

Floodplain soils lay downslope of the CFC-SFWC and are periodically inundated by floodwaters of the Minnesota River. These soils tend to be poorly developed as a result of the regular deposition of sediment in the floodwater. While peat soils may be present in some locations, the majority of the soils are dominated by mineral material originating as floodwater-deposited alluvium. Periodically flooded soils generally do not support calcareous fens because of the periodic disturbance, sediment burial, and the introduction of high levels of nutrients in the floodwaters limits the plant community to those that are adapted to high levels of nutrients and periodic disturbance (Bedford and Godwin, 2003;

The dominant soils on the active floodplain of the Minnesota River consist of the following soil series: Chaska (fine-loamy, mixed (calcareous), mesic Aeric Fluvaquents), Kalmarville (coarse-loamy, mixed, nonacid, mesic Mollic Fluvaquents), Minneiska (coarse-loamy, mixed (calcareous), mesic Mollic Udifluvents), and Oshawa (fine-loamy, mixed (calcareous) mesic Fluvaquentic Endoaquolls). The majority of the soils are calcareous, reflecting both the calcareous nature of the floodwater sediments, and the lack of a leaching regime that would remove the calcium carbonate.

3.4.3 Land Use History

The SFWC is a large, diverse wetland located in an area with an extensive history of anthropogenic disturbance that can be assessed through an analysis of historic aerial photography that dates back to 1937. Major land use impacts to the SFWC that predate 1937 include the construction of the railroad grade that resulted in hydrologic diversions that impacted CFC-SFWC Areas 1 and 2, and the construction of TH 212 that likely had impacts to both surface water drainage and subsurface groundwater flow from the North Unit SFWC to the South Unit that lies south of existing TH 212. Based on the air photo history, agricultural use and selected drainage attempts in CFC-SFWC Areas 1 and 2 also predate the 1937 aerial photo. The following discussion addresses the land use history of the SFWC and the embedded calcareous fen components sequentially by year and by the specific CFC.

3.4.3.1 CFC Area 1

The dominant impacts evident in the air photo history (**Figure 3.7**) include railroad grade and access road construction, peat/substrate mining, and surface and subsurface drainage.

Railroad Grade

The railroad embankment is a dominant topographic feature with approximately 25 to 30 feet of relief above the wetland to the south. The grade widens at the base, which likely consists of ballast rock to surcharge and compact underlying soils and to provide a base on which to construct the grade itself. The railroad grade may have hydrologically isolated CFC Area 1 from Area 2, and has diverted surface flows along the northern edge to the southwest along the northern edge of the grade. It is likely that surface flows were from northwest to southeast prior to railroad construction. During fieldwork several spring heads were observed at the base of the grade in the northeast portion of Area 1 especially; however, the impact of the railroad grade on groundwater flow is unknown. Given the proximity of the northern boundary of CFC Area 1 to the railroad grade, it is likely that substantial areas of historic fen were filled during railroad construction. The railroad grade has partially fragmented CFC Area 1 from CFC Area 2. The only surface water connection consists of a culvert passing under the railroad embankment southwest of CFC Area 2.

Access Road

An access road likely used during railroad construction parallels the railroad embankment to the south. The northwestern edge of Area 1 closely follows the grade and the access road. The access road was apparently active during 1937, but was subsequently abandoned or only received limited use. The scars for the access road are evident in all photo years. Drier conditions on the raised bed of the access road have resulted in substantial shrub invasion.

Peat and/or Substrate Mining

The Assumption Seminary Complex of buildings is evident in all photo years, as is extensive disturbance north and west of the complex. Active peat and/or substrate mining is evident in the 1937 photo and continues to 1963. Stripping of peat is particularly evident in the 1957 photo. Similarly, the spoil storage area progressively expands in size to 1963. The spoil storage area is currently abandoned and is dominated by cattails. Spoil windrows were observed in the area during 2005 fieldwork.

An area of probable excavation is evident east of the spoil storage area in the 1957 photo. This are is currently dominated by reed canary and common reed grass and has numerous seepage areas, spring heads and spring runs.

Drainage

Surface drainage and subsurface tiling of a significant peat mound that was historically a high quality calcareous fen is evident in all photo years, but is most obvious in the 1951 and 1957 photos (Figure 3.8). The reason for the tiling effort is unknown, but it may have been performed to facilitate peat mining of the area or to provide a water source to the sanatorium that predated the Seminary. Tile discharge outlets were observed on the eastern flank of the peat mound during fieldwork. Pieces of broken tile were also observed in the spring run to the west of the extensively tiled area. Close inspection of the aerial photos shows the tile scars in the same location from 1951 to 2003. The persistence of the tiling scars is likely the result of localized drainage affecting the adjacent plant community that would favor invasive and native plants that are adapted to drier conditions near the tile. The tile system is currently abandoned and is likely broken in several places. However, the peat mound that was drained was historic calcareous fen that is now experiencing invasion by dogwoods, glossy buckthorn, reed canary and common reed grass. This area presents an excellent opportunity for restoration.

3.4.3.2 CFC Area 2

The dominant impacts evident in the air photo history (**Figure 3.8**) include railroad grade construction and surface and subsurface drainage. Anthropogenic impacts are discussed for the entire portion of the

SFWC that extends from CFC Area 2 west to Audubon Road. Alternative TH 41 alignments E-1A and E-2 traverse the western portion of the North Unit SFWC, but avoid direct impacts to CFC Area 2 itself.

Railroad Grade

The most significant impact to CFC Area 2 is the construction of the railroad grade that has resulted in the diversion of surface flows to the southwest. The general topographic slope directing surface flows is to the south and east. The construction of the railroad grade has resulted in the accumulated surface flow being directed to the southwest following a ditch that parallels the railroad grade. Field observations of surface ponding and wet conditions to the east of CFC Area 2 suggest that the grade is acting as a dam maintaining elevated water tables in the portions of the North Unit of the SFWC that are north of the railroad grade. Periodic flooding after significant rainfall events may be adversely affecting historic calcareous fen components that may have existed prior to the construction of the railroad grade.

Drainage

Evenly spaced linear features suggest that subsurface tiling was attempted within and to the immediate west of CFC Area 2. These scars are evident in all photo years save 1990, and likely reflect different plant communities in the immediate area of the draintile. The tiling system is currently abandoned and may represent a restoration opportunity for CFC Area 2 and non-calcareous fen wetland to the west of CFC Area 2.

Surface ditch drainage is not evident in photos from 1937 through 1957. However, the 1990 photo indicates extensive surface drainage attempts in the southwestern portion of the north unit SFWC (Figure 3.8). Remnant ditches and drain tile scars are evident in the 2003 photo.

Drainage and the absence of fire may have resulted in a plant community change from seepage wet-meadow to a shrub-carr. The 1937 and 1940 photos indicate that the area had an open character. Shrubs appear to be invading in the 1951 and 1957 photos. The area north and west of CFC Area 2 is an apparent shrub-carr in the 1990 and 2003 photos. The presence of extensive shrub-carr would adversely affect the short stature calciphile plant community by shading out these shade-intolerant species.

Urbanization and Infrastructure

Residential development of the bluff top started prior to 1990 where ongoing construction is evident in the historic agricultural field to the northwest. The bluff-top area is completely developed in the 2003 photo.

The area north and west of the TH 212 curve seen in the lower center of all photos was in agricultural use from 1937 through 1990. The 2003 aerial shows the construction of Audubon Road, CSAH 10, and the diversion of Chaska Creek.

3.4.3.3 CFC Areas 3, 4, and 5

The dominant impacts to CFC Areas 3, 4, and 5 consist primarily of the construction of TH 212 that predates the 1937 photo (**Figure 3.9**). The grading for TH 212 forms the northern boundary of CFC Areas 3 and 4. Few additional anthropogenic alterations are evident in any of the aerial photos. The most important changes include a progressive increase in woody vegetation that is occurring in upland areas adjacent to the designated calcareous fen units. A radio tower facility was constructed in Area 3 sometime between 1990 and 2003. Areas that were in agricultural use in 1937 are still in agricultural use in 2003. All of the CFC-SFWC Areas 4 and 5, and a substantial portion of Area 3 lie within the floodplain of the Minnesota River.

3.4.4 Important Natural and Man Made Hydrographic Features of the SFWC

Natural and man-made hydrographic features were assessed through an interpretation of historic aerial photos along with geomorphic evidence and field observations (**Figure 3.10**).

CFC Area 1

The northern part of CFC Area 1 that is adjacent to and south of the railroad grade presents the strongest evidence of spring head and spring run hydrology observed by the authors within the entire north unit SFWC. Five spring heads and associated spring runs originate at or near the toeslope of the railroad grade (Figure 3.10). Spring runs coalesce to form a perennial stream that is actively down-cutting just south and east of the calcareous fen unit. The northern part of CFC Area 1 also presents the best expression of calcareous fen physical and floristic characteristics, including the presence of a diverse community of calciphiles, extensive deposits of calcium carbonate both within the soil profiles and as tufa deposits at the surface, calcareous peat, and high upward groundwater flow gradients (discussed below).

Tiling in a large raised peat dome in the central portion of Area 1 (Figure 3.10) was observed in the field as tile discharge and broken tile pieces in the ditched area to the west of the main tiled area. The reason for the tiling is not clear; however, the tile scars are evident in the same locations in most of the historic aerial photos examined.

CFC Area 2 and the Western Portion of the North Unit of the SFWC North of the Railroad Grade

Regularly-spaced linear features within and just to the west of CFC Area 2 suggest historic tiling. These linear features appear in most of the historic aerial photographs (Figure 3.8). Extensive, relatively recent surface ditching in the southwest portion of the SFWC North Unit north of TH 212 and east of Audubon Road was observed in historic aerial photographs (Figure 3.8).

Spring head and spring runs were also observed in the northwestern portion of the SFWC east of Audubon Road and south of the trail that follows the northwestern portion of the bluff. Historic agricultural areas just to the north of the western portion of the SFWC North Unit have been fully converted to residential use (Figure 3.10).

The most important hydrologic feature affecting CFC Area 2 is the diversion created by the construction of the railroad grade. Spring run and diffuse surface flows that presumably were directed from the northwest to the southeast now flow into the drainage ditch that parallels the railroad grade. The drainage ditch now directs the flow to the southwest to a culvert under the railroad grade that is located just south of the western portion of CFC Area 2 (Figure 3.10).

CFC Areas 3, 4, and 5

Extensive groundwater discharge was observed as spring heads and spring runs associated with the South Unit of the SFWC south of the terrace in and near CFC-SFWC Areas 3, 4, and 5 (Figure 3.10). Most of Areas 3, 4, and 5 lie within the 100-year floodplain of the Minnesota River. It is thought that calcareous fens cannot be supported in areas that periodically flood as the sediments bury the fen vegetation with nutrient rich material that encourages the persistence of invasive species that are adapted to high nutrient levels and periodic disturbance.

Potential Aquifer Recharge Areas and Working Hydrologic Model

Several bluff top wetlands exist north of the SFWC at elevations approximately 200 to 300 feet higher than the North Unit SFWC that could provide the hydraulic gradient driving groundwater discharge to the areas on the valley floor that are adjacent to the bluff (Figure 3.10). Discharge can be through quaternary sediments (e.g. sand stringers in the till) and/or discharge from bedrock subcrops near the bottom of the bluff.

CFC Areas 3, 4, and 5 in the South Unit of the SFWC are approximately 15-to-20 feet lower in elevation than the southern portions of the North Unit of the SFWC. The presence of extensive spring heads and spring runs associated with the toeslope positions of the terrace suggest that the source of the discharging groundwater originates as recharge from losing reaches of the portion of Assumption Creek that flows on the terrace and groundwater recharge occurring at the northern edge of the terrace feature. The location and elevation of the discharge areas suggests a complex hydrology where groundwater discharges at and near the bottom of the bluff, becomes channeled surface flow in spring runs, diffuse surface flows and subsurface throughflow across and within the sloping peat aprons in the North Unit SFWC, recharges the groundwater system underlying the coarse textured terrace feature, and then discharges again as spring heads and spring runs in the Southern Unit of the SFWC.

4 Methodology

4.1 Assumptions and Limitations

The Phase 1 assessment of the SFWC was performed to better characterize the hydrology, soils, flora, and geochemistry of the areas identified by MLCCS mapping as calcareous fens. The size of the wetland complex within which these units are embedded precludes a detailed investigation of the entire wetland system. However, the wetland system was placed into a geologic and hydrologic context in preparation for succeeding work under a more detailed Phase 2 analysis of potential impacts of alternative alignments E-1A and E-2.

4.2 General Approach

A GIS was developed to facilitate the placement of the SFWC into a hydrogeologic and land use context and to prepare report figures and graphics. Layers included soil, geology, topography (digital elevation model or DEM), hydrography, various plant community and wetland classifications, accurately georeferenced historic air photos, and other important physical and cultural features (e.g. minor watershed boundaries, parcel boundaries, public land survey sections, roads, municipal boundaries, CWI well locations, etc.). All sampling points (e.g. soil, surface and groundwater, plant transects, well nests) were located using a GPS (Global Positioning System) unit capable of sub-meter accuracy and placed into the project GIS. Additional layers were created by digitizing information present on accurately registered photo basemaps.

The characterization of the areas identified under MLCCS mapping as calcareous fens (CFC-SFWC Areas 1 – 5) follows the current criteria provided in Leete et al. (2005).

4.3 Hydrologic Assessments: Monitoring Wells and Field Observations

4.3.1 Monitoring Well Construction and Installation

The calcareous fen hydrology criterion was assessed by installing a water table well and a corresponding piezometer at representative locations in CFC Areas 1, 2, and 3 according to the methods described in Leete et al. (2005). All well construction materials were purchased from the Gooden Company (285 Como Avenue, St. Paul Minnesota 55103).

Water table wells were constructed of 2-inch Schedule 40 PVC materials consisting of an end cap, a 10-slot well screen extending from the soil surface to a depth of 2-to-4 feet depending upon the expected variation in the depth to the water table, and a 2-foot riser. PVC risers, well screens and end caps were glued together to form the well assembly. The screened interval was wrapped with permeable geotextile to minimize sedimentation in the well assembly after installation. Water table wells were installed in under-fit auger holes to a 4-foot depth from the surface. A 2-inch locking cap (Torquer^{tm}) was used to seal the top opening of the well and as a hanger for the Solinst^{tm} leveloggers used to determine water table fluctuations.

Piezometers consisted of an 18-inch length of 1.25-inch, flush threaded; Johnson wound, stainless steel drive point that was screened across 12 inches of its length. Well casings for the piezometers consisted of 4-foot lengths of flush-threaded Schedule 80 PVC. Piezometers were installed by driving the piezometer assembly into the ground using 4-foot lengths of 1-inch pipe as the drive shaft placed against the drive plate in the well screen, and a fence post driver to drive the assembly into the ground. A 12-inch galvanized pipe spacer was used to place the drive-pipe consistently above the flush threaded casing. As the well assembly was driven into the ground, 4-foot lengths of casing and pipe were successively threaded together and driven into the ground to continue the installation. The piezometers were installed to sand-contact refusal, and would be considered “sub-peat” piezometers that would reflect the hydraulic head at the peat/sand contact. When the piezometers were installed to depth, the excess riser was sawed off at approximately 4 to 5 feet from the ground surface.

Water table wells and piezometers installed for the project and monitored for water chemistry are subject to Minnesota Department of Health (MDH) monitoring well construction and installation regulations. Monitoring wells installed in sensitive calcareous fens require MDH variances to minimize disturbance to the fen plant community and chemical contamination introduced by MDH grout-sealing requirements (Leete et al., 2005). Variances for the water table wells and piezometers were granted by the MDH. Well installation was overseen by a licensed well contractor as well as a MDH representative. Each well and piezometer that was to be monitored for water chemistry was provided a unique well number by the MDH. Well installation logs were kept and were provided to the MDH. Once installed, wells and piezometers were completed by bailing or pumping to dryness or until the water removed was clear.

Data collected from each well included the well depth, substrate type, the depth to the screened interval, and the riser height above the ground. The elevation to the top of the casing and the ground surface was surveyed in by the SRF Consulting group.

4.3.2 Determination of Water Table Fluctuations and Hydraulic Gradients

Water table fluctuation and elevations in wells and piezometers were determined using Solinst^tm^ leveloggers (Solinst^tm^ Canada Ltd., 35 Todd Rd., Georgetown, Ontario, Canada L7G 4R8). Solinst leveloggers consist of a pressure transducer in a rugged stainless steel enclosure that registers the height of the water column above the pressure transducer. Solinst leveloggers were attached to a galvanized chain of known standard length and were subsequently hung from the Torquer^tm^ caps at the top of the well casing. Water levels in the well were converted to elevations in feet above mean sea level (fASL) using the known elevation of the top of the riser casing, the known elevation of the pressure transducer, and the length of the water column above the transducer. Water levels were recorded four times daily, and were averaged on a daily basis for report presentation.

4.4 Ground and Surface Water Sampling and Laboratory Analysis

The calcareous fen water chemistry criterion was evaluated at all MDH-listed well locations and at selected surface water sampling locations in and near CFC Areas 1-5 according to methods recommended in Leete et al. (2005). On the afternoon prior to the sampling event, all wells and piezometers were bailed or pumped to dryness and were left to refill and equilibrate overnight. Water sampling was performed on the day following the bailing. In-situ determination of pH, temperature, electrical conductivity (EC), and dissolved oxygen (DO) was performed using a peristaltic pump directing water through a flow-through cell with the applicable electrodes inserted into the cell. Measurements were collected using a Hach™ sensION 156 portable pH/conductivity/dissolved oxygen meter and the appropriate electrodes. Once pH, EC, and DO were determined, samples were collected in clean polyurethane sample containers that were iced in a cooler for transport to the lab. Samples were filtered through a 0.45 micron syringe filter for the determination of alkalinity by titration (Hach alkalinity test kit with digital titrator, model AL-DT). Alkalinity determinations were run within 24 hours of sample collection. Subsequent to the determination of alkalinity, filtered subsamples were acidified to a pH of around 4.5 with a few drops of concentrated nitric acid, placed into clean polyurethane bottles, and were sent to the geochemistry laboratory at the University of Minnesota (contact Dr. Emi Ito) for subsequent analysis of remaining cations and anions.

An additional subsample was sent to the isotope laboratory at the University of Arizona (contact Dr. Chris Estoe) for the determination of heavy oxygen ($d^{18}O$) and hydrogen (deuterium d^2H) isotopes.

4.5 Peat Depth Characteristics

Peat depth and substrate characteristics were determined for SFWC CFC Areas 1, 2, and 3. Peat depth characteristics for CFC Areas 4 and 5 were not determined due to safety considerations as the area was dissected with spring heads and spring runs that were difficult to cross, and also contained several unstable floating vegetation mats that would not support a person's weight. Areas 4 and 5 were also characterized by extremely dense vegetation that precluded a rapid assessment of peat depth and substrate characteristics.

Peat depths were determined using a standard ½--inch tile probe with 4-foot sections that could be extended to 12 feet. A grid of sampling points was developed in the GIS and was downloaded to a GPS unit capable of sub-meter accuracy. GPS waypoint methods were used to navigate to the specified sampling locations. The peat probe was pushed into the soil to a depth of 12 feet or to contact with the underlying sediments. The nature of the underlying substrate was recorded as sand or clay. If no underlying substrate was contacted, the sampling point was identified as peat to 12 feet. Substrate depth and nature were recorded in the GPS unit as attribute data associated with each sampling location. All spatial and attribute data were uploaded to a computer and were developed as a layer in the project GIS.

4.6 Soil Sampling, Description and Analysis

Calcareous fen soil criteria were assessed by describing and sampling sixteen soil profiles to a depth of 48 inches at representative locations within each CFC-SFWC area. Eight profiles were examined in CFC Area 1, four were examined in Area 2, and two profiles each were examined in Areas 3, 4, and 5. Soil description and sampling was performed using a Russian Peat Sampler ("Flag Sampler," Wildco Company) developed specifically to take undisturbed cores in soft peat and lacustrine material. High-resolution digital photographs were taken of each profile to document soil profile horizons. Each soil was described using standard NRCS soil description methods and horizon nomenclature (Soil Survey Staff, 2003). Each core was subsampled in 1-inch (2.5 cm) increments to 40 inches. Each 1-inch increment subsample was placed in 4-ounce Whirlpack™ plastic bag for subsequent determination of organic matter, mineral, and calcium carbonate content at the St. Croix Watershed Research Station, Science Museum of Minnesota using standard loss on ignition methods (Heiri et al., 2001; Contact Dr. James Almendinger).

4.7 Floristic Assessment: Walkovers and Quantitative Transect Sampling

Plant species composition of the SFWC was documented qualitatively and quantitatively. Walkover surveys were conducted periodically throughout the 2005 growing season, recording all vascular plant species observed within subsections of each area. Transects were established throughout the study area. Along each transect small plots were used to estimate vascular plant coverage, and bryophytes were sampled.

Based on dominant species, ecotopes were designated within each area. Ecotopes are defined as landscape units of relatively uniform ecological characteristics including environmental conditions and vegetation (Klijn and Udo De Haes, 1994 and Zonneveld, 1989). Ecotopes were defined using walkovers, GPS documentation, false color infrared and true color aerial photography, and data from quantitative sampling. Ecotope designation was an iterative process, being refined with each visit to the SFWC and after data analysis. The first characterization of ecotopes took place in May and June 2005. Additional walkovers and sampling took place in August and September 2005, after which ecotope designations were finalized.

After preliminary ecotope designations were made, locations of transects were defined at random within ecotopes. Initial sampling points were assigned by creating points within each ecotope using ArcMap GIS. Sampling points were subsequently located and staked in the field using a Leica GS5 GPS unit with sub-meter accuracy. With two exceptions, transects were oriented north-south, with the origins at the south ends. The other two transects were oriented east-west, with the origins at the west ends. The predefined point was used as the origin for each transect. Near Areas 1 and 3, a few transects were placed outside of the original MLCCS calcareous fen boundaries where walkover surveys revealed areas of groundwater discharge and the presence of at least one calciphile (typically *Cardamine bulbosa*)

Transects were 5 m long, following the methods of Janssens (2004) for vascular plant and bryophyte collection. Herbaceous plants were sampled in five plots placed along each transects. To minimize uncertainty and subjectivity in visual estimation of cover, plots were 25 cm x 25 cm. Although large plots are often used in DNR vegetation relevés, plot size of vegetation studies varies according the objectives of the study (Mueller-Dombois and Ellenberg, 1974; Kent and Coker, 1992). In this case, it was desirable to have reliable quantitative estimates of individual species abundance, so small plots were employed. Walkover surveys of undefined ecotope size were used to generate comprehensive species lists in the vicinity of each transect. Plots were spaced 1 m apart along the right side of the transect (i.e., west or north sides, for north-south or east-west transects, respectively) beginning at 1 m and ending at 5 m. Within each plot, every species was identified and absolute cover was estimated using a modified version of the Braun-Blanquet cover class scale (**Table 1**; Kent and Coker, 1992).

Plot sampling occurred in mid-June and early-September. During the June sampling, many species were not identifiable, particularly summer grasses and forbs that had no fruiting bodies, though their presence and cover were noted. Where possible, small representative samples were collected for later identification. During the September sampling, many spring species were no longer found (e.g., *Hypoxis hirsuta* and *Senecio pseudaureus*). Other species, particularly sedges in the genus *Carex*, were not identifiable without fruiting bodies. It was generally possible to recognize sedges only to genus in September. Because definitive species-level identifications were rarely possible in September, cover of sedges was typically not recorded during the last sampling period.

As indicated above, transect locations were assigned in the office using GIS, and when these points were located in the field, some were found to be unsuitable because of disturbance, access constraints, or redundant sampling in ecotopes. Transect 2 was found to be dominated by reed canary grass and was only sampled in September. Walkover surveys indicated that additional areas of calcareous fen were present outside of the original MLCCS polygons in Area 2. Two transects were added in these areas in September (transects 43 and 44). These late transects were not sampled for bryophyte composition. Transects were numbered sequentially. However, because some transects were excluded, the numbering is discontinuous. In particular, transects 3, 11, and 35 were excluded. A total of 41 transects were sampled.

In addition to plot sampling, a list of all identifiable vascular plant species was made in each ecotope in which transects were located. This list was compiled during both walkover and plot sampling periods in May, June, August and September. For individual plots along transects and within the general vicinity of the transect, the cumulative value of calciphile species was calculated using both 1995 and 2005 calciphile indicator species lists (**Table 2**; Berglund 1995; Leete et al. 2005).

Special interest was paid during botanical surveys to note the nature of disturbance to native plant communities and to document the presence and abundance of rare and protected plant species. The unusual environmental conditions and patchy distribution of calcareous fens result in the presence of many rare plant species in fens. Several protected plant species are known from the SFWC from a 1995 visit by the MnDNR (**Table 3**).

Bryophyte sampling was conducted in accordance with Janssens (2004). Along each transect, ten sample points were defined prior to sampling using a random number table, ranging from 0 to 500. The random number determined the distance (in cm) along the transect from which bryophytes were sampled. A long, straight wire was used to locate the sample point on the ground below the tape measure stretched along the transect. Bryophytes at each sample point were collected, placed in brown paper bags and dried for several days in front of a fan at room temperature (Janssens 2004). Samples were then provided to Jan Janssens of Lambda-Max Ecological Research for identification. Calciphile indicator point values for bryophyte species are given in Leete et al. (2005).

Shrub cover was measured along each transect sampled in June using the line-intercept method (Mueller-Dombois and Ellenberg, 1974). Many transects lacked shrub cover, but because shrub cover has increased over historic levels (as indicated by aerial photography), cover was quantified by species along each transect. The linear distance each shrub species intersected the transect was recorded and converted to percent cover through division by the total length of the transect (500 cm). The relative coverage was determined by adding the cover of each species on all transects and then calculating the proportion of the total represented by individual species.

For statistical analyses of vegetation data, species importance values were calculated for use in multi-variate ordination. Analyses were conducted using PC-ORD v. 4.25 (McCune and Mefford 1999). Ordination is a form of multi-variate statistical analysis. For ordination of Seminary Fen transect data, Non-metric Multidimensional Scaling (NMS) was used because it is appropriate for data that are not normally distributed (McCune and Grace 2002). The Sorensen (Bray-Curtis) measure of ecological distance was used in the NMS ordination. Results are presented graphically, plotting transect locations in two-dimensional space similar to Principal Components Analysis (PCA).

Data from coverage and frequency of occurrence were combined to create a species importance value on each transect. Cover classes (1-6) were converted to class mid-point percentages for each species in each plot on each transect. The average cover for each species was calculated for each transect (including zero cover in plots where a species was lacking). Percent cover was converted to a proportion, ranging from 0.0 to 1.0. To calculate frequency of occurrence, the number of plots a species occurred in on each transect was divided by the total number of plots (five per transect). The frequency was also expressed as a proportion. Cover and frequency were given equal weight in calculation of the species importance values. The cover and frequency proportions for each species on each transect were added, and divided by 2, yielding an importance value that ranged from 0.0 to 1.0.

The ordination results were plotted on a two-dimensional graph in a manner similar to Principle Components Analysis (PCA). Values were derived from the first two axes produced by the ordination analysis. Higher dimensions were not graphed. The location of individual transects on this graph reflects a summary of the importance values of the plant species in the plots along that transect. The closer two transects are in ordination space, the more similar they are in overall composition of the plant communities.

5 Results and Discussion

Calcareous fens are protected not because they have unique groundwater hydrology, water chemistry, and soils, but because these characteristics combine to form an environment favorable for state-listed, rare adapted plants. The results sections presented below are organized to provide a firm theoretical base on which to discuss the distribution and nature of the calcareous fen plant communities associated with the CFC-SFWC. Geohydrologic characteristics of recharge areas, flow path, and the flow matrix result in a specific water chemistry type. Discharge hydrology produces a specific, groundwater-saturated hydrologic regime that results in the formation of histosols and soils with histic epipedons that are associated with calcareous fens. The combination of hydrology, groundwater chemistry, and soils provides the environment that fosters the development of a calciphilic plant community that would meet the calcareous fen criteria provided in Leete et al. (2005). Thus we present our results in sequence: hydrology, water chemistry, soils, and finally vegetation characteristics.

5.1 Hydrologic Assessment

The geohydrologic setting of the SFWC favors groundwater discharge throughout the entire wetland system. Topographic relief is significant, and hydraulic gradients between the uplands north of the bluff and the SFWC itself are 250 to 300 feet or more (Figure 3.5). The bluffs and uplands to the north of the SFWC are; (1) composed of calcareous, unconsolidated glacial sediments through which infiltrating water can percolate, (2) have poorly integrated drainage and numerous wetland systems that can act as areas of focused recharge, and (3) are underlain by calcareous, permeable bedrock aquifers (Section 3.4.2). Groundwater flow paths through the sediments and underlying bedrock can be long and result in mineral dissolution, especially soluble calcium carbonate, as the groundwater travels from points of recharge to points of discharge.

Our basic working hypothesis of groundwater hydrology in the SFWC is that groundwater recharge occurs in the uplands above the bluffs. The large topographic gradient drives water flow from the uplands and underlying bedrock to be discharged to the broad valley floor of the Minnesota River. Because gradients are greatest at the toe of the bluff slope, groundwater discharge will be focused at the toe-of-slope positions, resulting in numerous spring heads and spring runs that coalesce and flow down gradient to an eventual confluence with the Minnesota River. Because of the calcareous nature of the glacial sediment and underlying bedrock, the discharging groundwater will be saturated with calcium carbonate.

Our hydrologic assessment is based on (1) observations of site geomorphology discussed in Section 3.4.2, (2) topography within the SFWC itself, (3) peat and substrate depth and type, and (4) quantitative observation of water levels in nested piezometers (sub peat wells) and water table wells. Our observations emphasize areas of the best expression of calcareous fen characteristics and focus on locations that would provide the best hydrologic information necessary to evaluate the effects of the construction of the TH 41 alignment alternatives E-1A and E-2 on the CFC-SFWC, and refines the general working model of hydrology described in Section 3.4.4.

5.1.1 Locations of Well Nests

Well nests were installed at two locations in the eastern portion of CFC Area 1, at two locations near the western portion of CFC Area 2, in CFC Area 3, and within Assumption Creek (**Figure 5.1**). The presence of numerous spring heads and spring runs indicated the presence of groundwater discharge that would satisfy the calcareous fen requirement in CFC Areas 4 and 5. Because of the lack of a diagnostic calcareous fen plant community combined with their location within the 100-year flood plain of the Minnesota River (Figure 4.1) well nests were not installed in CFC Areas 4 and 5. Hydrology in these areas was evaluated by observations of spring head, spring run, and topographic characteristics. The SFWC is large and has complex groundwater and surface water hydrology and stratigraphy. Budget and time constraints precluded the installation of additional wells under the Phase 1 effort.

5.1.2 CFC Area 1

Well nests were established in the two portions of CFC Area 1 that present the best expression of calcareous fen characteristics. Well Nest 1A consisted of (1) a sub-peat piezometer (1PZA1) screened between 737.5 and 738.5 fASL at the peat/sand contact, and (2) a water table well (1WTA1) screened to the surface at 755.1 fASL (Figure 5.1, **Figure 5.2**). Depth to sand at the Well Nest 1A location was 18 feet.

Well Nest 1B consisted of a sub-peat piezometer (1PZB1) screened between 726.4 and 727.4 fASL at the peat/sand contact and a water table well (1WTA1) screened to the surface at 743.6 fASL (Figure 5.1, **Figure 5.3**). Depth to sand at the Well Nest 1B location was 17 feet.

5.1.2.1 Well Nest 1A: Unique Calcareous Fen Site Adjacent to Railroad Embankment

Well Nest 1A was developed on a sloping peatland adjacent to and south of the railroad embankment (Figure 5.1). It is likely that a portion of the historic fen was filled during the construction of the embankment pad. However, the fill does not appear to have impeded groundwater flow under the railroad embankment as numerous spring heads are located at the toe-of-slope of the fill pad. The ground surface for this portion of CFC Area 1 is at 755.1 fASL, making it one of the topographically highest areas of those examined within the CFC-SFWC.

Field Observations

Diffuse surface flows were observed across the soil surface of the entire area of sloping peatland represented by Well Nest 1A. The immediate area is characterized by numerous spring heads that are generally located at or near the toe of the railroad embankment fill (Figure 5.1; **Figure 5.4**, Part A). Spring runs issuing from the spring heads coalesce into an unnamed perennial creek that flows south and east to a confluence with Assumption Creek (Figure 5.1; Figure 5.4, Part B). Because of high positive relief in the area that grades to the south, the main spring run has rapid flow and is actively down-cutting through calcareous peat sediments and the underlying substrate. Ongoing head-ward erosion into the sloping peat land was observed, resulting in partial to effective drainage of the affected areas east and south of the short stature plant community that is dominated by calciphiles. It is likely that the area affected by spring-run down-cutting and headward erosion was historically calcareous fen. However, buckthorns were observed invading the areas adjacent to the spring run that are actively experiencing down cutting (Figure 5.4, Part C). The established buckthorn is shading out herbaceous growth in the entire understory. The portion of the unit represented by Well Nest 1A that is unaffected by down cutting and headward erosion has the best expression of calcareous fen features of any of the CFC-SFWC that we have examined. We believe the active down cutting of the main spring run has the potential to degrade this high quality calcareous fen further as headward erosion proceeds into the main portion of the sloping fen.

Well Hydrographs

The hydrographs for CFC Well Nest 1A present the strongest upward hydraulic gradients observed across all well nests, and satisfy the hydrology criteria specified in Leete et al. (2005). Water levels in the piezometer are just over 4-feet above the ground surface, indicating very strong groundwater discharge (Figure 5.2). The presence of diffuse groundwater discharge across the entire sloping peatland results in continuous saturation to the surface reflected in constant, invariant water table levels at the soil surface in the water table well hydrograph. The presence of a continuously saturated soil surface precludes the invasion of plants adapted to varying water tables and favors the native calciphile plant community in all locations save those affected by headward erosion of the main spring run.

August through September were extremely wet, with two precipitation events greater than 4 inches, and five events of approximately 1-inch each interspersed between the heavy rains (Figure 5.2). In spite of the extremely high rainfall, the piezometer water levels are very stable, indicating that recharge for the area represented by Well Nest 1A is similarly stable and is likely distant from the well nest location. The gradual and progressive increase in water levels of approximately 0.1-foot in the piezometer represents a lag in the hydraulic head that further suggests that recharge may be occurring in areas quite distant from the Well Nest 1A location and may occur over a broad area.

The unusually high hydraulic gradients exhibited by the hydrographs for Well Nest 1A when compared to the other well nests installed in other CFC areas, combined with the observation that this area presents the strongest expression of calcareous fen vegetation and soil features (discussed below) suggests that the sloping fen area represented by Well Nest 1A is unique amongst the CFC-SFWC that were examined under Phase 1. We believe that it is likely that the groundwater discharge for this area is different from that in other CFC areas examined, and may reflect discharge through the underlying bedrock, likely the Franconia shale, that is recharged over a broad, upland area to the north of the bluff ridge.

5.1.2.2 Well Nest 1B: Isolated Mound Feature as Hydrologically Disturbed Historic Calcareous Fen

Well Nest 1B was developed at the apex of the significant peat mound just to the south of the sloping fen area represented by Well Nest 1A (Figure 5.1). Peat mounds typically reflect intense groundwater discharge and form by the process of paludification (peat accretion) where localized groundwater discharge provides a continuously saturated environment favorable for peat formation, yet is not intense enough to erode through the accreting peat sediments. Peat mounds are frequently associated with calcareous fens (Almendinger and Leete, 1998a). Peat accretion creates its own unique hydrologic regime that can “swamp” adjacent land, resulting in increased water tables above those that existed before the peat began to accumulate. The peat mound represented by Well Nest 1B is elevated approximately 10 feet above the surrounding wetland, but the apex is approximately 12 feet lower than the soil surface at Well

Nest 1A. The apex of the peat mound is not saturated to the soil surface. However, diffuse seepage, spring heads, and tile discharge was observed that radiate in all directions down-slope across the flanks of the mound.

Field Observations

The peat mound has been extensively disturbed by historic tiling efforts described in Section 3.4.3.1. The reason for the historic tiling effort is unknown. However, the land use history presented in Section 3.4.3.1 and the tile scars indicated in Figure 3.7 (see also Figure 3.10) suggest that tiling was extensive.

The peat mound represented by Well Nest 1B has been degraded by drainage attempts and is in the process of being invaded by shrubs, including buckthorn, red-osier dogwood (*Cornus racemosa*), various willows, and various invasive forbs (e.g. reed canary and common reed grass). No spring heads or spring runs were observed on the top of the peat mound. However, a significant spring run/ditch was observed to the west of the mound that receives diffuse seepage and tile discharge (**Figure 5.5,** Parts A-C). Diffuse seepage across the soil surface as well as tile discharge was observed on the north, east, and west flanks of the peat mound. Diffuse seepage from the mound flows north and joins a spring run at the base of the sloping peatland represented by Well Nest 1A. This surface flow joins the main spring run that is down-cutting and eroding into the high-quality sloping peatland by Well Nest 1A.

Well Hydrographs

The well hydrographs provided in Figure 5.3 indicate a strong upward hydraulic gradient that would satisfy the calcareous fen hydrology criterion specified in Leete et al. (2005). The hydrographs indicate a hydraulic head in the piezometer approximately 2-feet higher that that of the water table well. However, both piezometer and water table well hydrographs indicate a close response to individual precipitation events that suggest that the recharge area for the portion of CFC Area 1 represented by Well Nest 1B may either (1) be close to the Well Nest 1B location, or (2) exhibit a close hydrologic connection with the water table of the peat mound itself. Both wells mirror precipitation events, with water level increases closely following significant precipitation events. Declines in the water levels are observed in the intervals between precipitation events. However, the variations noted on the 1PZB1 piezometer hydrograph are dampened when compared to the water levels in the water table well hydrograph. The hydrographs for 1PZA1 with 1PZB1 present quite different traces, and may reflect a different water source for the groundwater discharge observed at Well Nest 1B when compared to that at Well Nest 1A. This difference is supported by the water chemistry and isotope data discussed below.

It is instructive to compare the 1WTB1 water table hydrograph with that of 1WTA1. As indicted previously, the hydrograph for 1WT1A presents very stable water levels and indicates that a water table is maintained at the soil surface, whereas the 1WTB1 hydrograph (1) shows rapid increases and declines of approximately 0.5-foot in response to precipitation events, and (2) presents a water table that is maintained approximately 0.5-foot below the soil surface. It is likely that these features are the result of an active drain tile system that rapidly removes water from the top 0.5 feet of the entire peat mound, resulting in an environment that is favorable for invasive plant species that are adapted to lower water tables that fluctuate in response to precipitation. These observations are supported by the soil and vegetation data discussed below.

In spite of the disturbance, some calciphiles, most notably *Carex prairia* and *Carex sterilis,* are maintaining a limited presence in portions of the plant community on the peat dome. Re-establishment of the historic hydrology by breaking the tile and more intensively managing the plant community (e.g. by fire) presents a restoration opportunity for the peat dome plant community represented by Well Nest 1B.

5.1.3 CFC Area 2

Well nests were established in the two portions of CFC Area 2 that present the best expression of calcareous fen characteristics in this area. Well Nest 2A consisted of (1) a subpeat piezometer (2PZA1) screened between 733.6 and 734.6 fASL at the peat/sand contact, and (2) a water table well (1WTA1) screened to the surface at 746.1 fASL (Figure 5.1, **Figure 5.6**). Depth to sand at the Well Nest 1A location was 14 feet. Well Nest 2B consisted of (1) a piezometer (2PZB1) screened between 737.8 and 738.8 fASL, and (2) a water table well (2WTB1) screened to the surface at 754.4 fASL (Figure 5.1, **Figure 5.7**). Depth to sand at the Well Nest 1B location was greater than 20 feet, thus the piezometer was screened entirely in peat or underlying lacustrine material. There are approximately 8 feet of downslope topographic relief between Well Nests 2B and 2A.

<u>**Field Observations**</u>

SFWC CFC 2 represents a gently sloping peatland with an 8 to 10-foot topographic gradient from the north to the south. Peat domes and areas of strong spring-head discharge were not observed, though several areas of "quaking ground" characterized by isolated occurrences of the calciphiles *Parnassia glauca* and *Lobelia Kalmii* indicated diffuse discharge of calcareous groundwater through the peat and underlying sediment. Diffuse surface flows as well as several spring heads originating to the east of CFC Area 2 flow south to meet the ditch on the north side of the railroad embankment (**Figure 5.8**, Part A). This perennial drainageway flows south and west until it reaches a confluence with a western tributary that originates as toe-of-slope spring head discharge in the northwestern part of the north unit of the SFWC (Figure 5.1). The combined flow is then directed through a culvert underneath the railroad embankment just south of the western portion of CFC Area 2 where it becomes Assumption Creek (Figure 5.1).

A northern extension to the original MLCCS mapping of CFC Area 2 was added based on (1) the presence of several high point calciphiles (*Parnassia glauca* and *Lobelia kalmii*), (2) weakly calcareous peat soils, and (3) upward groundwater flow as indicated in Well Nest 2B (see Figure 5.8, part B). The hydrology of this area is represented by the hydrograph traces in Well Nest 2B.

The northern part of the SFWC north of CFC Area 2 contains two large alluvial fans that receive sediment eroded from bluff coulees (Figure 5.8, parts B and C). These alluvial fans are elevated well above the surrounding wetland, are relatively coarse textured, and receive substantial amounts of floodwater during significant rain events. The portion of CFC Area 2 that was added to the original mapping lies between these two of these alluvial fans (Figure 5.8, Part B). Floodwater infiltrating into these fans could act as a significant recharge site for the area that was added to CFC Area 2, as well as portions of CFC Area 2 that lie to the south. Intermittent drainages observed to be flowing through the coulees infiltrate the alluvial pads and were observed to dry up after significant precipitation events.

Well Hydrographs

The well hydrograph for Well Nest 2A presents a consistent upward hydrologic gradient that would satisfy the hydrologic criterion in Leete et al. (2005). Well Nest 2A was installed during the beginning of August and includes several significant rain events (Figure 5.6). While the piezometer 2PZA1 water level remains a relatively constant 1-foot above the water level in the paired water table well (2WTA1) both hydrographs rise and fall similarly in response to individual precipitation events, suggesting that the recharge area is relatively close, with water levels in the recharge area responding rapidly to precipitation events. It may be that the recharge area for the portion of CFC Area 2 represented by Well Nest 2A is the alluvial fans located at the foot of the bluff to the north. However, it is also possible that the recharge area is the full reach of sloping peatland at higher elevations to the north of the Well Nest 2A location. In this case the hydrographs would reflect throughflow as the water in the entire wetland system moves down gradient to the south.

The well hydrograph for Well Nest 2B also presents upward hydrologic gradients that would satisfy the hydrologic criterion in Leete et al. (2005). However, this well nest was installed late (9/27/05) in response to field observations of the presence of calciphiles outside of the designated CFC Area 2, and thus has a limited data set. Upward gradients, while present, are small at approximately 0.5 foot (Figure 5.7). The hydrograph for the piezometer (2PZB1) may also be dampened by the fact that the screened interval is not close to sand and may be in fine-textured lacustrine material. A slow hydrologic response for piezometer 2PZB1 is also suggested by the slow rate of recovery exhibited by the well hydrograph when the well was completed and when sampled (Figure 5.7).

5.1.4 Assumption Creek Piezometer Nest and the Terrace Feature

As discussed in Section 3.4.2.1, a coarse-textured upland terrace feature (Figure 3.6, **Figure 5.9**) lies between CFC Areas 1 and 2 (north unit SFWC), and CFC Areas 3, 4, and 5 (south unit SFWC). This terrace feature may be one of the most important hydrologic components linking the north and south units of the SFWC. Field observations indicate that the tributaries of Assumption Creek that lie north of the railroad embankment are perennial streams originating as spring head/spring run systems that have been diverted from their natural course across the north unit of the SFWC by the railroad embankment. These tributaries join to become Assumption Creek and pass under the railroad embankment through a culvert just south of CFC Area 2 (Figure 5.1). Assumption Creek then flows southeast, takes a right angle turn and then flows east across the mid-line of the terrace. The course of Assumption Creek across the terrace midline may or may not be natural. It may represent a diversion that is contemporaneous with the construction of the railroad grade that resulted in extensive hydrologic alteration to surface flows within the entire SFWC.

However, we observed that the Assumption Creek tributaries north of the railroad embankment were perennial, whereas the reach flowing along the western portion of the terrace was intermittent. Assumption Creek again becomes a perennial gaining stream where it breaks out of the eastern portion of the terrace and remains a perennial stream to its confluence with the Minnesota River. Apparently Assumption Creek has very complex relationships to the groundwater system and is a perennial, gaining stream in its upper reaches, becomes an intermittent, losing stream in the middle reach that includes the western portion of the terrace, and then becomes a gaining, perennial stream in the eastern reach upstream of TH 212 (**Figure 5.10,** Parts A-C).

5.1.4.1 Assumption Creek Piezometer Nest and Field Observation of Gaining and Losing Stream Hydrology

In order to investigate the nature of Assumption Creek in the middle, losing reach that traverses the western portion of the terrace, a piezometer nest was established in an apparent losing area in the middle of the terrace (AC_piez1 and AC_Stage1, Figure 5.1). Hydrographs and well construction and location data are presented in **Figure 5.11**. The substrate underlying the fine-textured streambed silt in the area of the Assumption Creek well nest consisted of coarse textured sands and gravels that refused penetration of the driven well and piezometer past 2 to 3 feet from the streambed surface. In spite of the very short difference between the piezometer screened interval (730 to 731 fASL) and the ground streambed surface at 733 fASL, approximately 1.5 feet of downward hydraulic gradient is indicated, suggesting that Assumption Creek in the reach represented by the well nest is a losing stream that is recharging the water table.

5.1.4.2 Implications for Groundwater Movement between the North and South Components of the SFWC.

Numerous spring head and spring run features are observed south of the terrace feature and existing TH 212 that include SFWC CFC Areas 3, 4, and 5 (Figure 5.1). The presence of the terrace feature and the losing nature of the western reaches of Assumption Creek that flows across the terrace suggest that the source of the water discharging to the spring heads and spring runs south of TH 212 is (1) Assumption Creek itself when it is actively flowing across the terrace after precipitation events, and (2) groundwater recharge that is occurring along the contact between the north unit of the SFWC and the terrace itself. Our data and field observations suggest that the terrace feature itself is the recharge area for the CFC that are south of TH 212. This model is graphically presented in the hydrogeologic cross section in Figure 5.5.

5.1.5 CFC Area 3

Well nests were established in the middle portion of CFC Area 3. However, CFC Area 3 does not present a strong expression of calcareous fen characteristics and is disturbed by construction and maintenance of a radio tower facility. The lower portion CFC Area 3 is within the 100-year floodplain of the Minnesota River. Well Nest 3A consisted of (1) a sub-peat piezometer (3PZA1) screened between 707.4 and 708.4 fASL at the peat/sand contact, and (2) a water table well (3WTA1) screened to the surface at 719.5 fASL (Figure 5.1, **Figure 5.12**). Depth to sand at the Well Nest 3A location was 11 feet. There is approximately 20 to 30 feet of topographic relief between the north and south units of the SFWC which provides a substantial positive hydraulic gradient that could drive groundwater movement under the terrace. Under this model, the southern edge of the north unit SFWC would act as a recharge area for the southern unit of the SFWC that includes CFC Areas 3, 4, and 5.

Field Observations

SFWC CFC Area 3 represents a relatively small, strongly sloping peatland with a 5- to 10-foot downhill topographic gradient from the north to the south (**Figure 5.13**, Part A). Peat domes and areas of strong spring-head groundwater discharge were not observed, though one area of “quaking ground” indicated localized groundwater discharge. Vegetation generally consisted of tall stature forbs and grasses, and much of the area is experiencing invasion by common reed grass (Figure 5.13 Part B).

The southern portion of Area 3 lies within the 100-year floodplain of the Minnesota River and can be expected to experience periodic flooding. The utility hut for the radio tower is sandbagged suggesting concerns for flood damage to the facility (Figure 5.13 Part C).

Well Hydrographs

The well hydrograph for Well Nest 3A present a consistent upward hydrologic gradient that would satisfy the hydrologic criterion in Leete et al. (2005). However, the upward hydrologic gradient is small and on the order of 1.0 foot (Figure 5.12).

Well Nest 3A was installed during the beginning of August. The hydrograph includes several significant rain events (Figure 5.12). While the water level in piezometer 3PZA1 remains relatively constant at 1-foot above the water level in the paired water table well (3WTA1), the traces of both hydrographs are similar when the water table is below the soil surface. After the heavy rains in the beginning of September, the water table rose and was maintained at the surface throughout the remainder of the monitoring period. Piezometer levels rose approximately 0.5 foot after the 5-inch rain in early September, and again after the 4.5-inch rain in early October. The gradual decline in the water level in piezometer 3PZA1 during the dry period following the early October rain event suggests that the recharge area for CFC Area 3 is relatively close to Well Nest 3A, and is likely Assumption Creek and the portion of the terrace feature in contact with the north unit SFWC. The relatively rapid increase and decline in the piezometer water levels would represent the growth and dissipation of a groundwater mound associated with the terrace feature as groundwater recharge during the rain events is gradually discharged to the spring-heads and seepage areas south of TH 212. This is in direct contrast to the piezometer response in CFC Area 1, Well Nest 1A (1PZA1) that showed a gradual increase in water levels during the dry period.

5.1.6 Surface Water and Groundwater Discharge Observations: CFC Areas 4 and 5

SFWC CFC Areas 4 and 5 did not have wells and piezometers installed during the 2005 field season. Walkovers of the area indicated a lack of calciphiles that would meet the calcareous fen vegetation criteria, and sufficient evidence of groundwater discharge was observed as spring heads, spring runs, quaking ground, and diffuse seepage to ensure that the calcareous fen hydrology criterion of upward water flow would be met, thus well installation would not provide meaningful data. In addition, Areas 4 and 5 are well within the 100-year floodplain of the Minnesota River (Figure 5.1). Initial soil sampling indicated the presence of sediment layers resulting from periodic flooding from the Minnesota River.

The calcareous fen characteristics in Areas 4 and 5 were discussed with the Technical Support Group. Given a limited amount of well monitoring equipment, it was decided to not instrument these areas with well nests, but to evaluate the soil and vegetation and assume that the hydrology criterion would be met. However, we have documented several important spring-head and spring run characteristics in CFC Areas 4 and 5 (**Figure 5.14** and **Figure 5.15**, respectively).

Both CFC Areas 4 and 5 are located just south of the losing reach of Assumption Creek on the south side of the terrace feature (Figure 5.1). The majority of the water volume discharging to CFC Areas 4 and 5 is believed to originate as groundwater recharge at the contact between the north unit of the SFWC and the terrace, from the losing reach of Assumption Creek.

5.1.7 Summary: Theoretical Model of Groundwater Flow

Quantitative hydrologic modeling of groundwater flow in the area of the SFWC will be a component of the Phase 2 investigation and will refine further the general observations and hydrograph interpretations presented in the Phase 1 characterization. However, our field observations and well-nest hydrograph interpretations can be used to provide a general working hypothesis of groundwater flow in and around the SFWC that explains many of the important hydrologic features of the area (**Figure 5.16**). This model is a simplified combination of surface and subsurface flows, and should not be used for any site-specific interpretations. In particular the reader should be aware that groundwater flow occurs in three dimensions, and that much of the flow in the SFWC can be expected to have significant lateral (groundwater throughflow) and upward (groundwater discharge) components. Salient features of our model of groundwater flow in the SFWC include the following:

1. Groundwater recharge occurs on bluff-top wetlands and uplands north of the bluff escarpment. Head gradients are large and can drive downward groundwater movement through unconsolidated glacial sediment as well as the underlying bedrock. Recharge could also occur in distant areas to the north o the SFWC. The SFWC lies at the mouth of a buried pre-glacial bedrock valley that extends north under both lakes Waconia and Minnetonka. Exact groundwater recharge areas and locations are not known at this time.

2. Groundwater discharge is primarily associated with spring heads and diffuse seepage areas at toe-of-slope positions at the base of the bluff and associated alluvial fans. The presence of the majority of the spring heads and seepage areas at toe-of-slope position is the result of high hydraulic gradients at these locations. Hydraulic gradients would decrease further south into the relatively flat sloping peatland of the north unit SFWC.

3. Localized areas of discharge are also associated with areas further from the base of the bluff that are shallow to sand or that do not contain fine textured substrates. The sandy substrate under the peat likely has undulating relief. It is also possible that fine-textured lacustrine sediments have filled in lower areas in the sandy outwash. Peat in the area of the SFWC varies in thickness and substrate type. Seepage areas are more likely where peat is thin and fine-textured substrates are absent.

4. Groundwater throughflow dominates in the middle portions of the SFWC that are sloping peatlands with a gradient to the south. However, at any given point weak upward gradients are also observed. Groundwater flow occurs in three dimensions. In sloping peatlands with topographic gradients to the south, both lateral (throughflow) and upward (discharge) components to the flow directions would be observed.

5. Groundwater recharge likely occurs at the northern edge of the terrace feature and in losing reaches of Assumption Creek. Assumption Creek has very complex hydrology and has been substantially affected by historic diversions and channelization. In its current configuration, Assumption Creek headwaters lie within the north unit of the SFWC, with two main tributaries originating to the west and to the east of CFC Area 2, respectively. North of the railroad embankment the tributaries were observed to be perennial throughout the field season. However, once the tributaries join and flow

under the railroad embankment, the stream becomes intermittent and loses water to the groundwater system. We believe that most of the water recharged on and flowing through the terrace feature resurfaces as groundwater seeps and spring heads at the toe-of-slope positions at the terraces southern edge, including CFC Areas 3, 4, and 5.

5.2 Water Chemistry Assessment

The hydrogeologic setting of the SFWC suggests that virtually all groundwater should be saturated with calcium carbonate and would likely meet the chemistry criterion for calcareous fens as specified in Leete et al. (2005) (see also Section 3.2.2, above). It was also expected that if surface water in spring heads and spring runs that originate within the SFWC was dominated by groundwater discharge, surface water would meet the calcareous fen chemical criteria as well. Our reasoning for this hypothesis is that groundwater discharge to the SFWC is the result of groundwater recharge in areas distant from the SFWC and is characterized by long flow paths through calcareous sediments. Potential recharge areas would include wetland areas on the bluff top above the SFWC, groundwater recharge through uplands to the north of the bluff, and groundwater flow through calcareous underlying bedrock. It is possible that groundwater recharge for the aquifers discharging to the SFWC could be several miles distant and would flow through the large, buried pre-glacial bedrock valley that has its terminus in the area of the SFWC (Moline, 2001). This bedrock valley extends to the north and is present under both Lakes Waconia and Minnetonka, and is likely filled with stratified, calcareous glacial sediments.

Because virtually all of the potential groundwater flow sediments are calcareous, recharging groundwater would rapidly dissolve calcium carbonate to equilibrium, and would maintain this equilibrium along the full extent of the flow path to the point of groundwater discharge. Biological activity in soils and wetland sediments is high, thus recharging groundwater would become enriched in carbon dioxide (CO_2) resulting in “aggressive” water that would dissolve large amounts of calcium carbonate. When the calcite-saturated groundwater discharges to the soil surface in the SFWC, it would rapidly warm, and outgas CO_2 to atmospheric levels. The result would be disequilibrium in water chemistry that would result in super-saturation with respect to calcium carbonate. Calcium carbonate would precipitate in the surface and near surface environment until a new equilibrium would be reached. Plant transpiration in the rhizosphere also removes pure water, and can also result in calcite precipitation within the root zone.

Groundwater and surface water was collected at representative locations in observed spring heads and spring runs including several locations along Assumption Creek. Surface water samples were collected in all CFC-SFWC areas, as well as all water table wells and piezometers monitoring wells that were registered with the Minnesota Department of Health (MDH). Surface water sampling locations as well as piezometer and water table well locations that had water sampling and analysis performed are provided in Figure 5.1. Surface water samples were also collected at three wetlands on the top of the bluff above the SFWC to investigate the chemical nature of these potential recharge areas.

In addition to analysis of major ion chemistry, heavy isotopes of oxygen (^{18}O) and hydrogen (deuterium, ^{2}H) were determined to evaluate potential groundwater recharge sources and to discriminate between areas within the SFWC that were receiving groundwater discharge from different aquifer recharge areas. Heavy isotopes of oxygen and hydrogen are concentrated by evapotranspiration as the lighter molecules of water containing ^{16}O and ^{1}H are preferentially evaporated, leaving molecules containing the heavier isotopes to accumulate in the remaining liquid water. Once this water enters the groundwater flow system the ratios of light to heavy isotopes remain relatively constant. Isotopic concentrations of heavy oxygen and hydrogen are compared to standard mean ocean sea water (SMOW) and are conventionally expressed as per mil ($^{0}/_{00}$) deviation from the SMOW ratios. Water samples that are enriched in the heavy oxygen and hydrogen isotopes indicate that they have experienced more intense evaporation than those that contain less of the heavy isotopes (Kendall and McDonnell, 1998; Harris et al., 1999, Komor 1998).

5.2.1 General Observations and Chemical Characteristics of Surface Water and Groundwater

Several methods are available to summarize the major ion chemistry of surface water and groundwater. A Durov diagram (**Figure 5.17**) presents the analytical results of the major ion chemistry plotted along ternary diagrams representing the major cations (Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+}) and the major anions (Alkalinity as HCO_3^- and CO_3^{2-}, SO_4^{2-}, and Cl^-) as calculated by the geochemical modeling program AqQA[tm] (Rockware Inc., Golden Colorado). The units used to plot the diagrams are milliequivalents per liter (meq/L). The major cations and anions indicated above compromise the majority of the ions in natural waters, and when considered on a meq/L basis, the sum of the cations and anions will equal each other (Hem, 1989). The Durov diagram graphically presents a summary of virtually all of the calcareous fen chemical criteria listed in Leete et al. (2005). It provides calcium and magnesium as a percentage of cations, alkalinity as a percentage of anions, and includes a graphical representation of total dissolved solids (TDS) and pH.

Analytical values for the major ion chemistry of all water samples collected during 2005 are presented in **Table 4**. Samples that meet the calcareous fen chemical criteria are shaded in the table. Geochemical modeling of major ion chemistry is based on chemical activities and can provide an estimate of water saturation with respect to solid phase calcite. The resulting value is called a “Saturation Index” or SI. Water samples that have negative calcium carbonate (calcite) SI values are under-saturated with calcite and are capable of dissolving more calcium carbonate. Water samples with positive calcite SI values are saturated or supersaturated and will not dissolve calcite further or will actively precipitate solid calcite. Virtually all of the groundwater and surface waters collected within the SFWC have positive calcite SI values indicating that they have dissolved calcite to saturation and are capable of actively precipitating the mineral. The only exceptions are the surface water collected from two of the bluff top ponds (surface water samples BPSW1 and BPSW3). The water in these ponds likely originated as run-on, is relatively fresh, and will dissolve calcium carbonate as the water infiltrates the pond sediment and flows through the calcareous till substrate.

Our hypothesis of general calcareous groundwater discharge to the entire SFWC is confirmed by the chemical analyses presented in Figure 5.16 and Table 4. Virtually all surface water and groundwater samples satisfy the calcareous fen chemical criteria specified in Leete et al. (2005), and all of the SFWC water samples are saturated with respect to solid calcite. All samples are calcium-magnesium-bicarbonate dominated waters with neutral to alkaline pH values that are uniformly above pH 6.7. Total dissolved solids content is high ranging from 200 to 1200 mg/L, with the majority of the samples ranging from 500 to 1000 mg/L (Figure 5.16).

Leete et al. (2005) specify that the field-determined electrical conductivity (EC) of water samples in calcareous fens should be above 500 uS/m. The only samples below this EC level were the samples collected from the bluff-top wetlands and samples collected from the 2B1 well nest (Table 4). Low electrical conductivity is expected in the bluff top wetlands that are expected to be components of potential aquifer recharge that are high in the groundwater flow system. These wetlands would be dominated by precipitation and runoff and are unlikely to have a significant groundwater component that would be high in dissolved solids. The low values associated with Well Nest 2B are unexpected in that the major ion chemistry is not substantially different from other similar samples that had higher electrical conductivity (Table 4). The low EC values observed from Well Nest 2B may reflect an error in field measurement. Additional sampling would be necessary to confirm the low observed EC values in Well Nest 2B.

Leete et al. further specify that pH should be above 6.7 and that Ca and alkalinity values should be above 30 mg/L and 1.65 meq/L, respectively. All of the surface water, groundwater samples, and bluff top wetland water samples meet these criteria save one bluff top wetland (BPSW1) that had a Ca value of 24 mg/L (Table 4). These data suggest that the entire SFWC is a groundwater-discharge dominated, carbonated wetland system that would meet the chemical criteria for calcareous fens throughout the wetland system. The fact that all of the surface water samples meet the calcareous fen criteria is a further indication that the spring heads and spring runs located within the SFWC are primarily receiving groundwater discharge with little dilution from precipitation or off-site run-on.

Specific chemical characteristics associated with water from each of the CFC SFWS are provided in **Figure 5.18** and Table 4 and are discussed below.

5.2.2 CFC Area 1

Water sampling in Area 1 was conducted at Well Nest 1A (1PZA1 and 1WTA1) that represents the high-quality sloping calcareous fen just to the south of the railroad embankment, and at Well Nest 1B (1PZB1 and 1WTB1) that represents the large, historically-drained peat mound to the south of Well Nest 1A (Figure 5.1). Surface water samples were collected at spring heads within the high-quality calcareous fen (1SW1 through 1SW4) and from the spring run located just to the west of the large peat mound represented by Well Nest 1B (1SW5). Water was also collected from Assumption Creek where it flows under TH 212 (1SW7).

The data indicate that the areas sampled in CFC Area 1 vary in major ion water chemistry within the CFC Area 1 samples, and between the portion of CFC Area 1 sampled and CFC Areas 2, 3, 4, and 5. More specifically, the samples collected from Well Nest 1A are higher in total dissolved solids and far higher in chloride when compared to the samples collected from Well Nest 1B (Figure 5.18, Table 4). In addition, surface water samples SW1 and SW2 exhibit the same chemical characteristics as the samples collected from Well Nest 1A. Water samples collected from Well Nest 1B and SW3, SW4, SW5, and SW7 do not present elevated levels of chloride, and are similar to the surface water and groundwater samples collected at CFC Areas 2, 3, 4, and 5. It is interesting that SW 3 and SW4 were collected in close proximity to Well Nest 1A, but do not present elevated chloride levels and are lower in TDS. These data indicate that the water discharging to the sloping fen represented by Well Nest 1A is receiving water from a different aquifer than that which feeds the peat mound represented by Well Nest 1B and the remaining water sampling locations in CFC Areas 2, 3, 4, and 5. It is possible that the aquifer providing the elevated levels of chloride to the spring heads represented by SW2 and SW3 and to Well Nest 1A is the Franconia shale, a marine deposit that could have high chloride levels. As mentioned previously, the sloping calcareous fen in the area of Well Nest 1A is the highest quality calcareous fen observed within the SFWC. It presents the highest hydraulic gradients driving groundwater discharge, and has the highest quality calcareous fen community. We believe that these unique qualities are the result of groundwater discharge from a different aquifer than that which feeds the other areas.

5.2.3 CFC Area 2

Groundwater sampling in CFC Area 2 was conducted at Well Nest 2A (2PZA1 and 2WTA1) and at Well Nest 2B (2PZB1 and 2WTB1). Surface water samples were collected at two locations along the eastern perennial ditch tributary of Assumption Creek (2SW1 and 2SW2) and the western perennial ditch tributary of Assumption Creek (2SW3) and just downstream of the confluence of the two tributaries (2SW4) (Figure 5.1).

All groundwater samples meet the calcareous fen chemical criteria save the samples collected from Well Nest 2B, which did not present high enough EC values to meet the EC criterion (Figure 5.18, Table 4). However, as discussed above, the low values from Well Nest 2B may be a result of errors in field EC determination, as the water chemistry for the Well Nest 2B samples was similar to the other samples that did meet the EC criterion. However, EC values for all of the samples were not high, and generally were around an EC of 500-600 uS/cm. The data for all samples are essentially similar. Surface water samples 3, 4, and 5 were collected to determine if there were significant differences between the eastern and western tributaries of Assumption Creek and to determine the nature of the combined flows. The data suggest that few differences exist between the eastern and western portion of the headwaters of Assumption Creek. All of the surface water samples were very similar in their major ion composition. All of the surface water samples meet the chemical criteria for calcareous fens, indicating that calcareous groundwater discharge is the primary source of water feeding the tributaries.

Groundwater samples collected from Well Nests 2A and 2B also present similar major ion chemistry (Figure 5.18, Table 4). However, the groundwater is slightly lower in total dissolved solids when compared to the surface water. This may be the result of dilution from rainwater. Our model of the hydrology of CFC Area 2 is diffuse groundwater discharge with substantial throughflow components in the portions of the wetland that are distant from the bluff. Infiltrating rainwater intercepted by the sloping peatland itself could dilute the throughflow water and explain the slightly lower TDS values in the well nests. While the spring runs likely receive groundwater discharge along their length, much of the water originates as groundwater discharge nearer the bluff that would be higher in total dissolved solids.

None of the samples collected from Area 2A exhibited the elevated levels of chloride that were observed in the groundwater and selected spring head discharge water in the area of Well Nest 1A, suggesting that the source of aquifer discharge in CFC Area 2 differs from that observed in the area of CFC 1 that presents the best expression of calcareous fen features (Figure 5.18, Table 4).

5.2.4 CFC Area 3

Groundwater sampling in CFC Area 3 was conducted at Well Nest 3A (3PZA1 and 3WTA1). No surface water was collected, as spring head and spring run surface flows were absent in the designated CFC 3 Area. All of the groundwater samples collected from Well Nest 3A meet the calcareous fen chemical criteria provided in Leete et al. (2005) (Table 4). Similarly, the major ion chemistry for CFC Area 3 does not differ substantially from that observed in CFC Area 1 samples that were low in chloride and in the surface water and groundwater samples collected in CFC Area 2 (Figure 5.18).

5.2.5 Surface Water Chemistry: CFC Areas 4 and 5

Well nests were not installed in CFC Areas 4 and 5. However, surface water collected from spring runs receiving spring head and diffuse discharge (4SW1 and 5SW1) presented a major ion chemistry that was quite similar to groundwater and surface water collected in other areas of the SFWC. All of the surface water collected from the spring runs in CFC Areas 4 and 5 would meet the calcareous fen chemical criteria provided in Leete et al. (2005) (Table 4). However, the total width of the histogram bars in Figure 5.18 suggest that the 4SW1 and 5SW1 spring run samples have a slightly lower total dissolved solids content when compared to water samples collected in CFC Area 3. All three areas present the same ionic distribution patterns suggesting that the source of the water is the same for all three areas.

5.2.6 Isotope Analyses

The stable isotope analyses for surface water and groundwater collected from the SFWC are provided in **Figure 5.19**. As expected, the samples generally follow, but plot to the right of, the evaporation line for SMOW, indicating that evaporation was the dominant process acting on the samples. Less intense evaporation is indicated by values that present less negative oxygen (δ18O ‰) and hydrogen (δD ‰) deviation values.

Surface water and groundwater samples collected from the SFWC fall into three distinct groups. Water samples collected from the bluff ponds present evidence of lower evaporation values (less negative δ18O ‰ and δD ‰) values that would be expected in shallow, small ponds that rapidly recharge the groundwater system. Such ponds would have short residence times that would preclude the accumulation of the heavier oxygen and hydrogen isotopes in the surface water. The ponds where the surface water was collected (BPSW 1, BPSW2, and BPSW3) were located near the bluff escarpment above the SFWC where hydraulic gradients would be extremely high and would favor rapid infiltration and short residence times.

The majority of the surface water and groundwater samples present intermediate δ18O ‰ and δD ‰ values indicating that the source of recharge for much of the water discharging to the SFWC could be in areas that experience more intense evapotranspiration (Komor, 1994). These recharge areas could be larger wetlands more distant from the bluff escarpment that would have longer residence times as a result of lower hydraulic gradients and lower amounts of infiltration, and may also represent recharge through upland areas that would experience intense evapotranspiration in the soil rooting zone that would result in greater accumulation of the heavy isotopes. The data also indicate that there is little difference in the isotope data comparing surface water to groundwater samples, further indicating that the surface water collected at spring heads and spring runs is primarily composed of groundwater discharge and is not substantially diluted by precipitation and run-on. Komor (1994) found that the heavy oxygen and hydrogen composition of water samples collected from the deep peat piezometers indicated less intense evapotranspiration when compared to the water collected from shallow water table wells installed in the Savage Fen. However, the oxygen and hydrogen isotopic data from samples collected within the Seminary Fen wetland complex do not present a clear distinction that would separate deep groundwater from shallow groundwater. Instead, the data show a difference between water sample groups that may reflect different source aquifers.

Samples collected from CFC Area 1 near Well Nest 1A show the greatest accumulation of the heavy isotopes of oxygen and hydrogen (1PZ1A, 1WT1A, 1SW1, and 1SW2). These are also the same water samples that presented chloride enrichment discussed in Section 5.2.1.2 above. When considered together, the chemical and isotopic data suggest that the groundwater discharging within and near the high quality calcareous sloping fen near Well Nest 1A comes from a different aquifer than that which feeds the other areas of the SFWC. If the source of the groundwater near Well Nest 1A is the Franconia shale, the isotopic data indicate that the recharge source for the aquifer may be in larger bodies of water distant from the fen itself, and may represent aquifer recharge from larger lakes that are present over the pre-glacial buried valley the extends far to the north of the SFWC. Such lakes could include Lakes Waconia and Minnetonka.

5.3 Soil Assessments

The presence of histic epipedon (peat) soil surface satisfies the calcareous fen soil criterion provided in Leete et al. (2005). Leete et al. (2005) also indicate that the soils would typically present calcium carbonate disseminated within the peat matrix and as concentrations of virtually pure calcium carbonate at the soil surface (Tufa) as discussed in Section 3.2.3 and 3.4.2.3.

Soils develop as a function of organisms, climate, and relief acting on parent material through time. Soil morphology time-integrates soil forming factors and provides a post glacial-history of the SFWC that can be used to explain many of the hydrogeologic features present in the SFWC. An interpretation of soil characteristics can place the CFC-SFWC in a hydrogeologic context necessary to identify potential impacts of road construction on the entire wetland system.

Soil sampling locations across the entire CFC-SFWC are provided in **Figure 5.20**. The following discussion examines the characteristics of SFWC soils as reflected in the carbonate chemistry and morphology of soils collected within the CFC of the SFWC.

5.3.1 CFC Area 1: Classic Calcareous Fen and Disturbed Calcareous Fen Features

Figure 5.21 presents peat depth and substrate data and soil profile sampling and description locations for CFC Area 1. Detailed soil profile characterization was performed in two areas that presented the best expression of calcareous fen characteristics. Soil profiles SP1A1, SP1A2, and SP1A3 were collected along a transect of the high quality sloping calcareous fen that is located just south of the railroad embankment. SP1A4 was collected downslope of the high-quality fen adjacent to a down-cutting spring run. Soil Profiles for Transect 1B were collected at the top (SP1B1) and on the flanks (SP1B2, SP1B3, and SP1B4) of a significant peat dome just to the south of the high-quality fen represented by soil Transect 1A (Figure 5.21, Part B).

5.3.1.1 Peat Depth and Substrate Characteristics

CFC Area 1 is characterized by a variety of peat depths and substrate types. Thick peat deposits (greater than 12 feet) were most common (Figure 5.21, Part A). However, areas of thinner peat deposits over lacustrine clay and outwash sands were also observed, supporting the hypothesis that the area has a history as a post-glacial shallow lake with an undulating bed of glacial outwash. Peat thickness near Transect 1A that represents the best expression of calcareous fen characteristics in the SFWC were shallow to sand and suggest that the high upward hydrologic gradients occurring in this area (described in Section 5.1.2.1) are the result of the location near the bluff combined with underlying conductive, coarse-textured outwash sands through which discharging groundwater can rapidly flow. Peat associated with the peat mound feature represented by soil Transect 1B was generally deeper than 12 feet with an underlying substrate of fine-textured lacustrine deposits located generally on the periphery of the mound (Figure 5.21, Part A). It is likely that the peat mound itself is underlain by coarse-textured outwash sand that would provide high hydraulic gradients necessary for peat accretion and peat mound formation. Peat depths are thinner near the northern edge of the terrace feature and have a sand substrate that is associated with the terrace.

5.3.1.2 Soil Characteristics: Transect 1A: Classic Calcareous Fen

Figure 5.22 presents profile descriptions and loss-on-ignition data for soil profiles collected along Transect 1A. **Figure 5.23** presents important soil and landform characteristics of the high-quality sloping fen represented by Transect 1A. All of the soils collected along Transect 1A are characterized by the presence of a histic epipedon and large quantities of calcium carbonate in the soil profile (Figure 5.22). All of the soils would meet the calcareous fen criteria provided in Leete et al. (2005). Soil Profiles SP1A1 through SP1A3 were collected in a short stature, high quality sloping fen that contained spring heads, spring runs, and several high-point calciphiles (Figure 5.23, Part A). The soil profiles present morphological features that are typically associated with calcareous fens, including tufa at the surface (Figure 5.23, Part B) and stratified deposits of essentially pure calcium carbonate alternating with buried organic surfaces (Figure 5.22, Figure 5.23 Part C). Soil horizons in profiles SP1A1, SP1A2, and SP1A3 are extensively stratified with alternating layers of peat and marly limnic sediments (Figure 5.22, Figure 5.23, Part C), suggesting a dynamic history that likely represents an alternating succession of the development and abandonment of spring heads, spring runs, and flarks (shallow interconnected pools generally oriented perpendicular to the slope gradient). These areas would be characterized by extensive calcite precipitation in the discharging groundwater associated with active spring heads and spring runs, alternating with the development of peat layers upon abandonment of the surface flow features.

Soil profiles SP1A1, SP1A2, and SP1A3 would be classified into intergrades between the Edwards soil series (marly, euic, mesic Limnic Haplosaprists) and the Blue Earth soil series (fine-silty, mixed, superactive, calcareous, mesic Mollic Fluvaquents) depending upon the thickness of the peat surface and the nature of the underlying limnic sediments.

Soil Profile SP1A4 was collected at the base of the sloping fen near a spring run, and has different soil morphology when compared to the soil morphology evident in SP1A1 through SP1A3. SP1A4 consists of peat to 48 inches and is highly calcareous near the soil surface, but only weakly calcareous throughout the rest of the soil profile (Figure 5.22). The soil also presented tufa at the soil surface, likely the result of evapotranspiration concentrating calcite at the surface where evapotranspiration is more intense. It is likely that the 1SP4 profile represents the terminus of the high quality sloping fen and is located in a more stable position where discharging groundwater is more in equilibrium with atmospheric conditions and therefore less saturated with respect to calcium carbonate. Soil profile SP1A4 would be classified into the Houghton soil series (euic, mesic Typic Haplosaprists).

5.3.1.3 Soil Characteristics: Transect 1B: Classic Calcareous Fen Peat Mound that has been disturbed by Partial Drainage

Figure 5.24 presents profile descriptions and loss-on-ignition data for soil profiles collected along Transect 1B. **Figure 5.25** presents important soil and landform characteristics of the peat mound represented by Transect 1B. All of the soils collected along Transect 1B are characterized by the presence of a histic epipedon and large quantities of calcium carbonate in the soil profile (Figure 5.24). All of the soils would meet the calcareous fen criteria provided in Leete et al. (2005). All of the soils examined along Transect 1B would be classified into the Edwards soil series.

The peat dome feature represented by soil Transect 1B has a relief of approximately 10 to 12 feet when compared to the surrounding wetland (Figure 5.25, Part A). The soils collected along Transect 1B are similar to those described above for Transect 1A. The presence of stratified, marly limnic layers interlaced with organic layers in soil profiles SPB2, SPB3, and SPB4 suggests that the flanks of the peat dome were historically characterized by alternating sequences of spring head, spring run , and flark formation and abandonment similar to that described for Transect 1A (Figure 5.25, Part C). However, profile SP1B1 that was collected at the apex of the peat dome has a thicker organic surface and has a zone extending from 6 to 16 inches where calcium carbonate is depleted (Figure 5.24). The presence of a thick organic surface near the apex of calcareous fen peat mounds with highly calcareous stratified soils on the mound flanks is characteristic of peat dome fens (Almendinger and Leete, 1998a). The peat dome represented by the 1B transect has a history of drainage as discussed in Section 5.4.3.1 and Section 3.4.4. Several areas of calcareous groundwater discharge from tile outlets were observed along the flanks of the peat dome (Figure 5.5). It is possible that the lowered watertable associated with tile drainage attempts on the peat dome has resulted in a leaching regime being imposed at the soil surface of the apex of the peat dome, resulting in dissolution and leaching of calcium carbonate by infiltrating precipitation.

The data suggest that the peat dome represented by soil Transect 1B was historically a high-quality calcareous fen similar to the sloping fen to the north. However, partial drainage has resulted in a general lowering of the watertable and subsequent calcite dissolution on the apex of the mound. The area is characterized by an absence of spring heads, spring runs, and flarks that would be typical of high-quality calcareous fens. A lowered water table would also facilitate the invasion of plants observed in the area that are adapted to the altered hydrology. We believe that the peat dome represented by soil Transect 1B represents a good opportunity for fen restoration by removal of the historic tiling system that would result in a restoration of the pre-drainage hydrology.

5.3.2 CFC Area 2: Groundwater Discharge at the Base of the Bluff and the Impact of Throughflow

5.3.2.1 Peat Depth and Substrate Characteristics

Figure 5.26 presents peat depth and substrate data (Part A) and soil profile sampling and description locations (Part B) for CFC Area 2. **Figure 5.27** presents important soil and landform characteristics of soils collected along Transect 2A. Detailed soil profile characterization was performed in two areas that presented the best expression of calcareous fen characteristics (Figure 5.26, Part A). Soil profile SP2A1 was collected in an area that met the calcareous fen vegetation criteria and is located to the north of the railroad embankment. However, high point calciphiles were not concentrated in the area of SP2A1, but were distributed as diffuse populations interspersed among other wetland plant communities. SP2A2 was collected in an area that was outside and to the north of the original MLCCS calcareous fen polygon, but that also met the vegetation criteria based on a walkover observation of *Parnassia glauca* and *Lobelia kalmii* (Figure 5.26, Part B). The area where these high-point calciphiles were observed was added to the original MLCCS polygon based on the presence of histosols, calcareous groundwater, and obvious groundwater discharge.

CFC Area 2 is a sloping peatland that lacks the classic calcareous fen hydrologic features present in CFC Area 1. Spring heads, spring runs, and obvious peat domes were absent. The peatland gently slopes to the south, has a gradient of approximately 10 feet from the bluff to the railroad embankment that forms the southern boundary of CFC Area 2, and is characterized by diffuse surface flow as opposed surface flows concentrated in spring runs. CFC Area 2 is further characterized by a dominance of peat soils that are greater than 12 feet in depth (Figure 5.24, Part A). Where peat is thinner than 12 feet, the underlying substrate was found to consist primarily of lacustrine clay, suggesting that the area has a history as a post-glacial lake.

5.3.2.2 Soil Characteristics: Transect 2A, Gently Sloping Peatland dominated by Groundwater Throughflow with Groundwater Discharge Components

Figure 5.28 presents profile description and loss-on-ignition data for soil profiles examined along Transect 2A. Both of the soils collected in representative locations within CFC Area 2 meet the soil criteria for calcareous fens specified in Leete et al. (2005). However, the soils in Area 2 consist of deep histosols that do not exhibit the stratification observed in the profiles collected in CFC Area 1 (Figure 5.22, Figure 5.28). The lack of stratification in the soil profiles reflects the absence of focused, calcareous groundwater discharge that results in spring head and spring run formation. Both soils are variants of the Houghton soil series (euic, mesic Typic Haplosaprists). Soil SP2A1 was collected in the southern part of Area 2, and was only weakly calcareous throughout the profile. Soil SP2A2 was collected in the north part of CFC Area 2 and exhibited greater quantities of calcium carbonate in the profile (Figure 5.28), but did not present the stratification observed in the profiles collected in CFC Area 1 (Figure 5.22). The presence of greater quantities of calcium carbonate in the SP2A2 profile is the result of the proximity of the sampling location to base of the bluff that would have more intense discharge of calcareous groundwater. Both soils contained calcareous snail shell fragments the presence of which indicates that the groundwater is saturated with respect to calcium carbonate and would not dissolve the snail shell fragments (Figure 5.27, Part C).

Both profiles contain greater quantities of mineral material than those observed in CFC Area 1. The presence of elevated amounts of mineral sediment is likely due to the proximity of SP2A1 to the perennial drainageway flowing along the north side of the railroad embankment, and the proximity of SP2A2 to the alluvial fans deposited at the mouth of the coulees associated with the bluff escarpment to the north of the SP2A2 location. Periodic flooding would introduce mineral sediments into the profiles resulting in elevated mineral contents associated with the soil surfaces at both locations.

We believe that the soil profile and peat depth data collected in CFC Area 2 reflect diffuse discharge of calcareous groundwater near the toe-of-slope position of the bluff and the toe-of-slope positions adjacent to alluvial fans flanking the SP2A2 location, and the progressive downslope movement of calcareous groundwater (throughflow) through the peat to the south of CFC Area 2 near SP2A1. Because the discharging groundwater is calcareous and maintains a water table at the soil surface, the soils and ground and surface water chemistry meet the calcareous fen criteria as discussed in Section 5.2.1.

However, while groundwater discharge is represented at both locations as discussed in Section 5.1.3, upward hydraulic gradients are not large and the groundwater flow would have a substantial throughflow component given the positive downslope topographic gradient across the sloping peatland. Concentrated populations of high point calciphiles are absent, but the area is characterized by the occasional presence of individual species that are distributed throughout the community.

CFC Area 2 is the closest calcareous fen component to the proposed alternative alignments E-1A and E-2, and has the greatest potential to be affected by bridge construction and operation. The presence of elevated mineral sediment in the soil surface of both profiles (Figure 5.28) suggests that flooding introduces minor amounts of sediment into the profile. Because both alignments follow a nearby coulee to the bluff top, erosion during construction could result in the addition of sediment above that which occurs naturally.

5.3.3 CFC Area 3: Discharge Area South of the Terrace Feature and Existing TH 212

5.3.3.1 Peat Depth and Substrate Characteristics

Figure 5.29 presents peat depth and substrate data (Part A) and soil profile sampling and description locations (Part B) for CFC Area 3. Detailed soil profile description and sampling was performed in two areas that presented the best expression of calcareous fen characteristics. Soil profile SP3B1 was collected in an area that met the calcareous fen vegetation criteria and is located in the middle of the MLCCS unit near the 100-year floodplain of the Minnesota River. Soil Profile SP3A2 was collected near the southern edge of the MLCCS unit and is within the 100-year floodplain of the Minnesota River (Figure 5.29, Part B).

CFC Area 3 is a sloping peatland that lacks the classic calcareous fen hydrologic features present in CFC Area 1. The peatland slopes steeply to the south, has a gradient of approximately 10 feet from the fill pad for existing TH 212 to the southern edge of the sloping peatland, and is characterized by diffuse surface flow as opposed to surface flows concentrated in spring heads and spring runs. A few areas of turgid peat were observed that represent areas of focused groundwater discharge. CFC Area 3 is further characterized by a dominance of relative shallow peat soils that have a sand substrate that could act as a highly conductive layer for groundwater discharge (Figure 5.27). A few areas examined for peat depth indicate a lacustrine clay substrate suggesting that the area may have had a history as a shallow post-glacial lake.

5.3.3.2 Soil Characteristics: Transect 3A, Steeply Sloping Peatland dominated by Groundwater Discharge from the Terrace Feature

Figure 5.30 presents profile descriptions and loss-on-ignition data for soil profiles SP3A1 and SP3A2. **Figure 5.31** presents important soil and landform characteristics of CFC Area 3.

Both of the soils collected in representative locations within CFC Area 3 meet the soil criteria for calcareous fens specified in Leete et al. (2005). Both soils contained calcareous snail shell fragments the presence of which indicates that the soil and groundwater is saturated with respect to calcium carbonate and would not dissolve the snail shell fragments (Figure 5.31, Part B). Profile SP3A2 contains a highly calcareous subsurface consisting of stratified organic peat and coprogenous earth/marl sediments representative of calcareous fens (Figure 5.30, Figure 5.31, Part C).

Both profiles contain greater quantities of mineral material than those observed in CFC Area 1 (Figure 5.30). The presence of elevated amounts of mineral sediment is likely due to the proximity of SP3A1 and SP3A2 to the 100-year floodplain of the Minnesota River. Periodic flooding of the area would introduce mineral sediments into the profiles resulting in elevated mineral contents associated with the soil surfaces at both locations. However, distinct alluvial strata are absent suggesting that flooding is infrequent and would not substantially disturb the calcareous fen plant community.

Soil profile SP3A1 contains elevated levels of calcium carbonate at the soil surface that are underlain by a zone that is depleted in calcium carbonate (Figure 5.30). The reasons for the presence of the carbonate depleted zone are unclear. However, it is possible that a groundwater throughflow regime dominates at the SP3A1 location with the source of the discharging groundwater being water from the terrace feature that was recharged by surface flows from Assumption Creek and the terrace feature itself. Because the recharge areas consist of surface flows that would be in equilibrium with calcite at atmospheric pressures, discharge of the more aggressive groundwater at the toe-of-slope position south of TH 212 and groundwater flow through the biologically active soil surface would increase the partial pressure of CO_2 resulting in more aggressive groundwater capable of dissolving additional calcium carbonate.

Soil Profile SP3A2 that was sampled at the foot of the sloping peatland has higher amounts of calcium carbonate throughout the profile, and presents highly calcareous subsoil that is stratified with alternating layers of marl and peat. The presence of higher amounts of calcium carbonate in the peat surface could be the result of lateral leaching of calcium carbonate from the upslope to the down slope soils described above. The presence of stratified marl and peat in the subsoil suggests that CFC Area 3 may have historically been a calcareous fen that was similar to those calcareous fen features described for CFC Area 1. However, the presence of a thick layer of peat above the stratified layers and the absence of spring heads and spring runs suggests that the hydrologic conditions that resulted in the stratification are no longer operating and represent pre-historic or early Holocene conditions.

5.3.4 CFC Areas 4 and 5: Groundwater Discharge; Flooding, and Soil Disturbance

Soil description and sampling locations for CFC Areas 4 and 5 are provided in Figure 5.29. Peat depths and substrate characteristics were not determined for CFC Areas 4 and 5. Soil profile description and loss-on-ignition data are provided in **Figure 5.32** and **Figure 5.33** for CFC Areas 4 (SP4A1 and SP4A2) and 5 (SP5A1 and SP5A2), respectively. **Figure 5.34** and **Figure 5.35** present important soil and landform characteristics for soil transects collected in CFC Areas 4 and 5, respectively.

All soils collected from CFC Areas 4 and 5 present substantial amounts of mineral floodwater alluvium that would preclude the development and maintenance of a calcareous fen plant community (Figures 5.32 and 5.33). Soil profile SP4A1 was non-calcareous to weakly calcareous throughout, indicating that groundwater discharge, while calcareous, is not sufficiently supersaturated with respect to calcium carbonate to result in the presence of substantial amounts of calcium carbonate within the soil profile (Figure 5.30). Soil profile SP4A2 was collected near the north border of CFC Area 4. The soil profile was also weakly calcareous and was characterized by a thin peat surface over weakly calcareous, stratified sediment that is typical of near-shore deposition in a shallow post-glacial lake (Figure 5.30). Soil profile SP4A1 would be classified into the Houghton soil series, whereas soil profile SP4A2 would be classified into the Blue Earth series.

Both soil profiles collected from CFC Area 5 similarly presented soil surfaces that were weakly to non-calcareous (Figure 5.31). SP5A1 was weakly to non-calcareous throughout the profile, whereas soil profile SP5A2 did have calcareous, stratified sediments at 40 inches depth in the profile (Figure 5.31). However, thick weakly to non-calcareous peat and coprogenous earth sediments buried the calcareous sediments, indicating that the hydrologic processes that resulted in the deposition of the stratified, calcareous sediments are no longer operating. The presence of the calcareous sediments at depth in the profile suggests that the sediments may have been deposited in a shallow post-glacial lake and are not the result of the discharge of highly calcareous groundwater at the SP5A2 location.

5.3.5 Summary and General Observations: SFWC Hydrology, Chemistry, and Soils

5.3.5.1 Hydrogeologic Interpretation: The Seminary Fen Wetland Complex as a Post-Glacial Marl Lake

The postglacial hydrogeology of the SFWC is complicated. Diffuse and focused groundwater discharge has resulted in paludification, peat accretion, and the formation of a large peatland that has a gradual slope to the south from the toe-of-slope positions at the bluff edge to the terrace feature that separates the north unit of the SFWC from the south unit of the SFWC. Similarly, peatlands to the south of the terrace feature also present a gradual slope from the south of the terrace feature to the active floodplain of the Minnesota River.

It is possible that a shallow post-glacial lake existed in the area for a period following glaciation. Natural drainage of this shallow lake resulting from downcutting of Assumption Creek providing an outlet to the east would have initiated the paludification process over much of the area. The result is a complex stratigraphy of thin-to-thick peat deposits accreting over fine-to-coarse textured calcareous marl, fine textured lacustrine sediment in low areas of the shallow lake, and coarse textured outwash sediments in elevated areas of the undulating lake bottom. The presence of a pre-glacial shallow lake characterized by the general presence of calcareous marl deposits would result in virtually the entire wetland system being saturated with respect to calcium carbonate. Groundwater discharge would be more intense nearer the toe-of-slope positions at the base of the bluff and the terrace feature, and in areas where peat and lacustrine deposits are thin to the underlying sand. Groundwater discharge would be less intense in areas of thick peat over fine-textured lacustrine deposits. The distribution of the CFC of the SFWC as highly calcareous fen features embedded in a surrounding carbonated wetland system could explain the distribution of calciphiles found in the SFWC.

In particular, highly calcareous areas dominated by intense, focused groundwater discharge would produce calcareous fen peat domes and sloping peat features that would be characterized by highly calcareous peat soils underlain by stratified, marly sediments. Throughflow of calcareous groundwater in areas with less intense groundwater discharge that are underlain by less permeable lacustrine clay would be carbonated, but would not present the typical calcareous fen features that are associated with active, focused groundwater discharge. The highly calcareous fen areas would be dominated by calciphiles. However, the presence of thick to thin calcareous peat in areas with less intense groundwater discharge would favor the presence of calciphiles distributed thinly throughout the wetland plant community. Based on the soil, chemistry, and hydrology data provided in this report, it is our opinion that the entire north unit of the SFWC is a carbonated system capable of supporting low densities of high and low point calciphiles due to the presence of seed sources in highly calcareous areas combined with the general presence of calcareous peat that would favor calciphiles being present in low distributions in areas that are distant from zones of focused groundwater discharge.

5.3.5.2 Impact of the Terrace Feature

The terrace feature separates the north unit of the SFWC from the south unit, and explains the presence of spring heads and spring runs south of TH 212 that are distant from the base of the bluff where groundwater discharge is expected to be most intense. The aquifer feeding the CFC in the south unit of the SFWC appears to be the north unit, thus the distance between recharge and discharge areas for the groundwater flow system feeding the south unit of the SFWC is relatively short. Because the groundwater and surface water in the north unit of the SFWC is calcareous, the groundwater discharging to the CFC Areas south of the terrace feature and existing TH 212 is calcareous as well.

However, the groundwater flowing underneath the terrace will have spent considerable time in a near-surface environment on the north unit and will have precipitated most of the excess calcium carbonate within this unit. Thus the groundwater discharging to the south unit, while calcareous, does not provide a highly calcareous environment that results in large amounts of calcite within the soil profiles. While numerous spring heads and spring runs are present in the south unit, they rarely result in the presence of calciphile dominated plant communities and highly calcareous peat soils.

5.3.5.3 Floodplain Nature of Areas 4 and 5

Regular inundation by floodwater is cited by Leete et al. (2005) as a disturbance factor that prevents calcareous fen formation and/or maintenance of fens. Soils in CFC Areas 4 and 5 present high amounts of floodwater alluvium incorporated into the peat, and several profiles exhibited mineral horizons that represent intense historic and prehistoric flooding. Calciphiles were absent in CFC Areas 4 and 5. It is unlikely that either Area 4 or Area 5 were calcareous fens in the past, or have the potential for becoming calcareous fens in the future, in spite of the presence of soil, water chemistry, and hydrology features that meet the calcareous fen criteria. It is likely that CFC Areas 4 and Area 5 were miss-mapped during the original MLCCS mapping with the classification as calcareous fens being based on the observed presence of hydrologic, water chemistry, and soil features that would satisfy the calcareous fen criteria.

5.4 Vegetation Assessment

5.4.1 Walkover and General Vegetation Characteristics

The SFWC consists of a mosaic of plant communities and ecotopes. The type and distribution of these communities, and their constituent species, reflects the combined influences of biogeographic history, environmental conditions at varying spatial scales, and anthropogenic disturbance. Vegetation is dominated by herbaceous species, particularly graminoids, represented predominantly by grasses and sedges. As documented elsewhere, the SFWC has experienced extensive anthropogenic disturbance over the past century or more. The construction of the rail bed, attempts at drainage and peat mining, expansion of shrubs and establishment of invasive species have all occurred.

The calcareous fen plant communities observed at SFWC are consistent with the DNR Native Plant Community Description (Minnesota Department of Natural Resources, 2005) for “Extremely Rich Fen, Calcareous Fen Southeastern Type” (OPp93). The DNR description notes that vegetation can be quite heterogeneous depending upon topography and hydrology. Short-statured graminoid communities and small, open pools are distinctive and unique features of calcareous fens, especially in areas of marl. However, taller, thicker vegetation is also an important component of fen communities. There are several different ecotopes one can describe within the larger calcareous/extremely rich fen plant community. The structural and compositional differences in calcareous fen vegetation correlate with whether the substrate is primarily peat or marl (Hershock, 2002). Plant competitive hierarchies, associated with plant growth forms, differ between the substrates, resulting in observed differences in plant communities. The precise environmental factors responsible for these differences remain largely unknown, but Reed (2002) suggests that groundwater levels and soil chemistry may be key factors. The calcareous fen ecotopes intergrade into other wetland types such as seepage meadow/carr (WMs83), wet prairie, mixed cattail marsh (MRs83) and southern bulrush-arrowhead marsh (MRs93). Transects were placed to sample the diversity of ecotopes and plant communities within the SFWC (**Figure 5.36**) and to provide a means of determining which sites satisfy the DNR criteria for calcareous fen vegetation (Berglund 1995; Leete et al. 2005).

A complete list of plant species found in the SFWC during 1995 and 2005 surveys is presented in Table 5. Data collected during 2005 botanical surveys in presented in Appendix 1. Descriptions of the various ecotopes and plant communities are given below, and a summary of ecotopes and their distribution among transects and Areas 1-5 is presented in Table 6. Dominant species and the relationships of the ecotopes to each other and to various disturbance and environmental factors are discussed below. Throughout many of these communities, certain species are common, with their abundance varying, but they are nearly ubiquitous in the SFWC. These species are common wet meadow, wet prairie or sedge meadow species including *Eupatorium perfoliatum, Eupatorium maculatum, Lycopus* *americanus, Lycopus uniflorus, Pycnanthemum virginianum, Aster firmus/puniceus* complex, *Aster umbellatus, Helianthus grosseserratus, Lysimachia ciliata, Lysimachia quadriflora,* and *Lysimachia thyrsifolia*, among others. Wherever seepages or spring discharges are found, two species are common: *Cardamine bulbosa* and *Caltha palustris*. An additional species, *Rorippa nasturtium-aquaticum* is often near these species in spring runs.

5.4.1.1 Area 1

Area 1 has the greatest diversity of vascular plant species, calcareous fen species, and plant communities and ecotopes. The community with the highest concentration of high quality, classic, calcareous fen plant species is located in the northeast corner of Area 1, as noted earlier in the report. This community has the most high-point calciphiles, including many species that are uncommon in the rest of the SFWC and are rare or non-existent outside of calcareous fens. This area has dense tufa in the substrate, but flarks are generally not present as might be expected in an area of dense tufa. The ecotope designation is “short sedge fen.” Other authors have referred to this type of ecotope as “marl meadow” or “calcareous fen” among other names.

The predominant growth form in this ecotope consists of low stature graminoids, with scattered forbs. A few shrubs have become established as well. Dominant species include *Eleocharis rostellata*, *Scleria verticillata*, *Muhlenbergia glomerata*, and *Triglochin maritimum*. Associated species include *Carex sterilis*, *Andropogon gerardii*, *Parnassia glauca*, *Lobelia kalmii*, *Gentianopsis procera*, *Cirsium muticum*, *Carex tetanica*, *Liatris ligustylis*, *Scirpus pungens*, and *Cladium mariscoides*. *Triglochin palustris* and *Liparis loesellii* were both found but are rare within the community. *Rhynchospora capillacea* and *Scirpus cespitosus* were documented in 1995, but were not seen in 2005. This absence may simply reflect inadequate sampling intensity or search time rather than an actual disappearance from the site. Transect 6 was placed in this ecotope. A second short statured sedge ecotope was documented at Transect 10, although the size of the ecotope was much smaller than at Transect 6. **Figures 5.37 and 5.38** show these transects and associated vegetation.

A second calcareous fen ecotope, as noted in the OPp93 description, is a taller, denser community, dominated by sedges, particularly species of the genus *Carex*, designated here as “tall sedge fen” ecotope. Two high point calciphiles are abundant: *Carex prairea* and *Carex sterilis*. The ecotope is variable and intergrades into other sedge-dominated ecotopes, described below. Other sedge species that are common in this ecotope and sometimes locally abundant include *Carex sartwellii*, *Carex aquatilis*, and *Carex stricta*. Less abundant sedges included *Carex interior*, *Carex granularis*, *Carex hystericina*, and *Carex buxbaumii*. *Muhlenbergia glomerata* and *Scirpus acutus* are common throughout the ecotope. Other associated species include wet meadow species mentioned above as well as *Lobelia siphilitica*, *Galium labridoricum*, *Hypoxis hirsuta*, *Smilacina stellata*, *Bromus ciliatus*, *Pedicularis lanceolatus*, and occasionally *Triglochin martimum*. When *Cypripedium candidum* was found in the SFWC, it was generally in this ecotope. This ecotope is quite variable. However, further describing subcategories was beyond the scope of this project and would have required extensive additional sampling and analysis.

The taller sedge-dominated fen ecotopes are more abundant than the short sedge marl meadow ecotope. Substantial areas of these tall sedge ecotopes have been degraded through drainage, excavation, invasive species establishment as documented elsewhere in this report. This ecotope occurs in Areas 1-3. In Area 1, transects 1, 9, 18, and 42 represent this ecotope (**Figures 5.39-5.42**).

A related ecotope, also dominated by tall sedges, but one that seems wetter than previous, is a "*Carex stricta*/spring run" ecotope. Turgid peat or spring runs are common and the dominant species throughout is *Carex stricta*, though typically more abundant than in the tall sedge fen ecotope. Other sedges may be found, but are less abundant, and these include *Carex prairea*, *Carex tetanica*, and *Carex hystericina*. Wet meadow forbs are sometimes found as well as *Helianthus grosseserratus* and *Juncus alpino-articulatus*. Transects 4, 7, 15, and 41 represent locations in Area 1 where this ecotope is found (**Figures 5.43-5.46**).

The "*Carex-Thalictrum*" ecotope is similar to the tall sedge ecotope, with an obvious difference that *Thalictrum dasycarpum* is a common, and often dominant, species. Sedges tend to be less abundant in this ecotope than in the tall sedge ecotopes mentioned above, although they remain a major component. Dominant sedges are similar to above and include *Carex prairea*, *Carex sterilis*, *Carex sartwellii*, and *Carex stricta*. Less common sedges include *Carex buxbaumii*, *Carex granularis*, *Carex lacustris*, and *Carex hystericina*. Grasses found include *Bromus ciliatus*, *Muhlenbergia glomerata*, *Muhlenbergia richardsonis*, *Calamagrostis canadensis*, and *Calamagrostis stricta*. The usual collection of wet meadow forbs are present, as well as *Eriophorum angustifolium*. This community may represent a slightly disturbed and/or drier version of the tall sedge ecotope. While many wetland species are common among the two ecotopes, many other species, suggesting disturbance, occur in this ecotope such as *Solidago canadensis.* This ecotope occurs in Areas 1 and 3 and is represented by transects 12, 16, 25, 26, and 27 in Area 1 (**Figures 5.47-5.51**).

Another ecotope that seems drier yet is a "*Carex-Solidago*" ecotope, which suggests a more disturbed condition, reminiscent of old field vegetation because of the abundance of composites. Dominant species include various sedges, especially *Carex prairea*, *Carex sartwellii*, *Carex sterilis* and *Carex granularis*. Composites are a major component of this ecotope and include *Solidago canadensis*, *Solidago gigantea*, the *Aster puniceus*/*Aster firmus* complex, *Aster umbellatus*, *Helianthus grosseserratus*, *Helianthus giganteus*, *Euthamia graminifolia*, and *Silphium perfoliatum*. The scattered presence of *Spartina pectinata* suggests that this ecotope may have once been, in part, wet meadow or wet prairie plant communities. This community is represent by transects 21-23 (**Figures 5.52-5.54**) which are found in the western portion of Area 1. As discussed above, construction of the railroad bed may have disrupted historic hydrological patterns, diverting water from Area 2 to the west, away from the western part of Area 1. This *Carex-Solidago* ecotope may have developed through succession as a result of this altered hydrology. Associated with this ecotope are large tracts of monotypic or mixed *Phalaris arundinacea*, an invasive grass that is especially problematic after disturbance to wetlands. It is interesting to note that the wettest portion of Area 2 is along the railroad embankment, and opposite that area, on the south side, are areas of *Phalaris* and disturbed ecotopes.

A "*Phalaris arundinacea*" ecotope is abundant within and around Area 1. One noteworthy location is on the east side of the peat dome, again suggesting drier condition than originally found. This slope would have undoubtedly have been covered with a sedge-dominated wetland, but excavation and drainage on the west side, and drain tiles on the east side have likely diverted water away from the top and sides of the peat dome, leading to a replacement of the native sedge ecotope. Species now present include several common in disturbed conditions such as *Phalaris arundinacea*, *Apocynum cannabinum*, *Solidago canadensis*, *Solidago giganteus*, and *Helianthus grosseserratus*. Transect 14 was sampled in this area, and Transect 2 was sampled outside of the original MLCCS polygon in an area of *Phalaris* with groundwater discharge (**Figures 5.55 and 5.56**).

Within the excavated and drained portions, in the center of Area 1, a mixture of fen ecotopes and disturbance ecotopes are found. *Phalaris*, *Typha angustifolia* and *Phragmites australis* form monotypic or mixed stands and show evidence of encroaching into native fen ecotopes. Where water is abundant, *Carex lacustris* meadows can be found. This area of excavation and drainage represents a complex mosaic of native and exotic vegetation that where ecotope boundaries were not mapped because of extensive heterogeneity and interspersion.

In disturbed areas, *Typha angustifolia* may be found in dense colonies or mixed with other wetland species, especially *Phalaris*. One area in particular is interesting for the close proximity of native fen species and disturbance-tolerant species. The region in the center of Area 1 that was excavated and the peat wind-rowed was left with a series of small hills and valleys. Elevation varies approximately 1 to 2 feet between the high and low spots. The tops and sides of the windrows support a mixture of "*Typha-Phalaris*" ecotope. Other scattered wetland species present include *Eupatorium maculatum*, *Solidago gigantea*, *Lycopus uniflorus*, and *Solidago canadensis*, all consistent with a disturbed, but not drained, wetland. Turgid peat is found in the bottoms of the valleys, indicating an upwelling of groundwater. Many native calcareous fen species are found in these valleys including *Carex prairea*, *Carex sartwellii*, *Carex hystericina*, *Lobelia kalmii*, *Aster borealis*, *Cardamine bulbosa*, *Solidago riddellii*, and the state-protected species *Carex sterilis* and *Eleocharis rostellata*.

The discovery of these fen species was unexpected in a spot that had been significantly disturbed by excavation. However, their presence suggests that given the appropriate hydrological conditions and a nearby available seed source, important calcareous fen species can persist or possibly be restored. Transect 19 (**Figure 5.57**) is located in this area of excavation and deposition. By random placement of transects, these fen indicator species were missed during sampling, and the dominant species in the plots are *Typha angustifolia* and *Phalaris arundinacea*. However, when the entire area was searched by a walkover survey, numerous additional fen species were located.

Cattails occur in what appear to natural plant communities in the SFWC as well as obviously disturbed communities. *Typha angustifolia* can be found as scattered individuals throughout many of the wetland ecotopes. In Area 1, areas of cattail marsh ecotope were identified and are believed to be natural communities based on the diversity of species present. These areas are designated "*Typha angustifolia*" ecotopes. Little or no *Phalaris* or *Phragmites* is found, and many native fen and wet meadow species occur in association with the cattails. These species include *Carex stricta*, *Carex prairea*, *Carex sterilis*, *Bromus ciliatus*, *Eupatorium maculatum*, *Chelone glabra*, and *Lycopus americanus*. Transects 8 and 13 represent this ecotope (**Figures 5.58 and 5.59**).

The tall sedge fen ecotope intergrades into *Carex lacustris* seepage meadow or emergent marsh, designated "*Carex lacustris*" ecotope. It appears that these areas of lake sedge are wetter than the fen ecotopes either through surface or ground water ponding and inundation. Frequently, *Caltha palustris* is present in this ecotope, indicative of groundwater discharge. Topography may lead to ponding of this discharged water, leading to formation of a seepage meadow rather than a tall sedge fen ecotope. Throughout the SFWC, the *Carex lacustris* ecotopes are where the greatest encroachment of Phragmites is found, outside of the drained/excavated central region of Area 1. In the *Carex lacustris* ecotope, many common wet meadow forbs are found, also with occasional graminoids such as *Carex stricta*, *Carex prairea*, *Calamagrostis canadensis*, and *Calamagrostis stricta*. In Area 1, transects 17 and 24 were sampled in this ecotope (**Figures 5.60 and 5.61**).

The two buckthorn species (*Rhamnus cathartica* and *R. frangula*) primarily exist as scattered individual plants throughout Areas 1-3. They are sometimes are components of thicket associated with native willows and red-osier dogwood. In one area of particular note, buckthorns form a monotypic dense shrub thicket with little herbaceous understory. This thicket is in an area of stream incision and head board erosion adjacent to the short sedge fen ecotope. It should be noted that this ecotope is the location of the highest density of calciphiles and state-protected plants (in terms of both species richness and abundance). A comparison of the present extent of the buckthorn thicket (as documented by GPS) with the 1995 edge (as shown on the false-color infrared aerial photograph) indicates that the edge of the thicket has moved between 30 and 60 feet into the fen ecotope. A single transect (5) was placed in this buckthorn thicket, and the paucity of fen species under the buckthorn is evident (**Figure 5.62**). Ahead of the dramatic thicket edge, numerous small, scattered individual buckthorns have established and will form the next wave of thicket advancement. It is unknown if the rate of buckthorn encroachment reflects the biology of buckthorn itself, or if it reflects the rate of stream incision and lowering of the water table which may alter the relative competitive abilities of fen species compared to buckthorn. Regardless, buckthorn appears to pose a significant threat to the integrity of the highest quality area of calcareous fen in the entire SFWC.

Shrub carr could be defined as a separate ecotope throughout Area 1 (and other areas). Several native shrubs, particularly *Cornus stolonifera* and *Salix* species, have dramatically increased in abundance in recent decades. The increase in woody vegetation is evident from a comparison of historic aerial photographs. What would be mapped as shrub carr would generally consist of other fen and wetland ecotopes that have simply been overgrown by shrubs as a result of fire suppression. The herbaceous understory communities are often still present, although at lower abundance, and correspond to the ecotopes defined above. For this reason, shrub carr was not recognized as a unique ecotope at any of the transect locations.

5.4.1.2 Area 2

Ecotopes were not precisely mapped in Area 2 because of the complex interspersion and intergradations of ecotopes. The ecotopes found in Area 2 are the tall sedge fen, *Carex lacustris*, *Phragmites* and shrub carr ecotopes. In some areas, the *Carex lacustris* ecotope transitions into marshier ecotopes. In some parts of Area 2, *Acorus americanus* becomes a dominant along *Carex lacustris*. The location and extent of each of these ecotopes undoubtedly changes temporally as shrubs and *Phragmites* expand, and historic fires reduced shrub growth. A large portion of Area 2 is now dominated by *Phragmites*. These areas would have originally been wet meadow, sedge meadow or calcareous fen communities. However, invasive *Phragmites* has become established and is a threat to the integrity of native plant communities.

In Area 2, the growth of *Acorus* appears correlated with greater hydrological regime associated with impoundment from the railroad embankment. Species that occur in the ecotopes that have *Acorus* as a dominant species include *Carex aquatilis*, *Eupatorium maculatum*, *Lycopus uniflorus*, *Pycnanthemum virginianum*, *Lysimachia thyrsifolia*, *Leersia oryzoides*, *Sium suave*, and *Boehmeria cylindrica*.

Transects 40, 43, and 44 represent the tall sedge fen ecotope (**Figures 5.63-5.65**), and transects 37-39 represent the *Carex lacustris* ecotope (**Figures 5.66-5.68**). Transects 43 and 44 were sampled only in September because they were added after several calciphiles were discovered outside of the original MLCCS polygons. Transect 37 was not sampled in September because the stake could not be relocated. Shrub carr and *Phragmites* ecotopes were not sampled with transects. In most areas, it was not practical to separate these ecotopes from the previous two because of interspersion at a fine spatial scale.

5.4.1.3 Area 3

Ecotopes were not precisely mapped in Area 3 because of the complex interspersion and intergradations of ecotopes. The ecotopes found in Area 4 are the tall sedge fen, *Carex lacustris*, *Phragmites*, *Phalaris* and shrub carr. Outside of the MLCCS polygon, two transects were placed in a *Carex-Thalictrum* ecotope (Transect 28; **Figure 5.69**) and a *Phalaris arundinacea* ecotope (Transect 29; **Figure 5.70**). The tall sedge fen ecotope surrounds the radio tower, and supports a rich diversity of fen and wetland plant species, despite anthropogenic disturbance (Transect 30; **Figure 5.71**). Transect 31 is also in the tall sedge fen ecotope, but at a slightly lower elevation where the vegetation intergrades into *Carex lacustris* and *Phragmites* ecotopes (**Figure 5.72**). As in Area 2, the ecotope boundaries are shaped by succession, disturbance and fire. *Phragmites* and *Phalaris* expansion is a threat to native plant communities, including calcareous fen.

5.4.1.4 Area 4

Although Area 4 was designated as calcareous fen during MLCCS mapping, two non-fen ecotopes were found: "*Carex lacustris-Acorus americanus*" sedge meadow and shrub carr. The sedge meadow is generally found at lower elevations than the shrub carr. Transects 32-34 are located in Area 4 (**Figures 5.73-5.75**).

5.4.1.5 Area 5

Like Area 4, Area 5 was mapped by MLCCS as fen, but does not contain fen ecotopes. The plant communities are riparian floodplain communities, including riparian forest and marsh. The marsh communities are adjacent to and above a spring run creek. Dominant species include *Acorus americanus* and *Iris versicolor*, with a minor presence of the invasive species *Lythrum salicaria* and *Phalaris arundinacea*. In Areas 4 and 5, the *Carex lacustris – Acorus americanus* ecotope intergrades with an *Acorus americanus – Sparganium eurycarpum* ecotope (Transect 36; **Figure 5.76**). The *Acorus* ecotopes appear to be associated with periodic flooding from the Minnesota River, which results in deposition of sediments and nutrients. These deposition events would not occur in the other plant communities described in the SFWC, where *Acorus* and *Sparganium* are uncommon or absent. *Lythrum salicaria*, was only observed in Areas 4 and 5, and may not tolerate the environmental conditions of the calcareous fens found in Areas 1-3.

5.4.2 Calciphile Index Scores

As presented earlier, the 1995 technical guidelines for fen vegetation require a score of 50 points. The revised and regionalized 2005 guidelines require a score of 50 points, unless all chemical, hydrology and soil parameters are satisfied, at which point a score of 30 points is necessary to consider an area calcareous fen.

When the entire plant species list is considered, using both 1995 and 2005 survey results, overall, the SFWC scores 196 using the 1995 calciphile values and 281 using the draft 2005 calciphile values, putting it among the highest scoring calcareous fens in the state. Table 7 presents a summary of calciphile scores for each transect using both point values systems. The vicinity score given in the table is a score based on species presence/absence walkover surveys around each transect. Plot scores are for species found in subplots along each transect. The distribution of ecotope vicinity scores throughout the SFWC is shown in **Figures 5.77 and 5.78**.

5.4.2.1 Area 1

The distribution of ecotope vicinity scores throughout the SFWC is shown in **Figures 5.77 and 5.78**. The highest scores are in the northeast corner of Area 1, which has previously been noted as the area with the highest expression of calcareous fen attributes based on environmental parameters. Using either the 30-point or 50-point criteria from both Berglund (1995) and Leete et al. (2005), the vegetation criterion is met from across the entire span of Area 1. Scattered locations within Area 1 fail to meet the criteria, and those locations tend to be associated with disturbance from excavation, drainage or invasive species encroachment.

5.4.2.2 Area 2

In Area 2, all transects satisfy the 1995 and 2005 30-point criterion, but the easternmost transects fail the 50-point criterion. These locations are dominated by *Carex lacustris*, and have standing water impounded by the railroad embankment. *Phragmites* encroachment is also a problem in this area. Transects 40, 43 and 44 are all tall sedge fen ecotope, and satisfy the 50-point criterion. It is especially notable that 43 and 44 satisfy the criterion, because they were not sampled in June when *Carex* was most easily identified to species. The September sample date yielded scores of 70 and 100 points (2005 criteria). A high point calciphile, *Carex prairea*, could be identified based on vegetative characters. Given the frequent co-occurrence of *C. prairea* and *C. sterilis* in the SFWC, it is likely that scores would be higher if these transects were sampled in June.

5.4.2.3 Area 3

The highest calciphile scores were around the radio tower, in the tall sedge fen ecotope (1995 values = 54; 2005 values = 101). In the southern part of Area 3, where *Carex lacustris* becomes common, the 30-point threshold is met but not the 50-point threshold. It is notable that Transect 28, to the east of the original MLCCS polygon, scores 40 points using the 2005 draft guidelines. This transect is located in a *Carex-*

Thalictrum ecotope, although *Phalaris*, *Phragmites*, and shrubs all threaten the integrity of this spot. The calciphiles present here are *Carex hystericina*, *Carex prairea*, *Cardamine bulbosa*, and *Bromus ciliatus*, although these are not dominant species.

5.4.2.4 Area 4

Area 4 failed to meet calcareous fen vegetative criteria using either the 1995 or 2005 guidelines. The only calciphile found was *Salix candida*, and it was rare in the area.

5.4.2.5 Area 5

Area 5 failed to meet calcareous fen vegetative criteria using either the 1995 or 2005 guidelines. The only calciphiles found were *Bromus ciliatus* and *Carex aquatilis*.

5.4.3 Ordination Results.

The ordination results help understand the relationships among the different plant communities and ecotopes. When transects are grouped by ecotope on the ordination graph, differences in plant communities can be discerned (**Figure 5.79**). The short stature sedge ecotope that characterizes transects (6 and 10) are relatively close together on the far left end of the first axis. *Phalaris* and/or *Rhamnus* monotype ecotopes are at the extreme right, and ecotopes with a significant component of *Typha* are near the lower right. Other fen and wetland ecotopes are scattered within the middle, with a fair amount of overlap. The overlap among ecotopes in the center of the graph likely results from the numerous wetland species that are shared among the various ecotopes.

The first axis of the ordination apparently corresponds with the distribution of calciphiles, with high point species and transects to the left end of the axis and low point species to the right. This axis seems to represent a native fen species to invasive/exotic species continuum. The second axis is more difficult to interpret, but reflects some separation of different sedge-dominated wetland ecotopes. Tall sedge fen ecotopes and spring run sedge ecotopes are at the top center of the diagram, and *Carex lacustris* ecotopes (which often have a significant presence of *Phragmites*) are near the bottom center. The *Carex-Thalictrum*, *Carex-Solidago* and *Acorus* ecotopes are in the center of the diagram.

Together, the two axes reflect hydrology because ecotopes that are most directly dependent on groundwater discharge are to the left and top, and ecotopes less directly linked to groundwater discharge are more to the right and bottom. For example, the short sedge fen, tall sedge fen and *Carex stricta* ecotopes are all in the upper left half of the figure. These ecotopes were generally found in areas of spring runs, spring discharge or turgid peat, and where well nests indicated little response of water tables to precipitation events. Ecotopes that are in areas of obvious peat drainage, stream incision, and ponding or floodplain inundation are in the lower right half of the figure. Some of these ecotopes are near the well nests that were responsive to precipitation events. Many of these ecotopes are undoubtedly linked to groundwater discharge, but the relative importance is less than for ecotopes above the dotted line.

In **Figure 5.80**, transect numbers have been replaced with vicinity calciphile scores using both 1995 and 2005 draft technical guidelines. The highest values are on the upper left half of the figure, while the lowest values are on the lower right. This separation also corresponds roughly with the hypothesized separation of ecotopes based on the importance of groundwater discharge.

It is interesting to note the relative locations of Transects 5 and 6 in ordination space compared to the actual locations in the field. On the graph, they are widely separated, reflecting essentially no species in common. Transect 6 occurs in the area of most pristine, native fen plant communities, while Transect 5 is at the extreme of altered, invasive plant communities. In the field, the transects are relatively close to each other. Because transect 5 is in a *Rhamnus* thicket by an incised stream, the ordination demonstrates the threat to the marl fen community by *Rhamnus* encroachment and stream incision and lowering of the water table. The concentration of high point calciphiles and state protected species is in danger of being completely overwhelmed by buckthorn in coming decades.

Drainage of fen ecotopes or reductions of groundwater discharge would alter the plant communities of fen ecotopes. Succession would be towards more disturbed plant communities and/or communities more dependent on surface water. Graphically (in ordination space; Figures 5.79 and 5.80), this would be represented by a movement of transects from the upper left region of the ordination figures to the lower right. This would be accompanied by a reduction in calciphile indicator scores. Species with a high fidelity for calcareous fens would be lost, including many of the state-protected species currently found in the SFWC.

5.4.4 Bryophyte Assessment

Dr. Joannes A. Janssens identified the bryophytes collected along the vegetation transects, as well as bryophytes previously collected during a DNR vegetation relevé sampling in Area 2. He grouped the 2005 samples into four ecotopes, corresponding to one each from Areas 1-3 and a composite from Areas 4 and 5. The number of calcareous fen indicator species in each of the four ecotopes is reported. If three or more indicator species are found on a site, that site meets the bryophyte criteria for calcareous fens. Detailed results are presented in Appendix 2.

5.4.4.1 Area 1

Fifteen species of bryophytes were identified, including eight calcareous fen indicator species. This is consistent with the findings from vascular plants and totals 164 points of bryophyte indicator species.

5.4.4.2 Area 2

Seven species of bryophytes were identified, including five calcareous fen indicator species for a score of 85. The results from the earlier DNR collection yielded six calcareous fen indicator species for a total score of 130. Both surveys satisfy the bryophyte criterion for calcareous fens.

5.4.4.3 Area 3

Five species of bryophytes were identified for a score of 11 points, well below the 50 point threshold. Therefore, the bryophyte criterion was not met for this area, unlike the findings from vascular plants.

5.4.4.4 Area 4

Areas 4 and 5 were combined into a single ecotope sample, from which five bryophyte species were identified. Four of these species are calcareous fen indicator species, thus satisfying the bryophyte criterion with a score of 60. This result is inconsistent with the findings from vascular plants.

5.4.4.5 Area 5

See Area 4 discussion above.

5.4.5 Rare and Protected Species

The SFWC has been designated as an area of outstanding biodiversity significance by the MCBS. This designation reflects the heterogeneity and uniqueness of ecosystems in the area, high species richness, relatively intact native plant communities, and the presence of rare or protected plants. Several state-protected species were noted during a 1995 visit by the MnDNR (unpublished field notes; MnDNR Natural Heritage Information System).

5.4.5.1 Area 1

The greatest concentration of rare and protected vascular plant species in the SFWC is in Area 1 (**Figure 5.81**).The northeast corner of Area 1 has a concentration of protected species on marl substrate. *Eleocharis rostellata* and *Scleria verticillata* are locally abundant in this area, in addition to *Carex sterilis*. *Cladium mariscoides*, and *Triglochin palustris* were all observed as scattered, infrequent individuals or clones. Very few individuals of *C. mariscoides* and *T. palustris* were found.

In August 1995, the DNR placed a relevé (Harris #95015) in this northeast area. *Eleocharis rostellata* was observed to be a dominant species, while *C. sterilis* and *Rhynchospora capillacea* were less common components of the community. *Scleria verticillata* was present at low abundance, and *Triglochin palustris* was not observed. The 2005 PEC survey differs in that *R. capillacea* was not found but *T. palustris* was. The September 2005 sampling may have been too late to observe *R. capillacea* in fruit, when it can be readily identified. If spikelets fall from the plant, it would be difficult to identify this species because of its diminutive stature and the preponderance of vegetatively-similar graminoids in the plant community. Because the marl substrate native calcareous fen ecosystem is largely intact and relatively undisturbed, the apparent absence of *R. capillacea* likely reflects sampling error rather than local site extinction.

Protected species were observed in other locations within Area in 2005. The most abundant species is sterile sedge, *Carex sterilis*, which is found throughout fen plant communities. It is often as a dominant species, especially on organic substrates. Although it is found in a variety of calcareous environments throughout the northeastern United States and adjacent Canadian provinces, in Minnesota, it is largely restricted to calcareous fens. Its status as a threatened species in Minnesota reflects this fidelity to uncommon and fragile fen habitats. However, within the CFC-SFWC areas, it is an abundant species. Figure 5.81 shows the wide distribution of this species within the SFWC and local abundance as measured in quantitative transects.

Cypripedium candidum was observed as scattered individuals or colonies throughout Area 1. *Eleocharis rostellata* was observed at one location outside of the northeast corner of Area 1. It is found at the location where peat was excavated and apparently windrowed. The ridges of the windrows are dominated by weedy, disturbance tolerant vegetation such as *Phalaris arundinacea* and *Typha angustifolia*. In the valleys between the ridges, the substrate was saturated (the peat was turgid) unlike the ridges, and native wetland species were found including *Carex sterilis* and *E. rostellata*. The protected species in this area were found in multiple valleys between the windrows. Apparently, the hydrological conditions allowed the native fen species to out-compete and resist displacement by the invasives. This observation may have important implications for the possibility of restoration of native fen communities.

Another state-protected species, the threatened *Valeriana edulis* var. *ciliata* was observed in the eastern portion on peat substrate in 1995. It was found in the area near Transect 41, which was the site of DNR relevé (#95012). This species was not observed in 2005. It may be present, but at low abundance, and was missed during sampling and walkover surveys. The increasing shrubby growth in the SFWC may reduce its abundance, although it may persist in the seed bank. Management of the fen to limit woody growth, such as through cutting or prescribed burning, may reestablish this species or increase its abundance.

5.4.5.2 Area 2

Two protected species have been documented in Area 2, *Carex sterilis* and *Cypripedium candidum*. Both species were observed in 2005, and the former species was reported by the DNR in 1995. *Carex sterilis* is locally abundant in the southwest portion of Area 2, although it is not as abundant or widespread as it is in Area 1. In 1995, two relevés were sampled by the DNR (Harris #95103 and #95014) in which *Carex sterilis* was reported.

During September sampling, two additional transects (43 and 44) were placed outside the original MLCCS Area 2 calcareous fen polygon. A sedge was noted near these transects that appeared to be *Carex sterilis*. However, because the plant was only vegetative, and not fertile, a positive identification could not be made. It is considered likely that the locations and extent of this species is underestimated north of the railroad embankment.

A single colony of *Cypripedium candidum* was observed in Area 2 in 2005, close to Transect 40. The shrub growth in the vicinity is scattered to thick, and continued fire suppression may reduce populations of these two protected species as well as other native wet meadow and calcareous fen species. Transect 40 was located near the site of the 1995 relevé.

Area 2 apparently lacks marl substrate at the surface, and as such, does not support any of the other protected species characteristic of calcareous fens as found in the northeast portion of Area 1.

5.4.5.3 Area 3

A single protected plant species, *Carex sterilis*, has been observed in Area 3. This species was observed in both 1995 and 2005. As with other calcareous fen plant communities in Areas 1 and 2, the species was found to be locally abundant. In 1995, the species was also reported by the DNR east of Area 2, south of Highway 212. This site was not resurveyed in 2005.

Area 3 apparently lacks marl substrate at the surface, and as such, does not support any of the other protected species characteristic of calcareous fens as found in the northeast portion of Area 1.

5.4.5.4 Area 4

No protected plant species were observed in Area 4. The plant communities present are shrub carr and sedge meadow, rather than calcareous fen. Consequently, the protected plants found in calcareous fen are lacking.

5.4.5.5 Area 5

No protected plant species were observed in Area 5. The plant communities present are marsh and riparian forest, rather than calcareous fen. Consequently, the protected plants found in calcareous fen are lacking.

5.4.6 Disturbance and Vegetation

5.4.6.1 Area 1

The disturbance history of Area 1 is complex, as are the plant communities. Numerous forces have interacted to alter the original ecological processes of the SFWC. Hydrology has been altered through construction of the railroad embankment, attempted drainage, and development of incised streams. This has resulted in the establishment of many ruderal and invasive plant species. Of particular concern are common and glossy buckthorn (*Rhamnus cathartica* and *R. frangula*), *Phragmites australis* and *Phalaris arundinacea*. The central and western portions of Area 1 in particular show signs of altered hydrology. In the central region, the above-listed invasive species cover an extensive area, interspersed with native sedge/wet meadow and calcareous fen communities. In the western zone, *Phalaris arundinacea* is abundant as are other species, such as *Solidago canadensis,* reminiscent of old fields. It appears that the railroad embankment has reduced surface, and possibly, ground water flows to this part of Area 1. The advancement of *Phalaris* up the east side of the peat dome in Area 1 has likely been facilitated by hydrological disturbance.

Shrub growth has expanded dramatically over the past several decades throughout the SFWC. This is likely due to disruption of the natural ecosystem process of periodic burning. Fire suppression results from landscape-level anthropogenic changes, and is, therefore, considered a type of ecological disturbance. In Area 1, the shrubs involved include several species of willow (*Salix* sp.), red-osier dogwood (*Cornus stolonifera*), and exotic, invasive buckthorn. Fire suppression has undoubtedly allowed these species to spread unchecked. Because of their larger stature relative to herbaceous species of fens and wet meadows, the shrubs are superior competitors for light. This shading can thus exclude herbaceous species and reduce the richness and diversity of fen plant communities.

Examination of historic aerial photographs indicates that shrub growth in the SFWC was once minimal but has increased significantly (**Figure 5.82**). A combined analysis of Areas 1-3 indicates that shrub cover averages 15.96% ± 4.64% (mean ± standard error) of the land surface in calcareous fen and adjacent wetland plant communities. Nearly half of this shrub canopy is comprised of buckthorn.

Portions of Area 1 were excavated during the 20th century for mud cures or for peat. This activity would create areas for ruderal species to establish to the detriment of native species. The presence of a decrepit fence line in the northern portion of Area 1 suggests that the fen was used for grazing at one time. It is unknown what impact this may have had on hydrological patterns and plant communities.

5.4.6.2 Area 2

Area 2 has been historically affected by construction of the railroad embankment. This apparently altered hydrology and drainage patterns. It is possible that impoundment and diversion of surface flow has altered succession trajectories on both sides of the embankment. The calcareous fen communities on the north side may have been larger and impounded water increased the area of sedge meadow and shallow marsh. On the south side of the embankment, decreased water availability may have decreased the area of calcareous fen in favor of communities resembling old fields.

The principal disturbances currently threatening the ecological integrity of Area 2 are fire suppression and invasive species. As with other areas of the SFWC, shrub growth, of both native and exotic shrubs, has expanded dramatically in recent decades. Invasive species in the area include common and glossy buckthorn (Rhamnus *cathartica* and *R. frangula*) and *Phragmites australis*. Large colonies of Phragmites are present in Area 2 and can be expected to further expand. The growth of shrubs and exotic species may exclude many native wetland plant species if not suppressed.

5.4.6.3 Area 3

The most obvious disturbance affecting the vegetation of Area 3 is the placement of a radio tower and associated building and cables. Because these structures have been in place for several years, they do not appear to represent an imminent ecological threat to the fen communities. Invasive species have been introduced into the area as a result of soil disturbance during construction. *Phalaris arundinacea* is found on the edges of the fen, but does not have a significant presence within the fen. The fen is surrounded by large stands of *Phragmites australis*. This invasive species appears to be encroaching on the calcareous fen. It is likely that some portion of fen plant communities have already been overwhelmed by clonal expansion of *Phragmites*. Without active management, the entire calcareous fen in Area 3 may be lost to *Phragmites*.

5.4.6.4 Area 4

Area 4 has been historically disturbed by the construction of dirt roads and adjacent ditches. This may have altered wetland hydrology, however number spring discharges are found at the north end of the area. Woody growth and invasive species pose ongoing threats to native plant communities. Woody growth is abundant and has apparently been increasing in recent decades. Invasive species in Area 4 include *Phalaris arundinacea* and *Lythrum salicaria*.

5.4.6.5 Area 5

Area 5 is relatively undisturbed ecologically. A spring discharge supplies water to the wetland complex and a small stream. Invasive species in the area include *Phalaris arundinacea* and *Lythrum salicaria*, which are present, but not dominant, in the plant communities.

6 Conclusions: Phase 1 Characterization of the Seminary Calcareous Fen

6.1 Results Related to Calcareous Fen Criteria

The SFWC is a large wetland complex that is separated into north and south units by the intervening terrace feature. Groundwater flow is to the south towards the Minnesota River. The north unit is approximately 20 feet higher in elevation when compared to the south unit. Groundwater discharge in the north unit is focused at the bluff toe-slope, whereas groundwater discharge to the south unit is focused on the toe-slope positions to the south of the terrace feature. Peat depths are variable throughout the SFWC; however, virtually all of the soils within the wetland are histosols or have histic epipedons. Underlying substrates consist of fine-textured lacustrine material, marl, coprogenous earth, and outwash sands. The aquifer recharge area for the north unit is likely the uplands above the bluff of the Minnesota River. The aquifer recharge area for the south unit is the north unit SFWC and Assumption Creek, with the recharged groundwater flowing through the terrace feature.

Groundwater discharge to both the north and south units is calcareous, resulting in hydrology and water chemistry that uniformly meet the calcareous fen hydrology and water chemistry criteria. The stability of the groundwater discharge results in the formation of histosols that generally contain limited to substantial quantities of precipitated calcium carbonate, thus meeting the soils criterion as well.

Our Phase 1 characterization of the SFWC suggests that the entire wetland system is saturated with respect to calcium carbonate and would meet the calcareous fen hydrology, water chemistry, and soil criteria. The vegetation criterion is met in areas of focused groundwater discharge characterized by active precipitation of solid calcium carbonate. However, because the entire system is carbonated and saturated with respect to calcium carbonate, the presence of limited numbers of calciphiles distributed throughout the wetland plant community is possible. Thus the distinction differentiating calcareous fen from adjacent wetland is the presence of sufficient numbers of calciphiles to meet the vegetation criteria.

6.1.1 CFC Area 1

All portions of CFC Area 1 meet the hydrology criteria of both Berglund (1995) and Leete et al. (2005). Strong upward head gradients observed in Well Nests 1A and 1B confirm the dominance of groundwater discharge in the eastern portion of CFC Area 1 that can be extrapolated to the western portion of CFC Area 1 that presented evidence of sloping peatland and diffuse overland flows. Comparisons of the 1A and 1B well nest hydrologic data indicate that the area of high-quality calcareous fen on sloping peatland represented by Well Nest 1A may be receiving discharge from a different aquifer than other areas within the calcareous fen unit. The coalescence of spring runs near Well Nest 1A into a perennial stream that is actively downcutting through peat and underlying calcareous sediments has resulted in a lowering of the adjacent watertables and the presence of invasive plants that are adapted to drier conditions and water table fluctuation. Headward erosion of the perennial stream constitutes a threat to the unaffected portion of the high-quality calciphile plant community. Data from Well Nest 1B similarly indicate groundwater discharge, but the close relationship between the piezometer and water table well hydrograph traces indicates that the area is affected by historic tile drainage.

All portions of CFC Area 1 meet the water chemistry criteria proposed of both Berglund (1995) and Leete et al. (2005). The presence of elevated EC and chloride and the accumulation of heavy oxygen and hydrogen isotopes associated with ground- and surface water samples collected from and near Well Nest 1A is a further indication that the high quality calcareous fen is receiving groundwater discharge from a different aquifer than that which discharges to other areas within CFC Area 1, and CFC Areas 2, 3, 4, and 5.

All portions of CFC Area 1 meet the soil criteria of both Berglund (1995) and Leete et al. (2005). All of the soils are histosols or have histic epipedons. The presence of stratified marl and peat horizons within the soil profiles suggests an alternating sequence of spring-head and spring-run formation and abandonment that may be characteristic of the area. Soil profiles collected from the large peat mound represented by Well Nest 1B are similarly stratified, indicating that the peat mound was historically a high-quality calcareous fen similar to the high-quality sloping fen represented by Well Nest 1A. However, the presence of drain tile and invasive plants, combined with a calcium-carbonate depleted zone observed in the profile described on the top of the peat mound, suggests that the calcareous peat mound fen has been adversely affected by partial drainage.

Most portions of CFC Area 1 meet the vegetation criteria of both Berglund (1995) and Leete et al. (2005). The area represented by Well Nest 1A presents the greatest diversity and the highest calciphile point counts of any of the areas examined during the Phase 1 characterization. However, the partial drainage resulting from downcutting of the perennial stream has impacted the adjacent plant community, which lacks calciphiles. Similarly, the calciphile plant community associated with the peat mound in the area of Well Nest 1B has been impacted by drainage and includes invasive and native plants that are adapted to drier conditions and varying water table depths. However, calciphilic plants (most notably *Carex sterilis* and *Carex prairea*, but in a few microsites, *Triglochin maritimum*) are persisting in the area. The peat mound has been adversely affected by partial drainage, and represents an excellent opportunity for restoration.

6.1.2 CFC Area 2

A portion of calcareous fen that met all of the calcareous fen criteria was added to the original MLCCS map unit. This area exists as a narrow peninsula that extends from the north central portion of the original MLCCS unit north to the toe of the bluff.

All portions of CFC Area 2 meet the calcareous fen hydrology criterion of both Berglund (1995) and Leete et al. (2005). However, upward hydraulic gradients reflected in Well Nests 2A and 2B are not large, and reflect the dominance of groundwater throughflow with weak discharge components as opposed to having areas of focused groundwater discharge. CFC Area 2 exists as a gently sloping, uniform peatland characterized by the absence of significant spring heads and spring runs that are typical hydrologic features of calcareous fens. There is a possibility that significant groundwater recharge occurs through calcareous sediments of the alluvial fans that flank the northern portion of CFC Area 2.

All of the soils in CFC Area 2 meet the calcareous fen soils criterion. However, large quantities of calcium carbonate are generally absent in the soil profiles. The absence of stratified peat and marl layers further indicates that CFC Area 2 is characterized more by throughflow with calcareous groundwater than by areas of active, focused discharge. The area is characterized by relatively deep peat underlain by lacustrine sediment.

All of the surface water and groundwater samples collected from CFC Area 2 would meet the calcareous fen criteria. All of the samples present similar major ionic constituents, and are similar in heavy isotopes of oxygen and hydrogen. The chemical data indicate that the entire system including groundwater and surface water is saturated with respect to calcium carbonate.

Similarly, most portions of CFC Area 2 would meet the calcareous fen vegetation criteria of both Berglund (1995) and Leete et al. (2005). However, the plant community is relatively depauperate in calciphiles with the exception of *Carex sterilis* and *Carex prairea*. Several other calciphiles that were observed were spread thinly within the wetland plant communities. The lack of a discrete calciphile plant community is a further indication that CFC Area 2 represents a carbonated system that lacks areas of focused groundwater discharge.

CFC Area 2 has the highest potential for adverse impact from alternative alignments E-1A and E-2 due to the close proximity of the alignments to the unit. Impacts on all calcareous fen areas will be evaluated in Phase 2.

6.1.3 CFC Area 3

CFC Area 3 is located in the south unit SFWC and is distant from the bluff toeslope where groundwater discharge originating as aquifer recharge in the uplands above the bluff would be most intense. All portions of CFC Area 3 meet the calcareous fen hydrology criterion of both Berglund (1995) and Leete et al. (2005). However, upward hydraulic gradients reflected in Well Nests 3A are not large, and reflect the dominance of groundwater throughflow with weak discharge components as opposed to having areas of focused groundwater discharge. In addition, the close correspondence of the piezometer and water table well hydrographs with each other and with precipitation events suggests that the area of groundwater recharge is close and may be the terrace feature and Assumption Creek itself. CFC Area 3 exists as a steeply sloping, uniform peatland characterized by the absence of significant spring heads and spring runs that are typical hydrologic features of calcareous fens.

All of the soils examined in CFC Area 3 meet the calcareous fen soils criterion. However, large quantities of calcium carbonate are generally absent in the surface of the soil profiles. The absence of stratified peat and marl layers in the soil surface further indicates that CFC Area 3 is currently characterized more by throughflow with calcareous groundwater than by areas of active, focused groundwater discharge. The area is generally characterized by relatively deep peat underlain by sandy sediments. The presence of stratified marl and peat sediments in the subsoil of profile SP3A2 suggests that the area may have been calcareous fen more similar to that described for the high-quality sloping peatland in CFC Area 1. However, the presence of thick, uniform peat deposits over the subsoil suggests that the hydrologic characteristics that produced the stratification in profile SP3A2 are no longer active.

All of the groundwater samples collected from CFC Area 3 would meet the calcareous fen criteria. All of the samples present similar major ionic constituents, and are similar in heavy isotopes of oxygen and hydrogen. The chemical data indicate that the entire system including groundwater and surface water is saturated with respect to calcium carbonate.

Similarly, portions of CFC Area 3 meet the calcareous fen vegetation criteria of both Berglund (1995) and Leete et al. (2005). However, while calciphiles are present in the plant community, they are not as abundant as seen in calcareous fen portions of Areas 1 and 2. Several calciphiles observed were spread thinly within the wetland plant communities, further indicating that CFC Area 3 represents a carbonated system that lacks areas of focused groundwater discharge that would produce the calciphile plant community observed in the high quality sloping calcareous fen discussed for Area 1, above.

6.1.4 CFC Areas 4 and 5

CFC Areas 4 and 5 are located in the south unit SFWC within the floodplain of the Minnesota River. Both units would meet the calcareous fen hydrology, water chemistry, and soils criteria. The presence of the hydrology criterion can be assumed based on the presence of extensive spring-head and spring-run surface-flow features. The chemical criterion can be assumed based on the presence of spring run major ion chemistry that would similarly meet the water chemistry criterion. All of the soil examined were histosols or had histic epipedons, thus meeting the soils criteria.

However, all of the soils examined contained mineral strata that are the result of sediment deposition during flooding of the Minnesota River. Regular flooding precludes the development of calcareous fens because of the flooding disturbance and the introduction of high levels of nutrients present in the alluvial sediment.

Neither area would meet the vegetation criterion of either Berglund (1995) or Leete et al. (2005). The plant community is robust and dominated by rank, non-calciphilic plant species that are characteristic of floodplain wetlands (such as *Acorus americanus* and *Sparganium eurycarpum*). Combined, Areas 4 and 5 meet the proposed bryophyte criteria. However, we believe that CFC Areas 4 and 5 were mapped incorrectly as calcareous fen. MLCCS mapping for these areas was likely based on the presence of hydrology and soils that would meet the calcareous fen criteria without consideration of the vascular plant community.

6.2 Recommendations for Phase 2 Assessment of Potential Impacts

Both alternative alignments E-1A and E-2 are located to the west of the SFWS CFC Area 1, which is hydrologically separated from the alternatives by the railroad embankment. Because of the hydrologic separation produced by the railroad embankment and the distance from both of the alternative alignments, it is our opinion that Phase 1 information suggests that it is unlikely that either alternative would have a substantial impact on CFC Area 1.

However, there is the potential for substantial direct impacts to CFC Area 2, and potential indirect impacts to CFC Areas 3, 4 and 5. CFC Area 2 is in close proximity to alignment E-2. Alternative alignment E-1A is located within the western portion of the north unit of the SFWC and follows the bluff line where groundwater discharge results in spring heads and spring runs that flow to a confluence with the westerly flowing tributary to the north of the railroad embankment. Surface flows join to form Assumption Creek that subsequently flows across the terrace feature. The Assumption Creek piezometer data indicate that the losing portion of Assumption Creek provides much of the groundwater feeding CFC Areas 3, 4 and 5. Direct impacts may be more significant for alternative alignment E-2 due to its close proximity to CFC Area 2. Impacts to all calcareous fen areas will be evaluated under Phase 2.

The following is a list of considerations for a Phase 2 impact assessment of alternative alignments on the CFC-SFWC characterized above. The Phase 2 assessment should concentrate on the overall regional hydrology of the SFWC to investigate potential impacts on all of the areas that meet the calcareous fen criteria in Leete et al. (2005). However, the Phase 1 assessment suggests that CFC Area 1 will not likely be affected by either alternative alignment E-1A or E-2. Phase 2 will provide additional detail to assist in confirming or refuting this assertion.

1. The Phase 1 characterization of the CFC-SFWC provided a cursory review of the north unit SFWC west of CFC Area 2. A more detailed review of the western portion of the north unit SFWC needs to be performed to ensure that no outliers of calcareous fen exist in the area. We suggest that hydrology, soils, water chemistry, and vegetation in the western portion of the north unit that contains alternatives E-1A and E-2 be assessed along a grid directed by air photo interpretation. Seasonality is important for the botanical survey, and more than one review may be necessary in specific locations.

2. A detailed plant community inventory of ecotopes within a specific distance of the E-1A and E-2 alignments should be performed under Phase 2 (e.g. 500 feet either side of the applicable alternative). The communities should be ranked by quality, size, and sensitivity to a particular impact. Some communities may be sensitive to compaction, some more sensitive to salt loading, some more sensitive to shading, etc. Detailed literature reviews would be necessary to assess potential impacts to individual plant communities.

3. Impacts need to be assessed in the context of specific construction procedures and proposed features of the alignments, including span width, length, construction methods, timing for specific procedures and total length of time expected for completion, location of staging areas, fill pads, pier placement and dewatering requirements, and erosion control methods.

4. An assessment of the location and environmental characteristics of the areas directly impacted that would need to be mitigated should be performed.

5. An assessment of temporary impacts will need to be evaluated in the context of the proposed construction methods. For example, if winter construction is considered, what are the impacts to the plant community from loading and traffic on the snow/ice road, what are the impacts during melt? Erosion control, especially in the erosive bluff areas that have long delivered sediment to alluvial fans near CFC Area 2 will need to be evaluated. Specific questions would include: What plant communities are particularly sensitive to what disturbance type? Are there areas where temporary fill is required? What is the potential for revegetation success in impacted areas?

6. The direct, long-term impacts of shading and winter salting need to be determined for post-construction road operation, especially on the portions of CFC Area 2 that are adjacent to proposed alignment E-2. The focus should be on the plant communities that are most sensitive, and how have impacts been minimized and/or mitigated in the past. The potential for CO_2,CO and NO_X impacts to plant communities should be assessed.

7. The Phase 1 characterization data discussed above indicate that much of the wetland complex consists of peat over fine-textured sediments over sand, with focused groundwater discharge occurring where fine-textured sediments are thin or non-existent. The Phase 1 assessment of Assumption Creek hydrology suggests that much of the groundwater discharged near the bluff recharges the groundwater at the north terrace contact and in the stream bed, and then emerges as spring heads south of TH 212. The potential for salt movement and impacts to plant communities should be assessed in a hydrogeologic context for the entire SFWC with careful attention to calciphile communities in CFC Area 3.

Some potential impacts will be difficult to describe due to the hydrologeologic complexity of the area and interactions between the factors that combine to produce conditions favorable for calcareous fen development. The direction the Phase 2 assessment takes will be dependent upon the availability of appropriate literature that can be applied to the specific setting of the SFWC and the proposed alternative alignments. The Phase 2 assessment should evaluate potential impacts based on the existing literature refined with additional field work applicable to the specific alignment alternative.

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Tables

Table 1 Modified Braun-Blanquet Cover Class Scale for visual estimation of vascular plant cover.

Cover Class Value	Cover Range	Median
1	0-5%	2.5%
2	6-25%	15.5%
3	26-50%	38%
4	51-75%	63%
5	76-95%	85.5%
6	96-100%	98%

Table 2 Calciphile Indicator Vascular Plant Species. Point values are from Berglund (1995) and Leete et al. (2005).

1995 Point Value	2005 Regional Point Value (Minnesota Valley)	Species	Common Name
25	25	*Carex prairea*	prairie sedge
25	25	*Carex sterilis*	dioecious sedge
25	25	*Eleocharis rostellata*	beaked spikerush
25	25	*Rhynchospora capillacea*	needle beaksedge
25	25	*Scleria verticillata*	low nutrush
25	25	*Triglochin palustris*	marsh arrowgrass
5	25	*Cladium mariscoides*	smooth sawgrass
5	25	*Parnassia glauca*	American grass-of-Parnassus
5	--	*Primula mistassinica*	Mistassini primula
5	25	*Scirpus cespitosus*	tufted bulrush
5	25	*Tofieldia glutinosa*	sticky false asphodel
5	5	*Salix candida*	sageleaf willow
5	5	*Valeriana edulis*	edible valerian
5	0	*Carex viridula*	little green sedge
5	0	*Juncus alpino-articulatus*	northern green rush
5	0	*Juncus brevicaudatus*	narrow panicled-rush
5	0	*Saxifraga pensylvanica*	swamp-saxifrage
1	25	*Lobelia kalmii*	brook lobelia
1	25	*Potentilla fruticosa*	shrubby cinquefoil
1	25	*Triglochin maritima*	seaside arrowgrass
1	5	*Cardamine bulbosa*	bulbous bittercress
1	5	*Carex hystericina*	bottlebrush sedge
1	5	*Liparis loeselii*	yellow widelip orchid
1	5	*Oxypolis rigidior*	stiff cowbane
1	0	*Carex granularis*	limestone meadow sedge
1	0	*Parnassia palustris*	Arctic grass-of-Parnassus
0	5	*Aster borealis*	northern bog aster
0	5	*Berula erecta*	cutleaf waterparsnip
0	5	*Betula pumila*	bog birch
0	5	*Bidens coronata*	crowned beggarticks
0	5	*Bromus ciliatus*	fringed brome
0	5	*Carex aquatilis*	long-bracted tussock sedge
0	5	*Carex interior*	inland sedge
0	5	*Gentianopsis procera*	lesser fringed gentian
0	1	*Eriophorum angustifolium*	tall cottongrass

Table 3 Rare and Protected Vascular Plant Species Reported from the Seminary Fen Wetland Complex[1].

Species	Common Name	State Status
Carex sterilis	Sterile sedge	Threatened
Cladium mariscoides	Twig-rush	Special Concern
Cypripedium candidum	Small white lady's-slipper	Special Concern
Eleocharis rostellata	Beaked spikerush	Threatened
Rhychospora capillacea	Hairlike beakrush	Threatened
Scleria verticillata	Whorled nutrush	Threatened
Triglochin palustris	Marsh arrowgrass	Formerly Special Concern[2]
Valeriana edulis var. *cilata*	Edible valerian	Threatened

[1] As documented by the DNR Natural Heritage Program. None of these species are protected under the Federal Endangered Species Act.

[2] *Triglochin palustris* was previously listed by the DNR as a Species of Special Concern. However, discovery of additional populations demonstrated that the species was not as rare as suspected. However, the DNR continues to track records of the species to insure that protected status in the future is not necessary; H. Texler, pers. comm..

Table 4
Water Chemistry Data Collected from the Seminary Fen Wetland Complex, 2005. Calcareous Fen Chemical Criteria (Leete, 2005) are shaded in gray. Yellow shading indicates samples that meet the applicable chemical criterion

Sample ID	Date	pH[6]	EC[7]	Cations[1]					Anions[2]			Criteria Ratios[3]		Calcite SI[4]	Isotope Data[5]	
				Ca	Ca	Mg	Na	K	Alk.[8]	Cl	SO4	CaMg Ratio	Alkalinity Ratio		δ18O ‰	δD ‰
			uS/cm	mg/L	Meq (+) /L				Meq (-)/L			%	%		‰	‰
SFWC-CFC Area 1																
1PZA1	8/30/05	7.11	925	130	6.47	3.93	0.47	0.11	7.60	1.41	1.37	95	73	0.29	-8.4	-60.6
1WTA1	8/30/05	6.9	914	119	5.96	3.66	0.43	0.10	7.84	1.13	1.26	95	77	0.07	-8.9	-60.9
1PZA1	9/22/05	7.06	946	129	6.44	3.88	0.47	0.09	7.59	1.37	1.35	95	74	0.31		
1WTA1	9/22/05	6.93	940	127	6.33	3.80	0.46	0.09	11.59	1.38	1.39	95	81	0.34		
1PZB1	8/30/05	7.25	620	86	4.28	2.84	0.38	0.10	7.08	0.06	0.49	94	93	0.26	-5.5	-43.7
1WTB1	8/30/05	7.09	625	93	4.64	2.68	0.38	0.10	7.20	0.06	0.14	94	97	0.13	-5.4	-42.7
1PZB1	9/22/05	7.36	639	86	4.32	2.85	0.39	0.08	8.79	0.05	0.50	94	94	0.49		
1WTB1	9/22/05	7.17	682	95	4.73	2.71	0.40	0.08	7.15	0.05	0.14	94	97	0.31		
1SW1	8/30/05	7.71	908	121	6.04	3.81	0.71	0.13	7.64	1.74	1.25	92	72	0.85	-8.3	-58.9
1SW1	9/21/05	7.47	931	123	6.12	3.76	0.80	0.11	7.51	1.83	1.19	92	71	0.69		
1SW2	8/30/05	7.26	906	126	6.27	4.00	0.39	0.14	8.16	1.14	2.18	95	71	0.47	-8.6	-58.8
1SW2	9/21/05	7.25	910	122	6.07	3.72	0.37	0.10	8.19	1.05	2.04	95	73	0.53		
1SW3	8/30/05	7.31	683	99	4.92	3.14	0.37	0.10	11.08	0.13	0.99	94	91	0.56	-6.7	-49.1
1SW3	9/21/05	7.34	705	99	4.96	3.06	0.39	0.09	7.59	0.14	0.77	94	89	0.49		
1SW4	8/30/05	7.27	693	119	5.93	3.24	0.41	0.13	10.12	0.05	1.14	94	89	0.56	-5.4	-42.1
1SW4	9/21/05	7.44	671	88	4.39	2.78	0.39	0.12	6.63	0.08	0.75	93	89	0.56		
1SW5	8/30/05	7.54	697	95	4.76	2.86	0.41	0.10	8.18	0.19	0.62	94	91	0.82	-6.1	-45.5
1SW5	9/21/05	7.46	694	99	4.92	2.86	0.42	0.08	8.03	0.19	0.72	94	90	0.63		
1SW7	8/30/05	7.98	684	95	4.76	3.05	0.51	0.10	8.52	0.34	0.69	93	89	1.09	-5.8	-46.4
1SW7	9/21/05	7.86	706	99	4.94	3.04	0.52	0.09	7.35	0.33	0.67	93	88	1.02		
SFWC-CFC Area 2																
2PZA1	8/30/05	7.63	492	75	3.74	1.95	0.28	0.09	7.20	0.05	0.30	94	95	0.56	-4.4	-37.9
2WTA1	8/30/05	6.96	564	88	4.38	1.93	0.32	0.07	5.52	0.03	1.22	94	82	-0.12	-5.6	-36.1
2PZA1	9/22/05	7.58	488	68	3.42	1.92	0.30	0.07	6.55	0.03	0.21	94	96	0.51		
2WTA1	9/22/05	6.99	618	93	4.64	2.03	0.31	0.06	7.55	0.03	0.40	95	95	0.15		
2PZB1	10/21/05	7.2	280	80	3.99	2.64	0.39	0.10	6.88	0.04	0.08	93	98	0.19	-5.4	-43.0
2WTB1	10/21/05	7.17	264	77	3.85	2.19	0.32	0.07	5.36	0.04	0.30	94	94	0.05	-5.2	-32.0

(continued)

Table 4. Continued

Sample ID	Date	pH[6]	EC[7]	Cations[1]					Anions[2]			Criteria Ratios[3]		Calcite SI[4]	Isotope Data[5]	
				Ca	Ca	Mg	Na	K	Alk.[8]	Cl	SO4	CaMg Ratio	Alkalinity Ratio		δ18O ‰	δD ‰
			uS/cm	mg/L	Meq (+) /L				Meq (-)/L			%	%		‰	‰
2SW1	8/30/05	7.2	677	96	4.78	3.06	0.44	0.04	8.23	0.01	0.27	94	97	0.34	-4.8	-31.4
2SW1	9/21/05	7.08	697	92	4.60	2.68	0.43	0.06	8.26	0.06	0.11	94	98	0.32		
2SW2	8/30/05	8.07	629	93	4.63	2.71	0.45	0.05	6.64	0.07	0.39	94	94	1.08	-5.7	-37.6
2SW2	9/21/05	7.84	632	90	4.49	2.57	0.44	0.04	7.79	0.09	0.13	94	97	0.98		
2SW3[9]	8/30/05	7.58	616	97	4.86	2.26	0.40	0.08	6.12	0.40	0.76	94	84	0.57	-6.4	-42.4
2SW3	9/21/05	7.74	638	97	4.84	2.19	0.37	0.06	6.27	0.40	0.55	94	87	0.84		
2SW4	8/30/05	7.91	633	96	4.77	2.41	0.43	0.08	6.23	0.32	0.68	93	86	0.95	-6.2	-41.5
2SW4	9/21/05	7.8	634	95	4.72	2.34	0.40	0.06	6.47	0.28	0.41	94	90	0.90		
SFWC-CFC Area 3																
3PZA1	8/30/05	7.43	691	92	4.58	2.89	0.66	0.09	7.19	0.28	0.97	91	85	0.51	-7.7	-58.6
3WTA1	8/30/05	7.34	647	91	4.56	2.87	0.67	0.10	7.28	0.23	0.56	91	90	0.37	-5.7	-42.7
3PZA1	9/22/05	7.48	683	90	4.49	2.87	0.66	0.07	7.59	0.19	0.92	91	87	0.59		
3WTA1	9/22/05	7.32	696	94	4.68	2.90	0.65	0.09	7.39	0.19	0.35	91	93	0.46		
SFWC-CFC Area 4																
4SW1[9]	8/30/05	7.67	545	75	3.73	2.33	0.46	0.10	5.92	0.15	0.40	92	92	0.55	-5.0	-41.2
4SW1[9]	9/21/05	7.67	547	75	3.76	2.25	0.46	0.09	6.11	0.16	0.39	92	92	0.64		
SFWC-CFC Area 5																
5SW1[9]	8/30/05	7.69	537	75	3.72	2.18	0.44	0.09	6.08	0.26	0.48	92	89	0.56	-5.1	-42.4
5SW1[9]	9/21/05	7.81	552	75	3.73	2.16	0.48	0.08	6.27	0.28	0.50	91	89	0.83		
SFWC Bluff Top Wetlands																
BPSW1	9/22/05	6.97	169	24	1.18	0.41	0.24	0.04	2.04	0.18	0.12	85	87	-0.90	-3.5	-19.1
BPSW2	9/22/05	8.27	392	54	2.68	1.40	0.27	0.04	3.83	0.32	0.33	93	85	1.01	-4.7	-30.9
BPSW3	9/22/05	6.94	261	30	1.50	0.65	0.48	0.10	2.27	0.86	0.05	79	71	-0.74	-1.6	-19.9

1 – Major cations include: Ca – calcium, Mg – Magnesiou, Na – sodium, K - potassium
2 – Major anions include: Alk. – alkalinity, Cl – chloride, SO4 - sulfate
3 – Cation and anion ratios as specified in Leete et al. 2005. CaMg ratio is (Ca+Mg)/(Ca+Mg+Na+K). Alkalinity ratio = (Alkalinity)/(Alkalinity+Cl + SO4). All units as meq/L
4 – Calcite saturation index calculated based on chemical activities using Rockware[tm] AqQA geochemical modeling software. Positive calcite SI values indicate probable equilibrium with solid calcite, and the potential to readily precipitate calcium carbonate upon evaporation, pH increase, or out-gassing of CO2.
5 – Heavy oxygen and hydrogen isotope values in parts per mil deviation relative to standard mean ocean water.
6 – pH determined in the field, Calcareous fen chemical criteria require pH > 6.7.
7 – Electrical conductivity determined in the field. . Calacareous fen chemical criteria require EC > 500 uS/cm
8 – Alkalinity by acid titration performed in the lab on chilled samples within 24 hours of collection. . Calacareous fen chemical criteria require Alkalinity > 1.65 meq/L.
9 – Values are close enough to consider the calcareous fen criteria to be met as all other chemical criteria are met.

Table 5 Vascular Plant Species Documented in the Seminary Fen Wetland Complex: 1995, 2005

Latin Name	Common Name
Acorus americanus	sweet-flag
Agrostis stolonifera	creeping bentgrass
Amorpha fruticosa	desert false indigo
Andropogon gerardii	big bluestem
Angelica atropurpurea	purplestem angelica
Apocynum cannabinum	indianhemp
Aster borealis	northern bog aster
Aster firmus	purplestem aster
Aster novae-angliae	New England aster
Aster spp.	aster
Aster umbellatus	parasol whitetop
Bidens spp.	beggars ticks
Boehmeria cylindrica	smallspike false nettle
Bromus ciliatus	fringed brome
Calamagrostis canadensis	bluejoint grass
Calamagrostis stricta	northern reedgrass
Caltha palustris	yellow marsh marigold
Campanula aparinoides	marsh bellflower
Cardamine bulbosa	bulbous bittercress
Carex aquatilis	long-bracted tussock sedge
Carex buxbaumii	Buxbaum's sedge
Carex cordorrhiza	creeping sedge
Carex granularis	limestone meadow sedge
Carex hystericina	bottlebrush sedge
Carex interior	inland sedge
Carex lacustris	lake sedge
Carex lasiocarpa	woolyfruit sedge
Carex livida	livid sedge
Carex oligosperma	few seeded sedge
Carex prairea	prairie sedge
Carex sartwellii	Sartwell's sedge
Carex sterilis	sterile sedge
Carex stipata	owlfruit sedge
Carex stricta	tussock sedge
Carex tetanica	rigid sedge
Carex vesicaria	blister sedge
Carex viridula	little green sedge
Chelone glabra	turtlehead
Cicuta bulbifera	bulblet-bearing water hemlock
Cicuta maculata	spotted water hemlock
Cirsium muticum	swamp thistle
Cladium mariscoides	smooth sawgrass
Convolvulus arvensis	field bindweed
Cuscuta spp.	dodder
Cypripedium candidum	white lady's slipper
Echinocystis lobata	wild cucumber
Eleocharis compressa	flat stem spikerush
Eleocharis elliptica	elliptic spikerush
Eleocharis erythropoda	bald spikerush
Eleocharis rostellata	beaked spikerush
Epilobium leptophyllum	bog willow herb
Epilobium spp.	willow herb
Equisetum arvense	field horsetail
Equisetum pratense	meadow horsetail
Eriophorum angustifolium	tall cottongrass
Eupatorium maculatum	spotted joepyeweed
Eupatorium perfoliatum	common boneset
Euthamia graminifolia	flat-topped goldenrod
Fragaria virginiana	Virginia strawberry
Galium boreale	northern bedstraw
Galium labradoricum	northern bog bedstraw
Galium spp.	bedstraw
Gentianopsis procera	lesser fringed gentian
Glyceria striata	fowl mannagrass
Helenium autumale	sneezeweed
Helianthus giganteus	giant sunflower
Helianthus grosseserratus	sawtooth sunflower
Hierchloe odorata	sweetgrass
Humulus lupulus	hops
Hypoxis hirsuta	common goldstar
Impatiens capensis	jewelweed
Juncus alpino-articulatus	northern green rush
Juncus brevicaudatus	narrow panicled-rush
Lathyrus palustris	marsh pea
Leersia oryzoides	rice cutgrass
Liatris ligulistylis	Rocky Mountain blazing star
Liparis loeselii	yellow widelip orchid
Lobelia kalmii	brook lobelia
Lycopus americanus	American water horehound
Lycopus uniflorus	northern bugleweed
Lysimachia ciliata	fringed loosestrife
Lythrum salicaria	purple loosestrife

Table 5 Vascular Plant Species Documented in the Seminary Fen Wetland Complex: 1995, 2005 (Cont.)

Latin Name	Common Name
Mentha canadensis	wild mint
Muhlenbergia glomerata	spiked muhly
Muhlenbergia racemosa	marsh muhly
Muhlenbergia richardsonis	mat muhly
Panicum spp.	panicum
Parnassia glauca	American grass-of-Parnassus
Pedicularis lanceolata	swamp lousewort
Phalaris arundinacea	reed canarygrass
Phragmites australis	common reed
Pilea fontana	lesser clearweed
Poa palustris	fowl bluegrass
Poa pratensis	Kentucky bluegrass
Potentilla fruticosa	shrubby cinquefoil
Prenanthes racemosa	purple rattlesnakeroot
Primula mistassinica	Mistassini primula
Pycnanthemum virginianum	common mountain mint
Rhynchospora capillacea	needle beaksedge
Rorippa nasturtium-aquaticum	watercress
Rubus pubescens	dwarf red blackberry
Rubus strigosus	grey leaf red raspberry
Rumex orbiculatus	greater water dock
Sagittaria latifolia	broadleaf arrowhead
Salix bebbiana	Bebb's willow
Salix candida	sageleaf willow
Salix discolor	pussy willow
Salix exigua	sandbar willow
Salix gracilis	meadow willow
Salix lucidua	shining willow
Salix serissima	autumn willow
Saxifraga pensylvanica	swamp-saxifrage
Scirpus acutus	hardstem bullrush
Scirpus atrovirens	green bulrush
Scirpus cespitosus	tufted bulrush
Scirpus fluviatilis	river bulrush
Scirpus pungens	common three-square
Scirpus validus	softstem bulrush
Scleria verticillata	low nutrush
Scutellaria galericulata	marsh skullcap
Senecio pseudaureus	western golden ragwort
Silphium perfoliatum	cup plant
Sium suave	hemlock waterparsnip
Smilacina stellata	starry false lily of the vally
Solidago canadensis	Canada goldenrod
Solidago gigantea	giant goldenrod
Solidago riddellii	Riddell's goldenrod
Sparganium eurycarpum	broadfruit bur-reed
Spartina pectinata	prairie cordgrass
Taraxacum officinale	dandelion
Thalictrum dasycarpum	purple meadow-rue
Thylepteris palustris	marsh fern
Triglochin maritima	seaside arrowgrass
Triglochin palustris	marsh arrowgrass
Typha angustifolia	narrowleaf cattail
Typha latifolia	broadleaf cattail
Urtica dioica	stinging nettle
Valeriana edulis	edible valerian
Verbena hastata	swamp verbena
Viola nephrophylla	northern bog violet
Zizia aurea	golden zizia

Table 6 Summary of Seminary Fen Ecotopes, Based on Dominant Vascular Plant Species.

Ecotope	Significant Species	Transects	Area
A. Short sedge fen lawn/marl meadow	*Eleocharis rostellata, Scleria verticillata, Muhlenbergia glomerata, Triglochin maritimum, Parnassia glauca*	6, 10	1
B. Tall sedge fen	*Carex prairea, Carex sterilis, Carex sartwellii, Carex aquatilis, Carex stricta, Carex interior, Carex granularis, Carex hystericina, Carex buxbaumii, Muhlenbergia glomerata, Scirpus acutus*, sometimes *Carex lacustris*	1, 9, 18, 42	1
		40, 43, 44	2
		30, 31	3
C. *Carex stricta* seep/spring run	*Carex stricta, Carex prairea, Carex tetanica, Carex hystericina*	4, 7, 15, 41	1
D. *Carex-Thalictrum* meadow	*Thalictrum dasycarpum, Carex prairea, Carex sterilis, Carex sartwellii, Carex stricta, Carex buxbaumii, Carex granularis, Carex lacustris, Carex hystericina, Muhlenbergia glomerata, Muhlenbergia richardsonis, Calamagrostis canadensis, Calamagrostis stricta*	12, 16, 25, 26, 27	1
		28	3
E. *Carex-Solidago* meadow	*Carex prairea, Carex sartwellii, Carex sterilis Carex granularis, Solidago canadensis, Solidago gigantea, Aster puniceus/Aster firmus* complex, *Aster umbellatus, Helianthus grosseserratus, Helianthus giganteus, Euthamia graminifolia, Silphium perfoliatum.*	21, 22, 23	1
F. *Phalaris arundinacea*	*Phalaris arundinacea, Apocynum cannabinum*	2, 14	1
G. *Phalaris-Typha*	*Phalaris arundinacea, Typha angustifolia*	19, 29	1
H. *Carex lacustris*	*Carex lacustris*	17, 24	1
		37, 38, 39	2
I. *Carex lacustris-Acorus americanus*	*Carex lacustris, Acorus americanus, Phragmites australis*	32, 33, 34	4
J. *Acorus americanus-Sparganium eurycarpum*	*Acorus americanus, Sparganium eurycarpum, Carex lacustris, Leersia oryzoides*	36	5
K. *Typha angustifolia*	*Typha angustifolia, Impatiens capensis, Carex stricta, Carex prairea, Carex sterilis*	8, 13	1
L. *Rhamnus*	*Rhamnus cathartica, Rhamnus frangula*	5	1
M. *Phragmites australis*	*Phragmites australis*	N/A	1, 2, 3
N. Shrub carr	*Cornus stolonifera, Salix discolor, Salix bebbiana,* other *Salix* spp.	N/A	1, 2, 3, 4

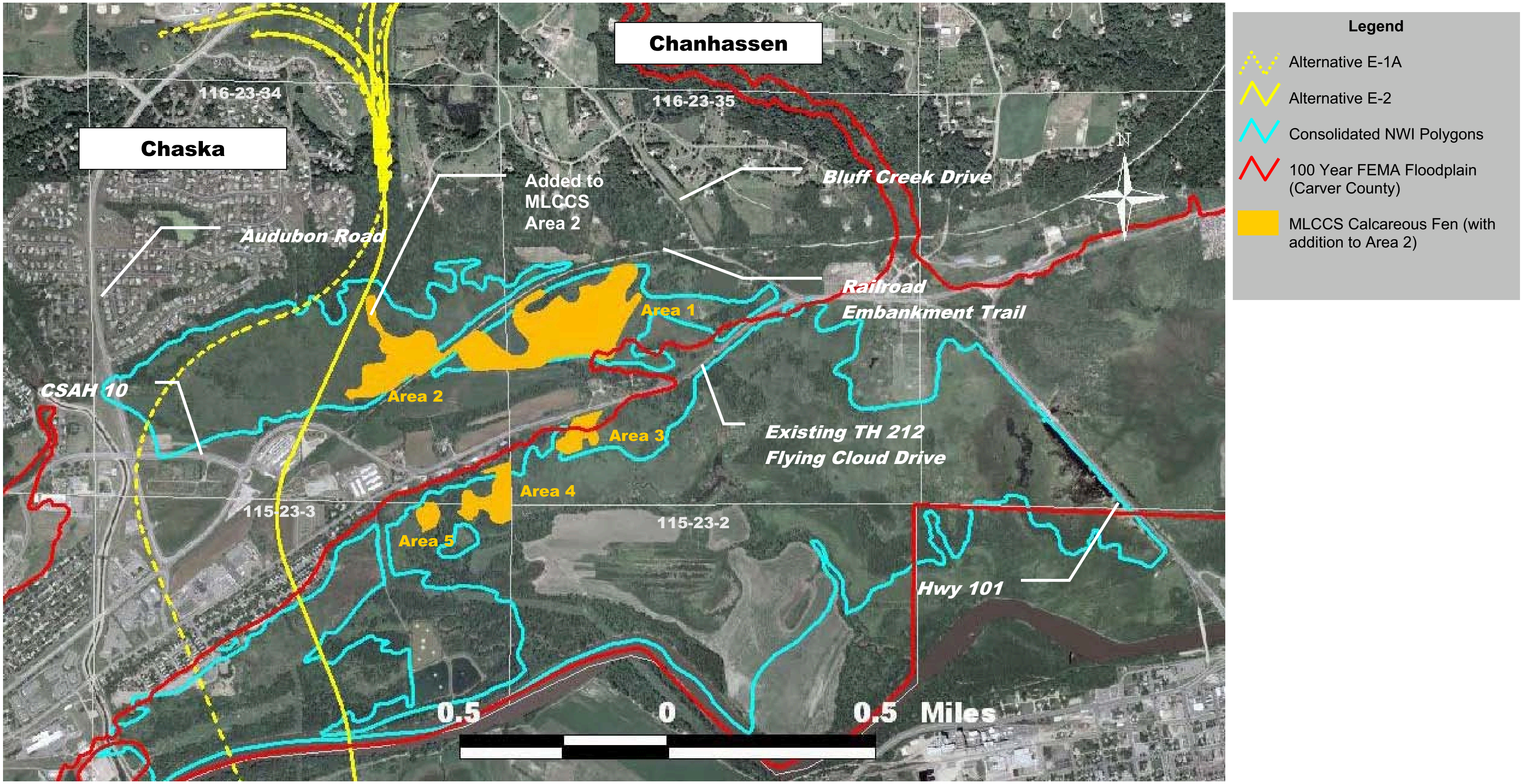
Table 7 Seminary Fen Transect Vascular Plant Calciphile Scores. Vicinity Scores are for a presence-absence cumulative species list compiled through walkover surveys. Plot Scores are for species found within the subplots along each transect.

Transect	Calciphile Indicator Species List Used	Vicinity Score	Plot				
			1	2	3	4	5
1	1995	67	0	1	0	1	25
	2005	110	5	5	0	15	25
2	1995	0	0	0	0	0	0
	2005	0	0	0	0	0	0
4	1995	2	0	1	0	0	0
	2005	15	5	5	0	0	0
5	1995	1	1	0	0	0	1
	2005	0	0	0	0	0	0
6	1995	113	56	26	0	0	1
	2005	215	100	55	5	5	30
7	1995	27	26	26	1	1	25
	2005	45	30	30	5	5	25
8	1995	1	0	0	0	0	0
	2005	5	0	0	0	0	0
9	1995	51	0	0	0	0	25
	2005	65	15	5	0	0	25
10	1995	107	0	30	0	0	5
	2005	190	5	50	0	5	25
12	1995	1	1	1	0	0	0
	2005	10	0	10	0	0	0
13	1995	56	0	0	25	0	0
	2005	65	0	0	30	0	0
14	1995	0	0	0	0	0	0
	2005	0	0	0	0	0	0
15	1995	1	0	1	0	0	0
	2005	5	0	5	0	0	0
16	1995	27	0	0	25	25	25
	2005	35	5	0	25	30	30
17	1995	26	0	0	0	0	0
	2005	30	0	0	0	0	0
18	1995	58	25	25	25	25	0
	2005	100	25	25	25	25	0
19	1995	78	0	0	0	0	0
	2005	120	0	0	0	0	0
21	1995	52	0	1	1	0	0
	2005	65	0	0	0	0	0
22	1995	0	0	0	0	0	0
	2005	5	0	0	0	0	0
23	1995	52	1	1	1	0	0
	2005	75	10	5	5	0	0
24	1995	1	0	0	0	0	0
	2005	10	0	0	0	0	0
25	1995	50	50	25	25	50	0
	2005	55	55	25	25	50	0
26	1995	51	0	0	0	0	25

Table 7 Seminary Fen Transect Vascular Plant Calciphile Scores. Vicinity Scores are for a presence-absence cumulative species list compiled through walkover surveys. Plot Scores are for species found within the subplots along each transect. (Continued)

Transect	Calciphile Indicator Species List Used	Vicinity Score	Plot				
			1	2	3	4	5
	2005	56	0	0	0	0	25
27	1995	50	0	0	0	0	0
	2005	61	0	0	0	0	0
28	1995	27	0	0	0	0	0
	2005	40	0	0	0	5	5
29	1995	0	0	0	0	0	0
	2005	0	0	0	0	0	0
30	1995	54	25	25	25	0	25
	2005	101	25	25	25	0	25
31	1995	26	1	0	0	0	25
	2005	45	5	0	0	0	25
32	1995	0	0	0	0	0	0
	2005	0	0	0	0	0	0
33	1995	0	0	0	0	0	0
	2005	0	0	0	0	0	0
34	1995	5	0	0	0	0	0
	2005	5	0	0	0	0	0
36	1995	0	0	0	0	0	0
	2005	10	0	0	0	0	0
37	1995	26	0	0	0	0	25
	2005	30	0	0	0	0	25
38	1995	26	0	25	0	0	0
	2005	40	0	25	0	0	5
39	1995	31	0	0	25	25	25
	2005	45	0	0	25	25	30
40	1995	31	25	0	25	0	25
	2005	46	25	5	25	0	30
41	1995	32	0	0	0	0	0
	2005	95	0	0	0	0	0
42	1995	53	25	25	25	25	25
	2005	100	25	30	25	25	25
43	1995	37	25	0	25	1	25
	2005	100	25	0	30	5	25
44	1995	31	25	25	25	26	25
	2005	70	25	25	25	50	25

Figures



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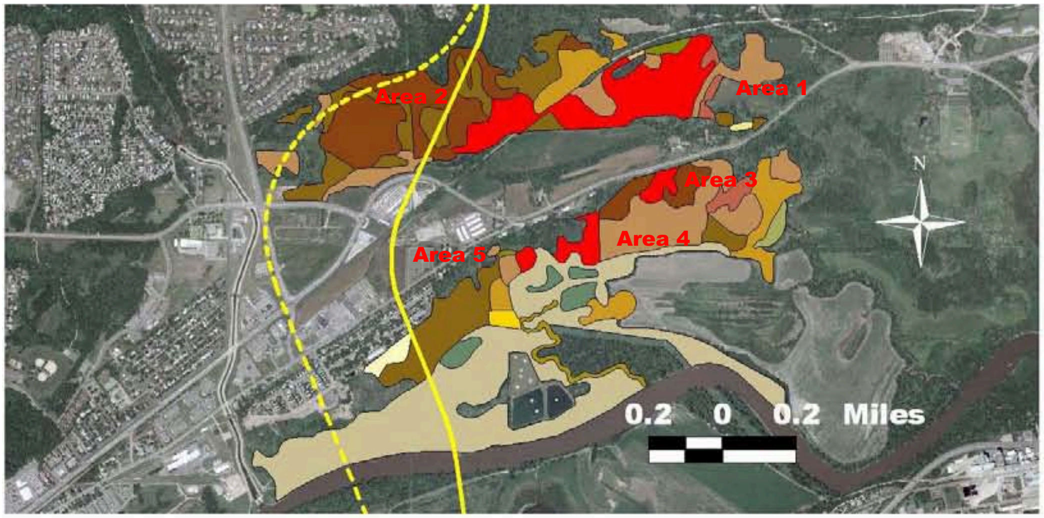
General Location and Important Cultural and Natural Features

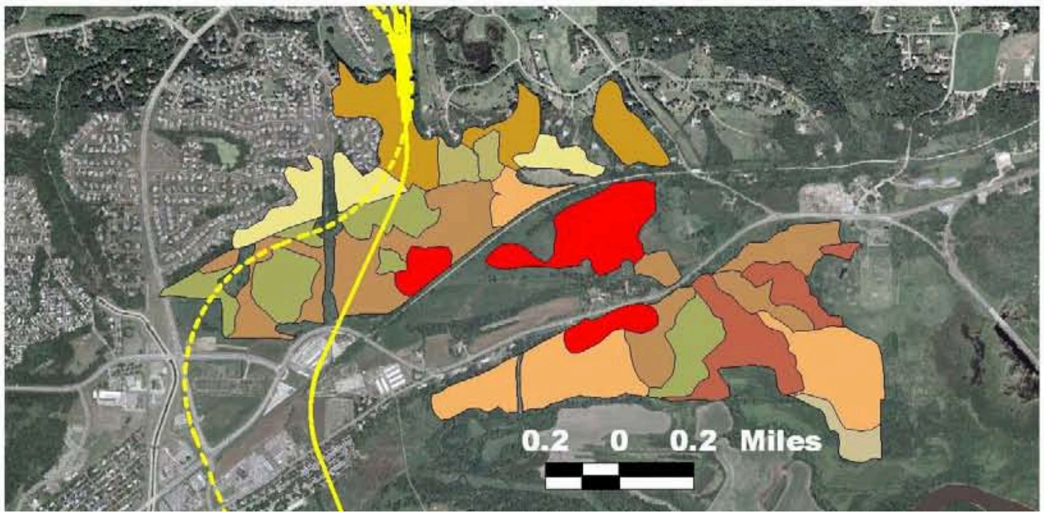
Phase 1 Characterization, Seminary Fen Wetland Complex, Carver County MN

FIGURE 2.1

PEC Project No. 2005-031



Mlccs_clipped.shp
- Altered/non-native dominated saturated shrubland
- Altered/non-native dominated temporarily flooded shrubland
- Calcareous seepage fen prairie subtype
- Cattail marsh - seasonally flooded
- Floodplain forest
- Mixed emergent marsh - seasonally flooded
- Mixed hardwood swamp - seasonally flooded
- Palustrine open water
- Saturated altered/non-native dominated graminoid vegetation
- Shrub swamp seepage subtype
- Slow moving linear open water habitat
- Temporarily flooded altered/non-native dominated grassland
- Wet meadow
- Wet meadow shrub subtype
- Willow swamp



Mcbs_fenarea.shp
- ASPEN WOODLAND
- CALCAREOUS SEEPAGE FEN (SOUTHEAST) PRAIRIE SUBTYPE
- DRY OAK SAVANNA (CENTRAL) SAND-GRAVEL SUBTYPE
- EMERGENT MARSH
- FLOODPLAIN FOREST
- MAPLE-BASSWOOD FOREST (BIG WOODS)
- OAK WOODLAND-BRUSHLAND (BIG WOODS)
- SHRUB SWAMP SEEPAGE SUBTYPE
- WET MEADOW

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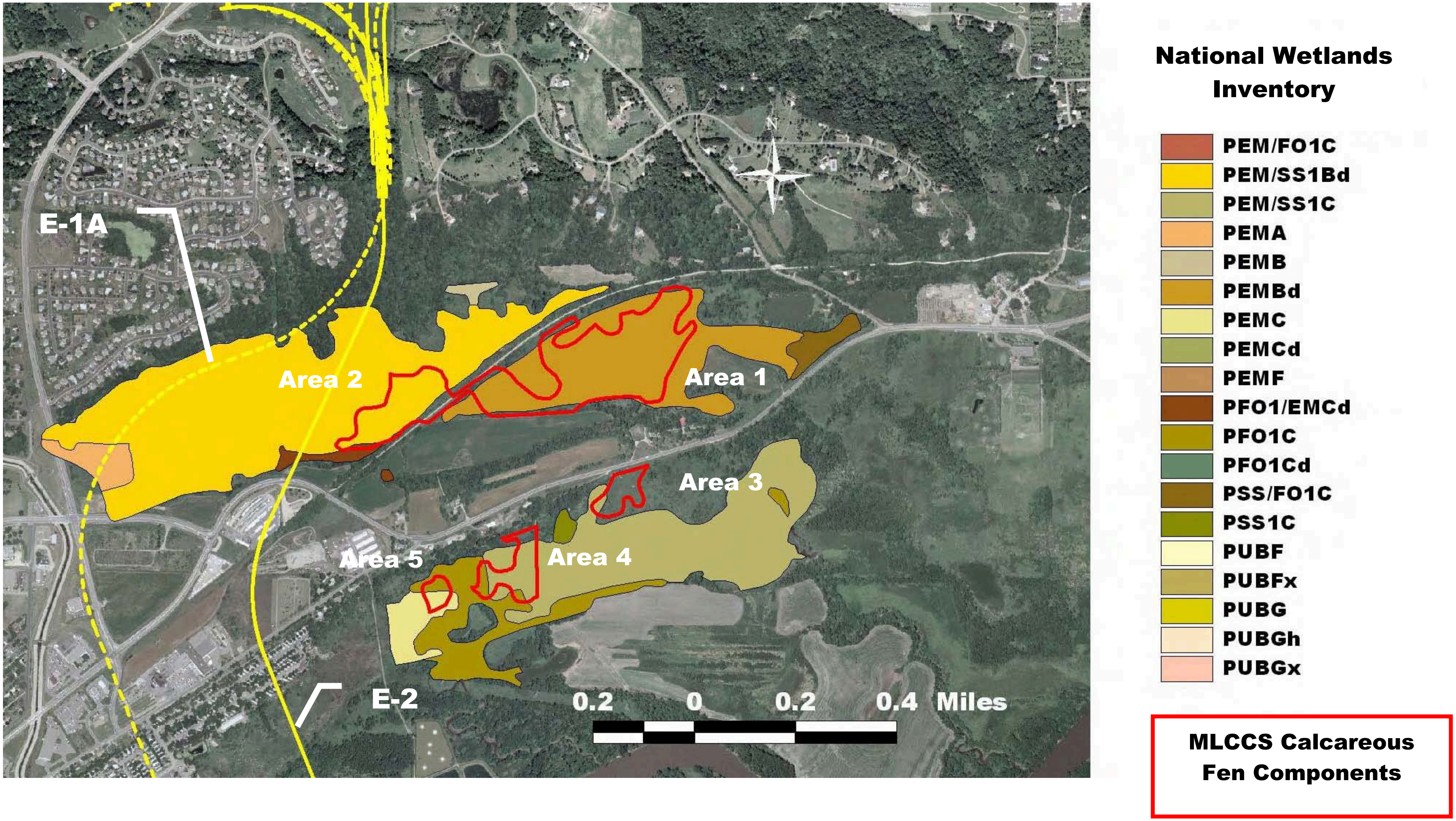
Minnesota Land Cover Classification System and Minnesota County Biological Survey Plant Communities (Calcareous Fens in Red)

Phase 1 Characterization: Seminary Fen Wetland Complex, Carver County MN

FIGURE 3.1

PEC Project No. 2005-031



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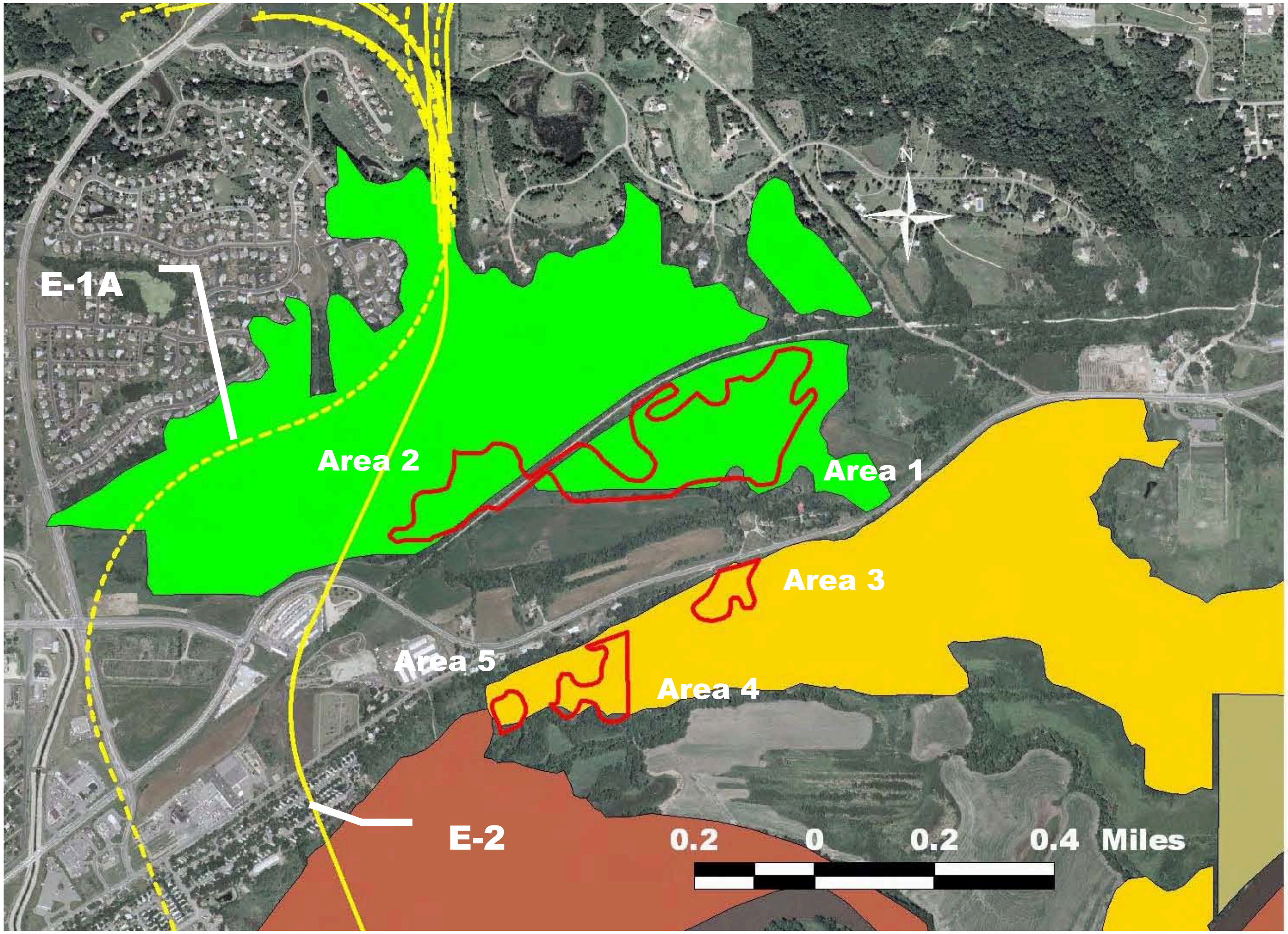
National Wetlands Inventory

Phase 1 Characterization: Seminary Fen Wetland Complex, Carver County MN

FIGURE 3.2

PEC Project No. 2005-031



MCBS Biodiversity Significance

- Below
- High
- Moderate
- Outstanding

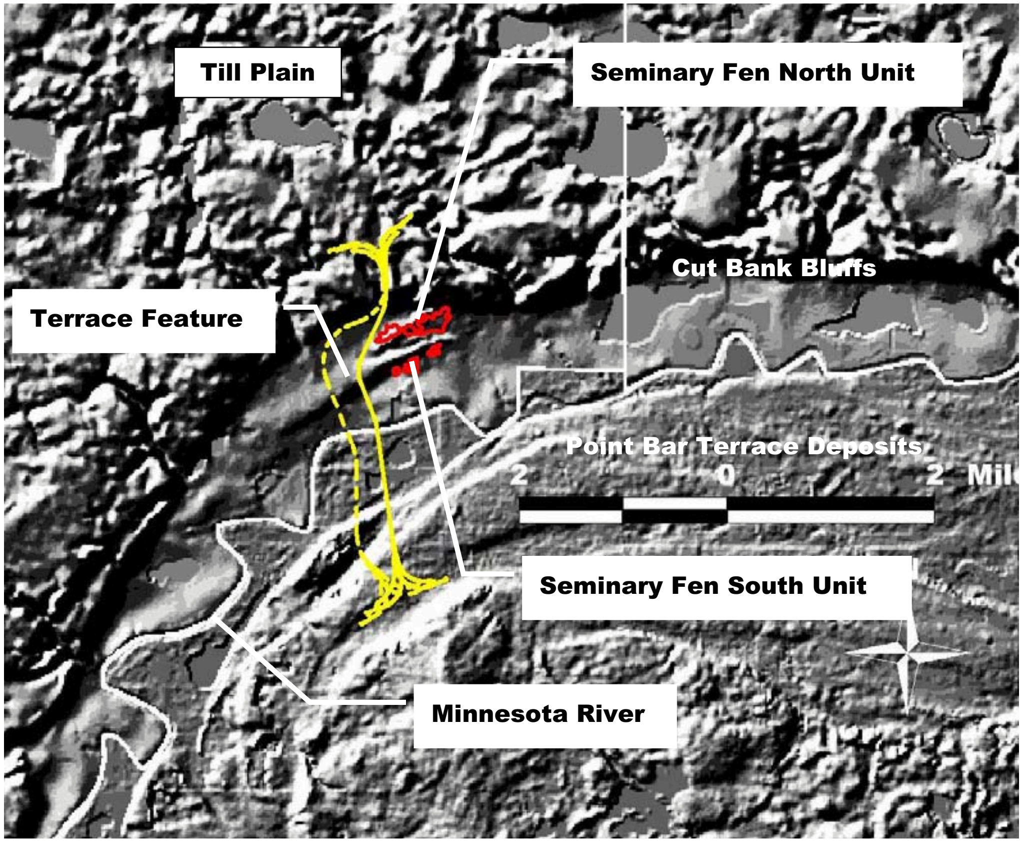
MLCCS Calcareous Fen Components

MCBS Areas of Biodiversity Significance

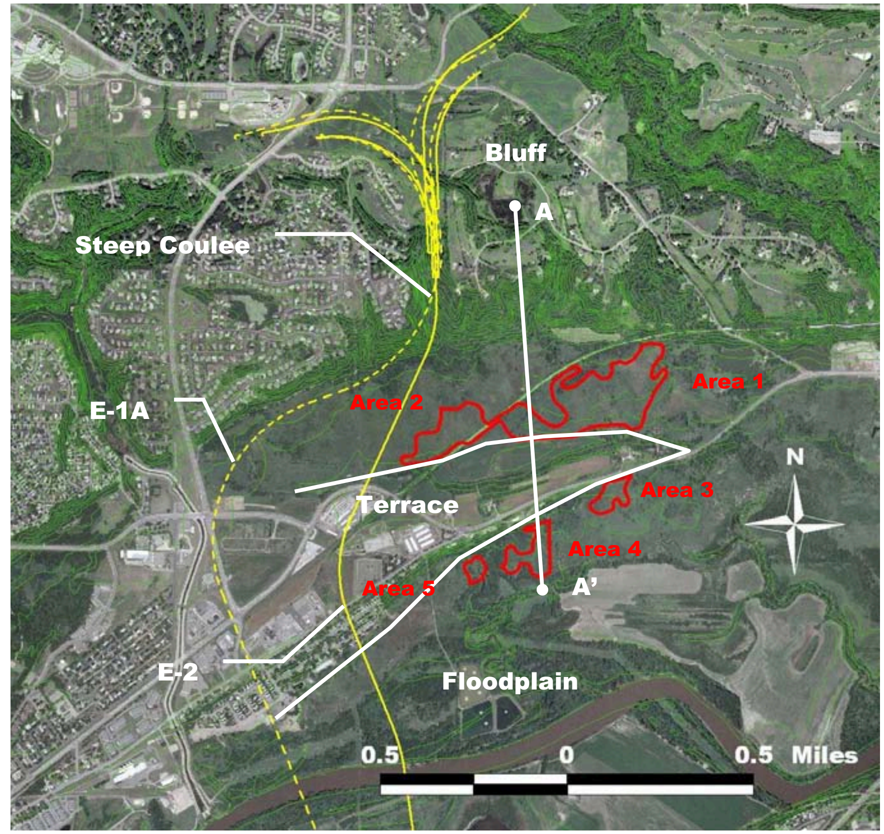
Phase 1 Characterization: Seminary Fen Wetland Complex, Carver County MN

FIGURE 3.3

PEC Project No. 2005-031

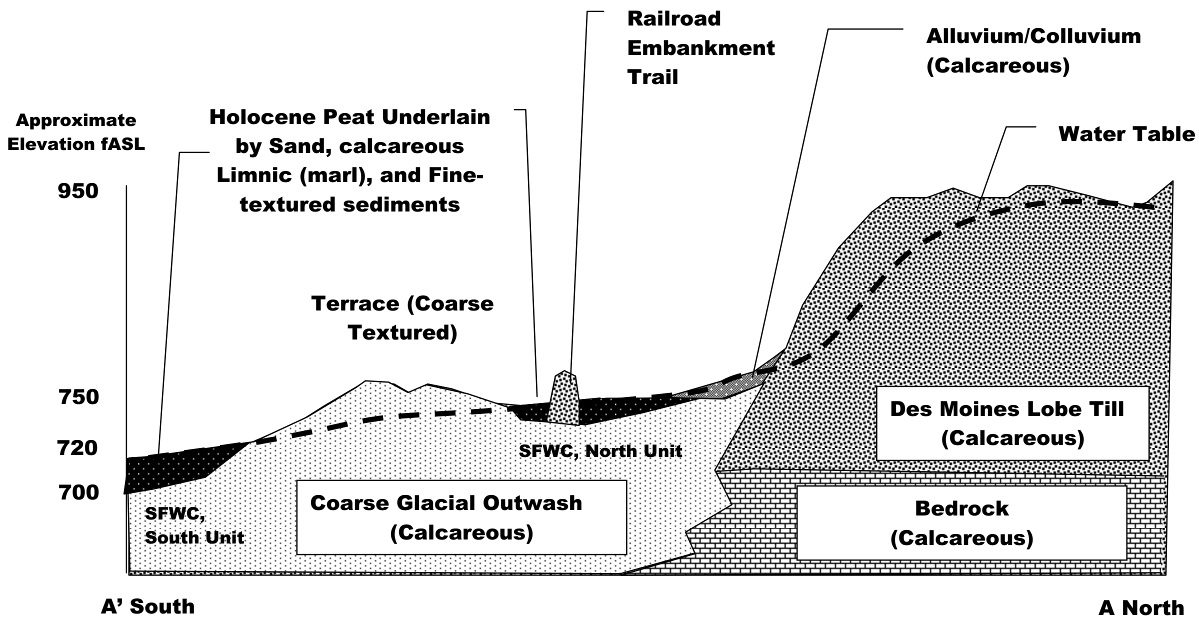


Shaded Relief Map: Seminary Fen Area



Topography and Relief: Seminary Fen Area

Line A – A' is theoretical Cross-Section (Figure 2.5)



Theoretical Cross-Section

The theoretical cross-section was based on field observations of peat characteristics, the presence of limnic marl, coprogenous earth, and sand sediments under the peat, County Well Index (CWI) data, soil survey data, and topographic shots of well locations. The dip in the terrace feature identifies the location of the western reaches of Assumption Creek where well data indicated that the creek was a losing stream. Jordan sandstone was not indicated in any of the CWI records examined. Jordan sandstone is likely discontinuous if present in the area. Most of the CWI records indicated that the Prairie du Chien formation was underlain by fine-grained St. Lawrence bedrock unit that would act as an aquitard (Kanivetsky, 1989; MnDNR Staff, 1998).

Note that both the north and south units of the SFWC present sloping surfaces.

STRATIGRAPHIC CLASSIFICATION				DESCRIPTION OF ROCK UNITS	
SYSTEM/ SERIES	YEARS BEFORE PRESENT	GROUP OR FORMATION NAME	MAP SYMBOL	THICKNESS	DOMINANT ROCK TYPES
MIDDLE ORDOVICIAN		ST. PETER SANDSTONE	Os	Occurs as erosional remnants; maximum reported thickness 35 feet	Fine- to medium-grained, poorly cemented quartzose sandstone; basal contact minor erosional surface
LOWER ORDOVICIAN		PRAIRIE DU CHIEN GROUP	Op	Typically occurs as erosional remnants; maximum reported thickness 152 feet	Sandy dolomite with thin beds of quartzose sandstone; in the south may contain thin beds of quartzose sandstone and soft shale
UPPER CAMBRIAN	500 m.y.	JORDAN SANDSTONE	€j	85 to 100 feet	Fine- to coarse-grained, poorly cemented quartzose sandstone
		ST. LAWRENCE FORMATION	€s	45 to 60 feet	Silty dolomite interbedded with siltstone, soft shale, and very fine grained quartzose sandstone
		FRANCONIA FORMATION	€f	130 to 150 feet	Very fine grained, glauconitic quartzose sandstone and shale; in the south may contain thick beds of slightly glauconitic dolomite
		IRONTON & GALESVILLE SANDSTONES	€ig	45 to 55 feet	Fine- to very coarse grained quartzose sandstone with thin beds of soft shale
		EAU CLAIRE FORMATION	€e	65 to 80 feet	Interbedded siltstone, mudstone, and shale with scattered beds of very fine grained quartzose sandstone
		MT. SIMON SANDSTONE	€m	140 to 165 feet	Medium- to coarse-grained, poorly cemented quartzose sandstone; may contain pebbles to granules of quartz in lower 20 feet and thin beds of mudstone. Basal contact major erosional surface
MIDDLE PROTEROZOIC	520 m.y.	HINCKLEY & FOND DU LAC FORMATIONS, UNDIVIDED	mPhf	Combined thickness probably exceeds 1000 feet. Hinckley probably does not exceed 20 feet and thus is too thin to map as a seperate unit	Fine- to coarse-grained quartzose sandstone of the Hinckley sporadically overlies the interbedded shale and arkosic sandstone of the Fond du Lac
	950 m.y.	SOLOR CHURCH FORMATION	mPs	Unknown, but probably attains several thousand feet	Interbedded mudstone, siltstone, and lithic sandstone
	1100 m.y.	CHENGWATANA VOLCANIC GP.	mPc	Unknown, but probably attains several thousand feet	Basalt flows; largely inferred from gravity and magnetic studies

Bedrock Geology (after Balaban and Swiggum, 1982)

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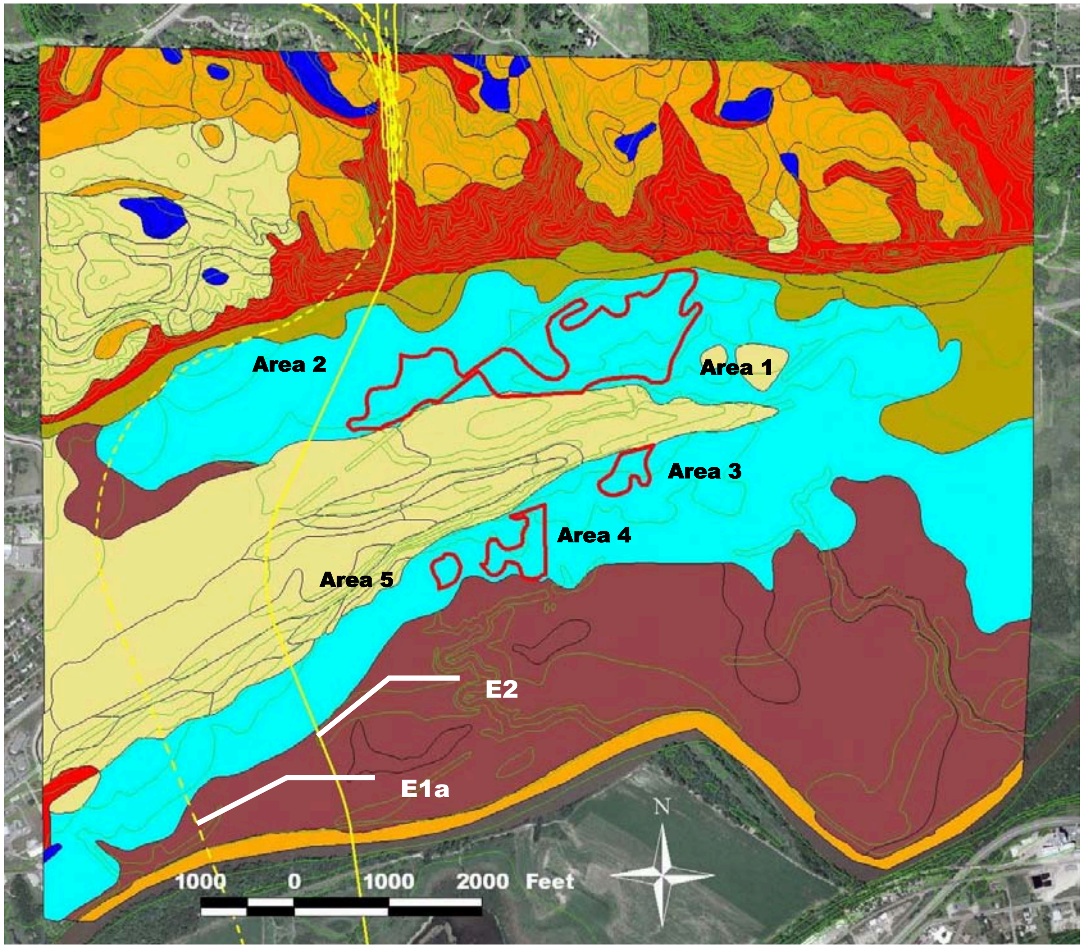
Theoretical Geologic Cross-section Consistent with CWI Depth to Bedrock Data, Topography, and Field Observations

Phase 1 Characterization: Seminary Fen Wetland Complex, Carver County MN

FIGURE 3.5

PEC Project No. 2005-031



Soil Map Units Classified by Geomorphic Setting

Table 1. Soils in the Area of the SFWC Classified According to their Geomorphic Setting.

Soil Series	Taxonomic Class	Slope Ranges	Parent Material
Bluff Top			
Lester	Mollic Hapludalfs	2-18	Calcareous Till
Kilkenny	Oxyaquic Vertic Hapludalfs	2-18	Calcareous Till
Rasset	Typic Argiudolls	2-18	Calcareous Colluvium/ Outwash
Blufftop Wet			
Glencoe	Cumulic Endoaquolls	0-2	Local Alluvium
Hamel	Typic Argiaquolls	0-2	Slope Alluvium/ Colluvium Till
Klossner	Terric Haplosaprists	1-2	Organic Material
Bluff			
Kilkenny	Oxyaquic Vertic Hapludalfs	18-40	Calcareous Till
Lester	Mollic Hapludalfs	18-40	Calcareous Till
Alluvial Fan			
Terril	Cumulic Hapludolls	0-6	Colluvium
Minneiska	Mollic Udifluvents (Calcareous)	0-6	Calcareous Alluvium
Backswamp/Lake Basin			
Blue Earth	Mollic Fluvaquents (calcareous)	0-1	Clacareous coprogenous earth
Terrace			
Estherville	Typic Hapludolls	2-18	Outwash
Hawick	Entic Hapludolls	2-18	Outwash
Minnieska	Mollic Udifluvents (calcareous)	0-2	Calcareous Alluvium
Sparta	Entic Hapludolls	2-18	Outwash
Floodplain			
Chaska	Aeric fluvaquents (calcareous)	0-2	Alluvium
Kalmarville	Mollic Fluvaquents	0-2	Alluvium
Minnneiska	Mollic Udifluvents (calcareous)	0-2	Alluvium
Oshawa	Fluvaquentic Endoaquolls (calcareous)	0-2	Calcareous Alluvium

Note that all CFC-SFWC are embedded in Blue Eath soils that are characteristic of limnic (or lacustrine) settings. None of the CFC-SFWC are in floodplain or terrace positions or are associated with terrace soils. Additional soils that would be found as inclusions in the Blue Earth map units include Palms (Loamy, mixed, euic, mesic Terric Haplosaprists), Muskego (coprogenous, euic, mesic Limnic Haplosaprists), and Houghton (euic, mesic Typic Haplosaprists) soils. However, it should be noted that the NRCS has no appropriate classification for calcareous fen soils that are dominated by the presence of precipitated calcium carbonate.

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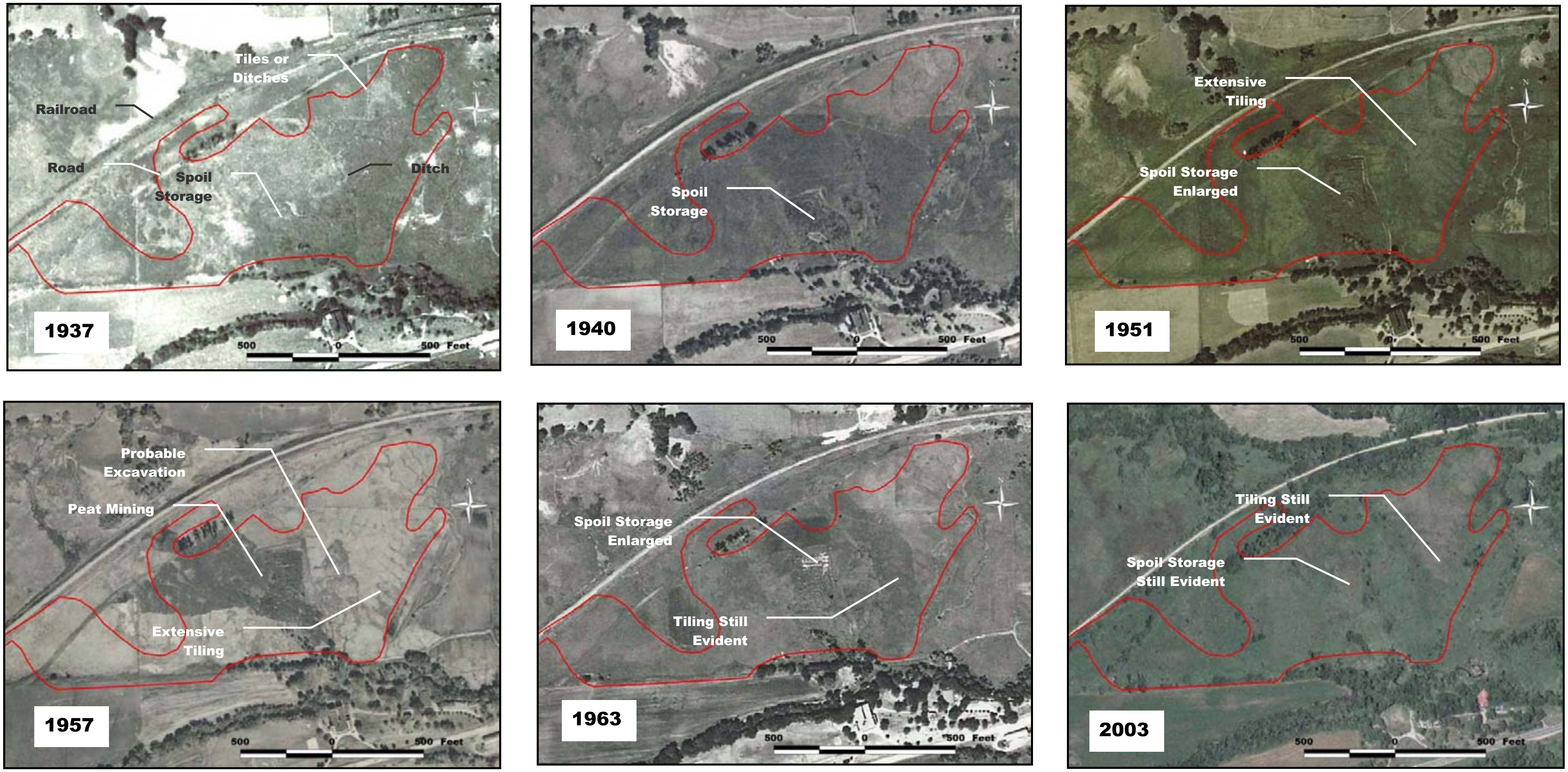
Site Soils Grouped by Geomorphic Setting and Parent Material

Phase 1 Characterization: Seminary Fen Wetland Complex, Carver County MN

FIGURE 3.6

PEC Project No. 2005-031



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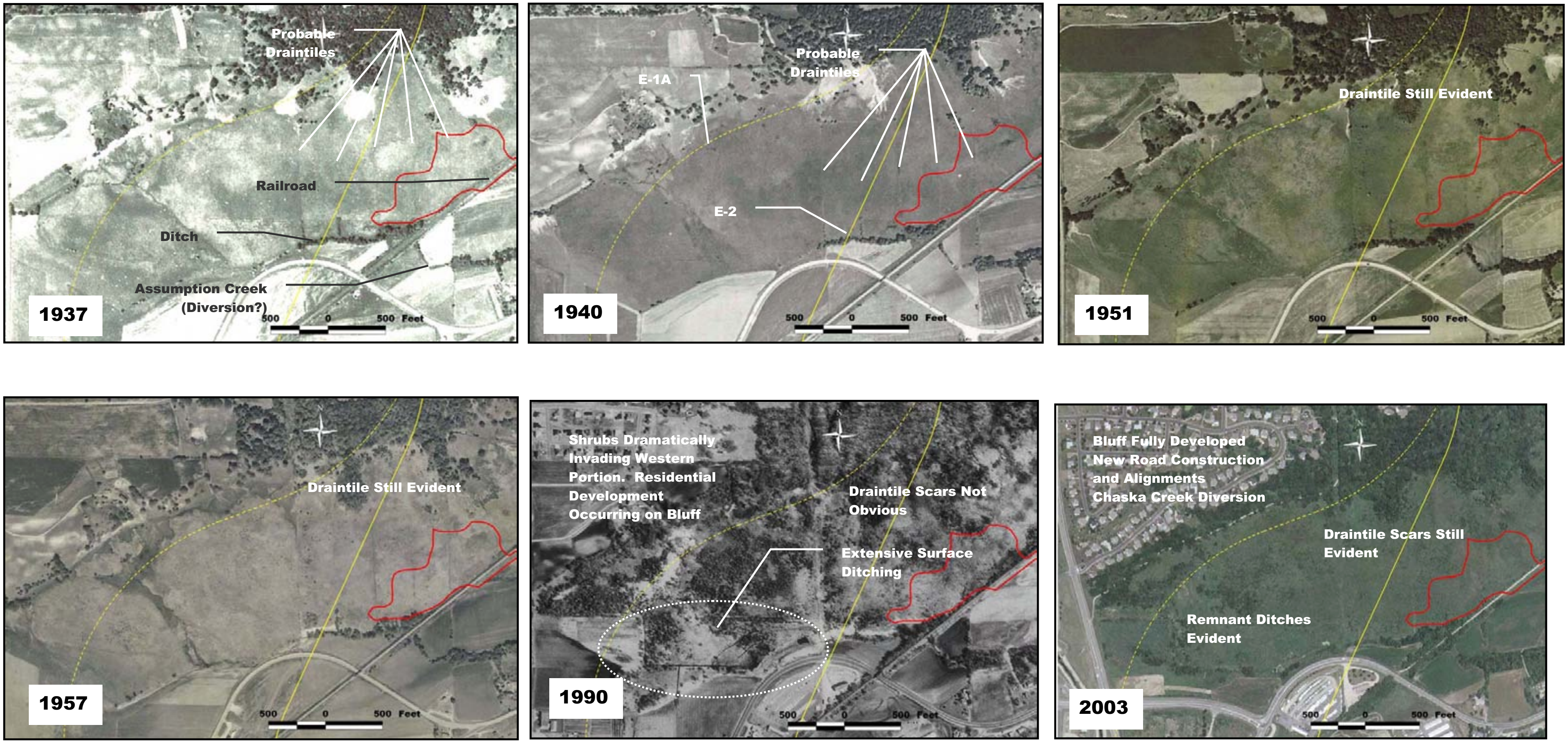
Air Photo History: CFC-SFWC Area 1

Phase 1 Characterization: Seminary Fen Wetland Complex, Carver County MN

FIGURE 3.7

PEC Project No. 2005-031



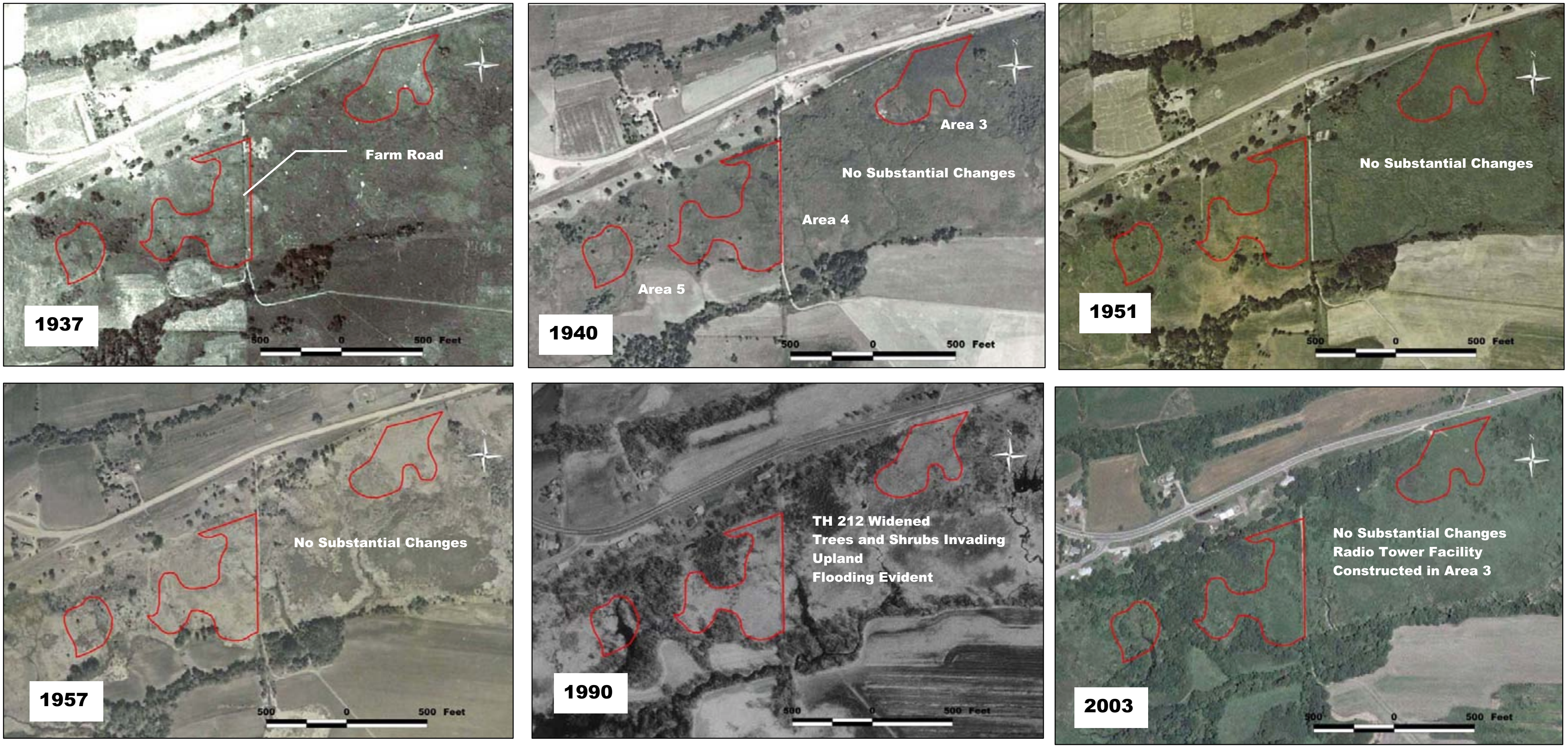
Peterson Environmental Consulting, Inc.

Air Photo History: CFC-SFWC Area 2, Western Portion of SFWC

Phase 1 Characterization: Seminary Fen Wetland Complex, Carver County MN

FIGURE 3.8

PEC Project No. 2005-031



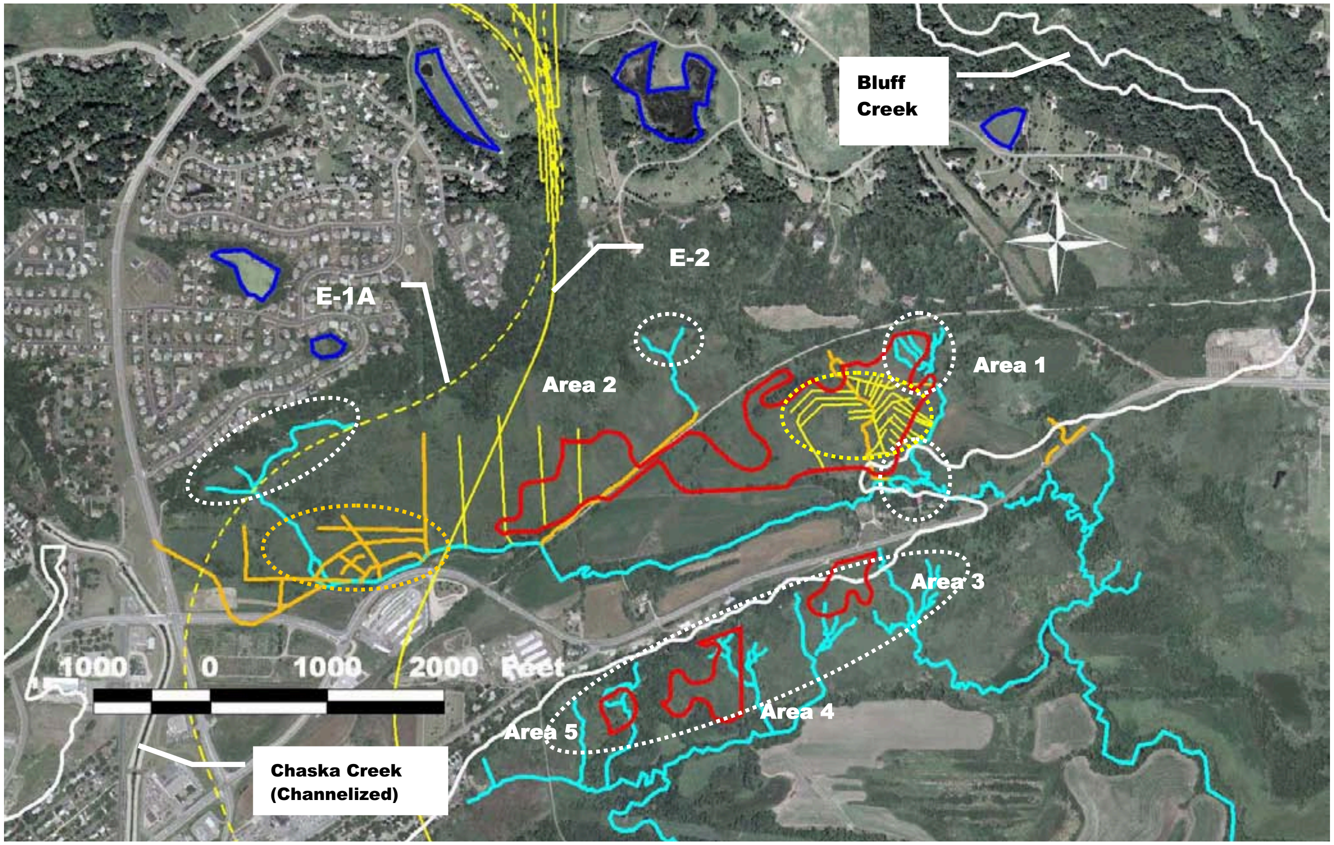
Peterson Environmental Consulting, Inc.

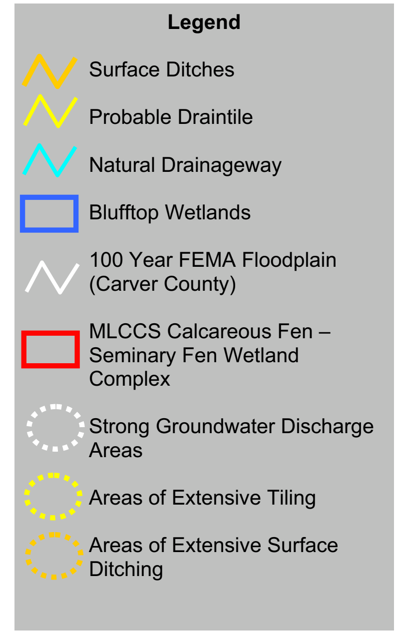
Air Photo History: CFC-SFWC Areas 3, 4, and 5

Phase 1 Characterization: Seminary Fen Wetland Complex, Carver County MN

FIGURE 3.9

PEC Project No. 2005-031





Important hydrologic alterations in the area of the SFWC include the following:

1. Extensive **drain tiling** of a large peat mound in the east central portion of Area 1.
2. **Channelization, diversion, and surface drainage alterations** to the eastern tributary of Assumption Creek north of the railroad grade.
3. **Surface ditching and probable drain-tile installation** west of Area 2.
4. **Active downcutting** of the large spring run associated with the eastern portion of Area 1.
5. **The channelization of Chaska Creek** has resulted in a lower stage and possible interception of groundwater from the western portion of the SFWC.

Natural and man-made hydrographic features were assessed through an interpretation of historic aerial photos along with field observations. The northern part of Area 1 that is adjacent to and south of the railroad grade presents the strongest evidence of spring head and spring run hydrology observed by the authors within the entire SFWC. Spring runs coalesce to form a perennial stream that is actively downcutting just south of the calcareous fen unit. Spring head and spring runs were also observed in the northwestern portion of the SFWC east of Audubon road and south of the trail that follows the northwestern portion of the bluff.

Extensive groundwater discharge was observed as spring heads and spring runs associated with the southern SFWC unit south of the terrace in and near CFC-SFWC Areas 3, 4, and 5. These areas are within the 100-year floodplain of the Minnesota River. Tiling in the central portion of Area 1 was observed in the field as tile discharge and broken tile pieces in the ditched area to the west of the main tiled area. The reason for the tiling is not clear; however, the tile scars are evident in the same locations in most of the historic aerial photos examined. Extensive surface ditching was observed the southwest portion of the SFWC from North of TH 212 and west of Audubon Road.

Most of Areas 3, 4, and 5 lie within the 100-year floodplain of the Minnesota River. It is thought that calcareous fens cannot be supported in areas that periodically flood as the sediments bury the fen vegetation with nutrient rich material that encourages the persistence of invasive species that are adapted to high nutrient levels and periodic disturbance.

Several bluff top wetlands exist north of the SFWC that could provide the hydraulic gradient driving groundwater discharge to the areas on the valley floor that are adjacent to the bluff.

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Important Natural and Man-made Hydrographic Features

Phase 1 Characterization: Seminary Fen Wetland Complex, Carver County MN

FIGURE 3.10

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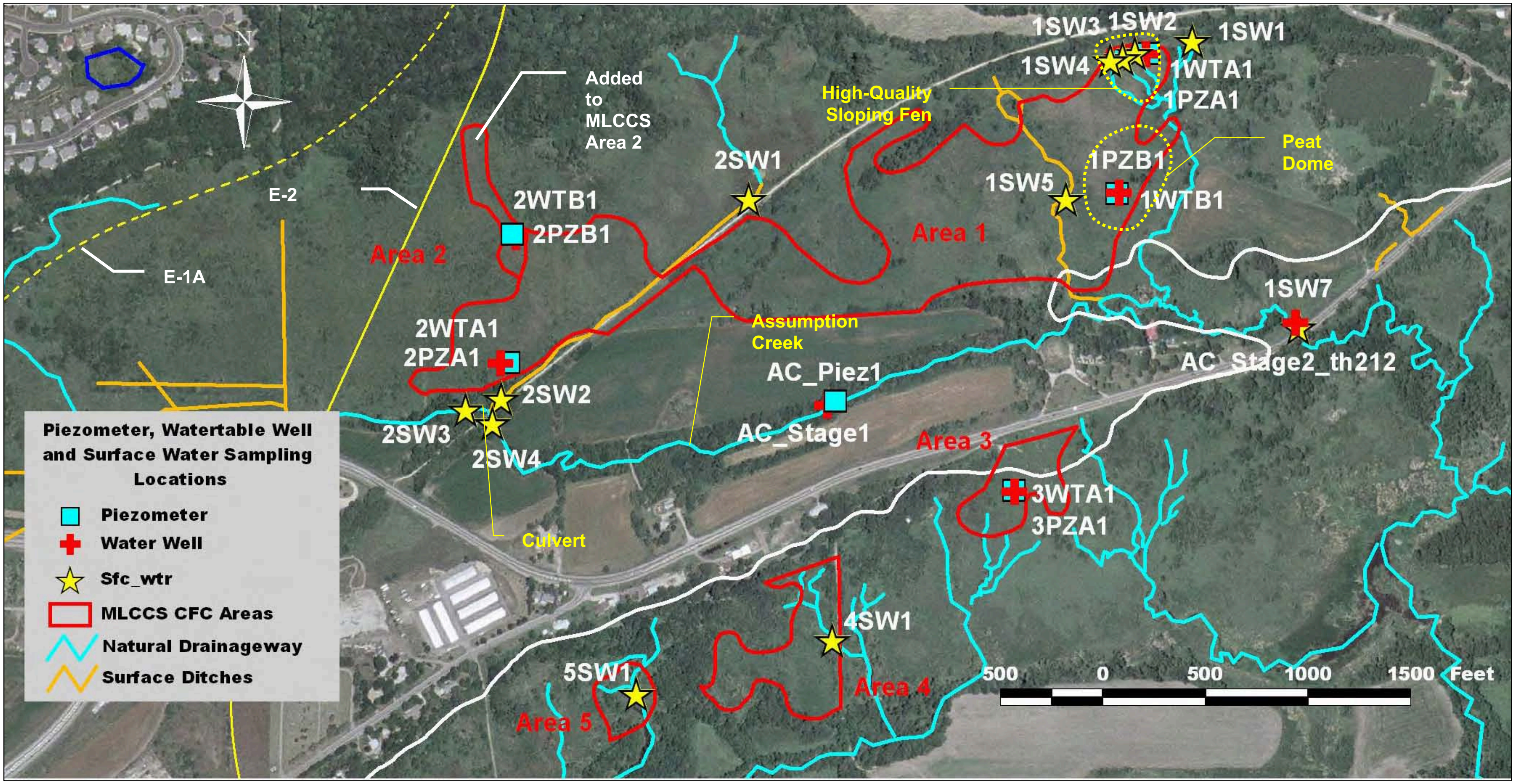

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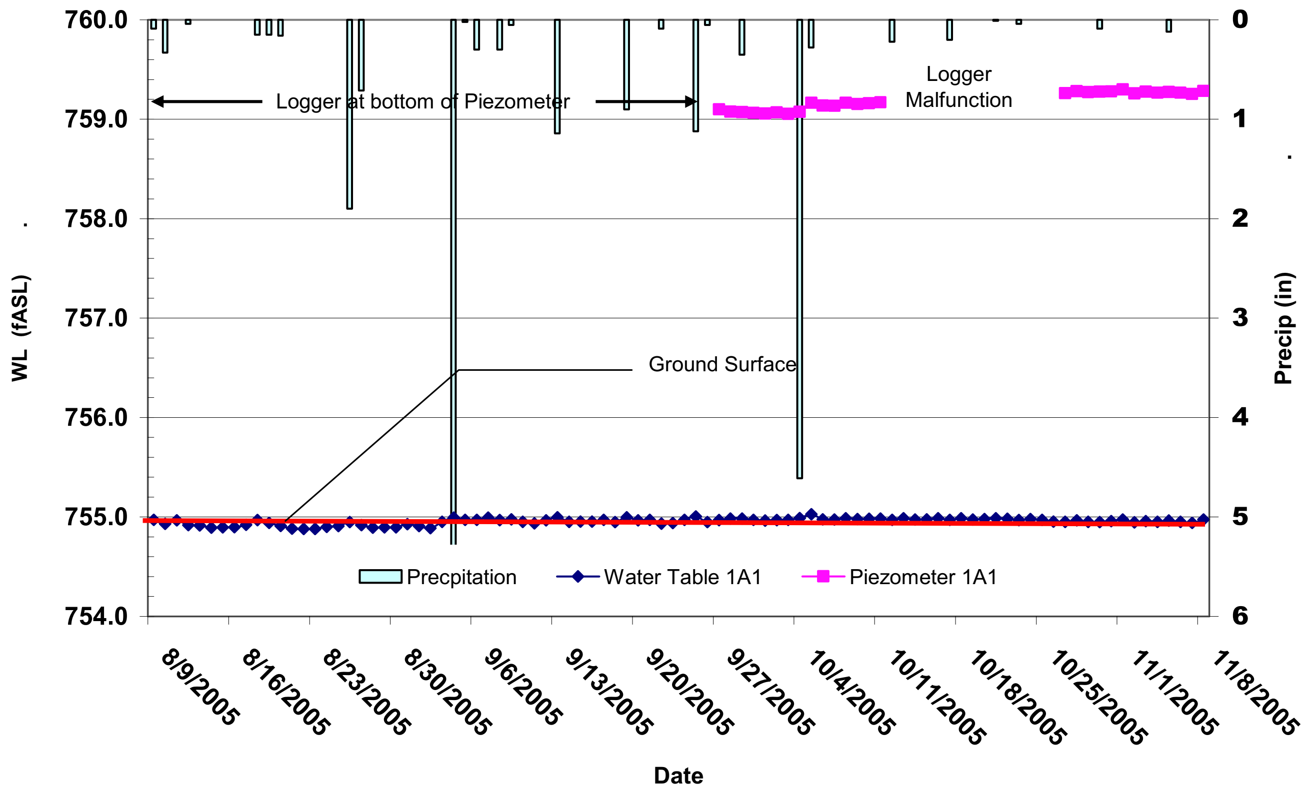
Seminary Fen Area Piezometer, Water Table Well, and Water Sampling Locations

Phase 1 Characterization: Seminary Fen Wetland Complex, Carver County MN

FIGURE 5.1

PEC Project No. 2003-031



	1PZA1	1WTA1
Type	Piezometer	Water Table
Location (UTM NAD83 M: X,Y)	456087.5, 4962320.2	456086, 4962320.5
Material	1.25-inch Sch. 80, flush threaded	2-inch Sch. 40 PVC; Glued Couplings
Screen Type	Johnson 1.25-inch wound stainless steel 10-slot drive point	Johnson 2-inch Sch. 40 10-slot PVC
Installation	Driven	Set in underfit Augered hole
Installation Date	09/27/05	08/09/05
Data Logger	2005: Solinst #41376	2005: Solinst #41370
MDH Number	5378.0	5379.0
Chemistry	Yes	Yes
Top-of-Casing (fASL)	761.2	755.5
Ground Surface (fASL)	756.5	755.1
Bottom of Well (fASL)	737.5	749.6
Screened Interval (fASL)	737.5 - 738.5	753.1 - 755.1
Depth-to-Sand	18 feet (738.5 fASL)	18 feet (738.5 fASL)
Notes	After installation, levelogger broke off and fell to bottom of well. Gap represents malfunction in replacemement levelogger	

Seminary Fen 2005 Well Nest Hydrographs
SFWC CFC Area 1: Well Nest 1A
Phase 1 Characterization: Seminary Fen Wetland Complex, Carver County, MN
Figure 5.2

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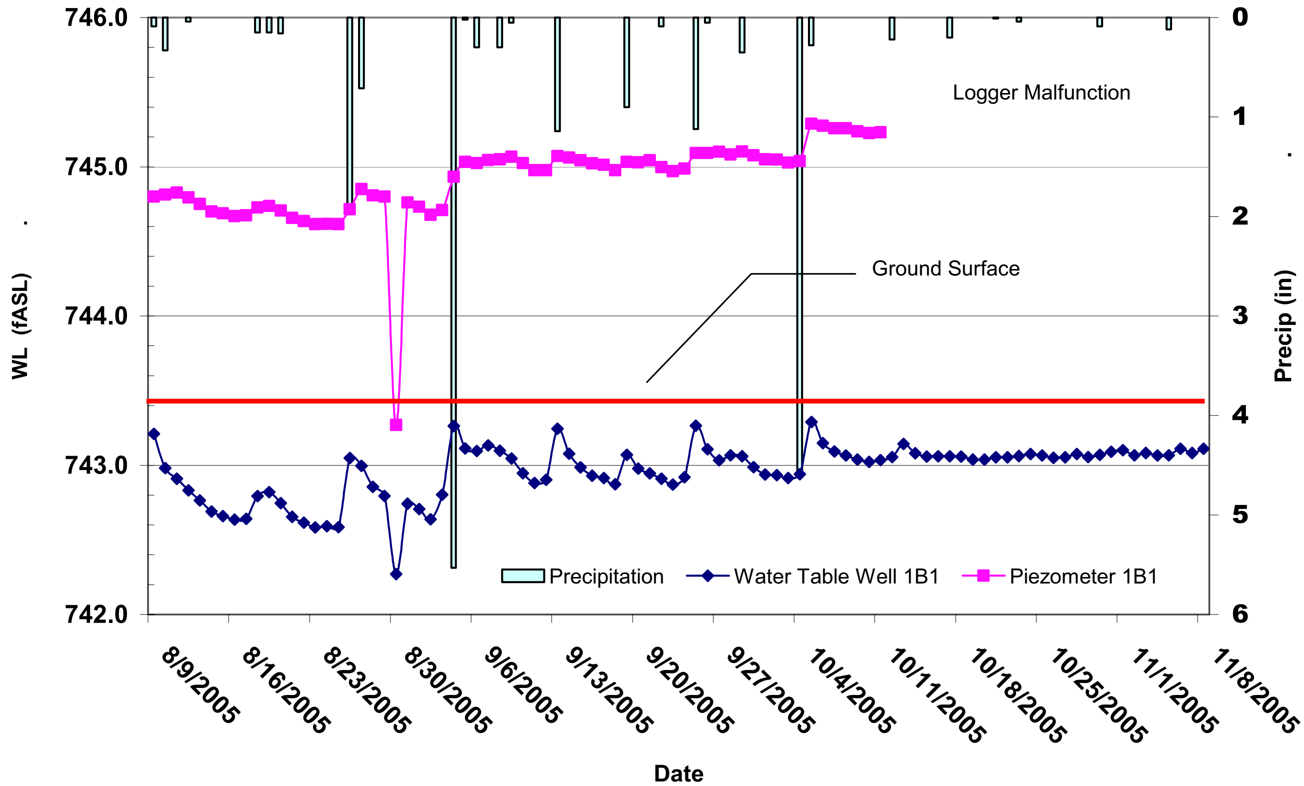
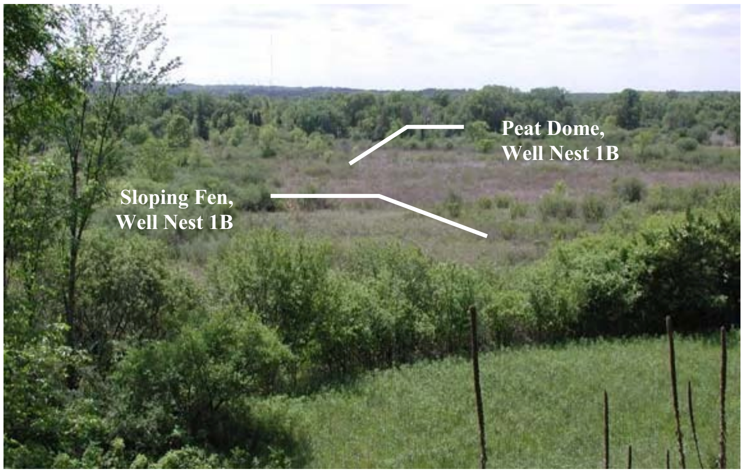
PEC Project No. 2005-031

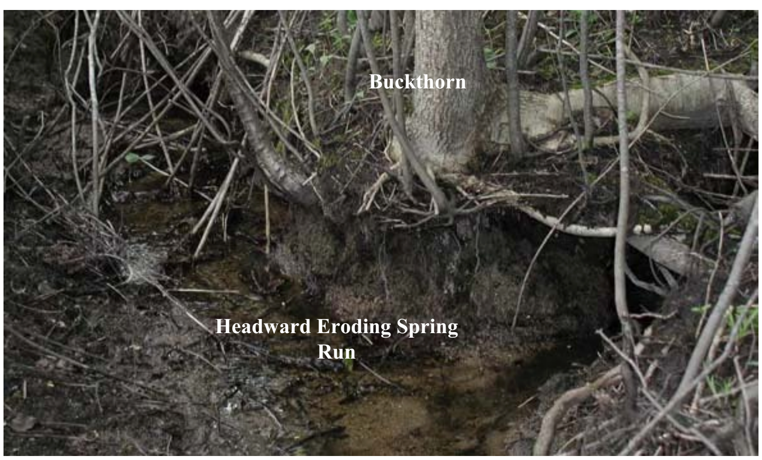


	1PZB1	1WTB1
Type	Piezometer	Water Table
Location (UTM NAD83 M: X,Y)	456041.4, 4962113.4	456044.1, 4962114.3
Material	1.25-inch Sch. 80, flush threaded	2-inch Sch. 40 PVC; Glued Couplings
Screen Type	Johnson 1.25-inch wound stainless steel 10-slot drive point	Johnson 2-inch Sch. 40 10-slot PVC
Installation	Driven	Set in underfit Augered hole
Installation Date	08/09/05	08/09/05
Data Logger	2005: Solinst #40785	2005: Solinst #41109
MDH Number	5376.0	5377.0
Chemistry	Yes	Yes
Top-of-Casing (fASL)	747.2	745.0
Ground Surface (fASL)	743.5	743.6
Bottom of Well (fASL)	726.4	739.2
Screened Interval (fASL)	726.4 - 727.4	741.6 - 743.6
Depth-to-Sand	17 feet (726.5 fASL)	17 feet (726.5 fASL)
Notes	Water Level dip around 9/1/05 represents the well being purged. Recover is rapid.	



A. SFWC CFC Area 1 observed from the railroad embankment. Well Nest 1A is just beyond the shrub line in the foreground. Well Nest 1B was developed on a 10-12 foot high peat mound visible in the center of the photograph.

B. Active spring head at the northern edge of the sloping peatland represented by Well Nest 1A. Several such spring heads are present. Spring runs issuing from the spring heads coalesce into a main spring run that flows east and south.



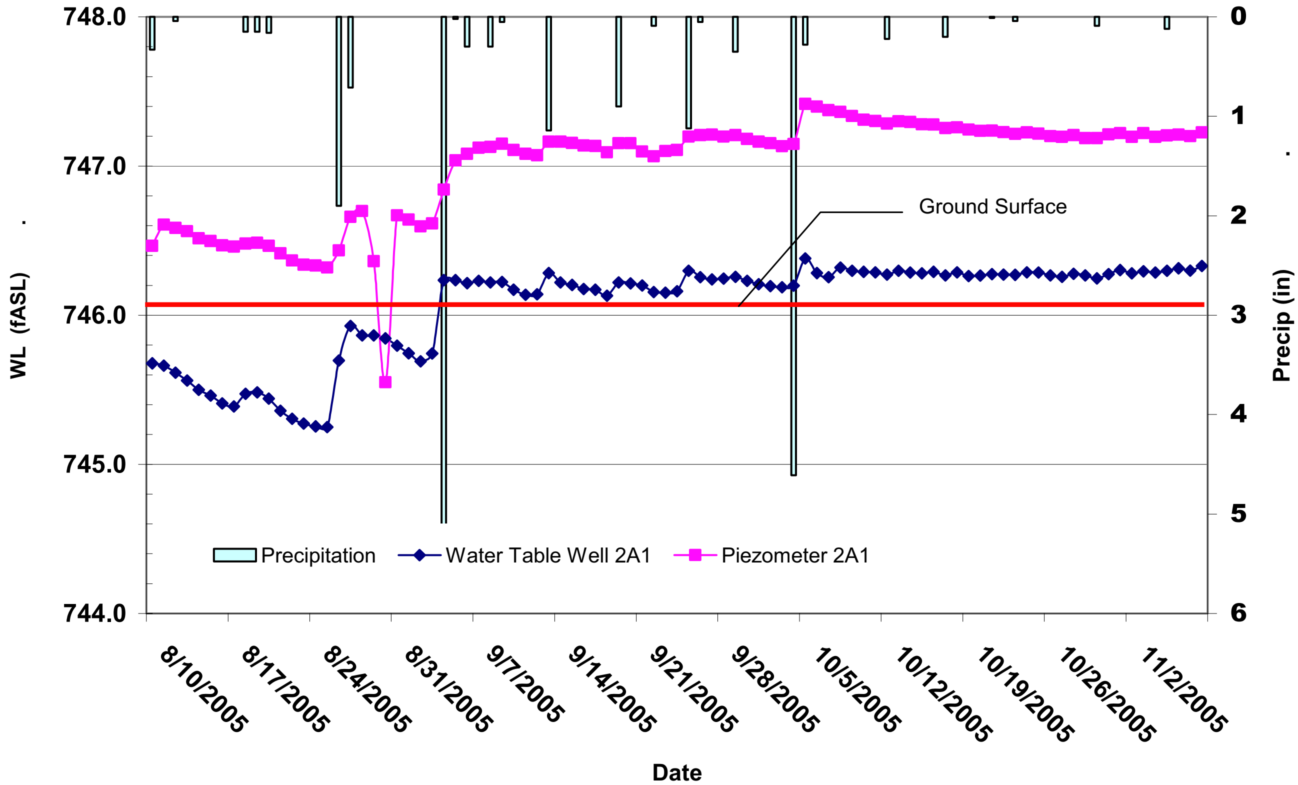
C. The main spring run near Well Nest 1A is actively downcutting into peat and the underlying substrate. Headward erosion is proceeding into the main portion of the calcareous fen portion of the sloping peatland. The area is dominated by a thick growth of buckthorn that shades out most of the herbaceous understory vegetation. Continued headward erosion by this spring run is a potential threat to the remaining short stature calcareous fen plant community.

A. East flank of the peat dome near Well Nest 1B showing tile discharge. Note reed canary grass ringing discharge area and shrubs invading the top of the peat dome.

B. Broken tile pieces in the spring run/ditch to west of peat dome. Tile discharge was observed at several locations along the western and eastern flanks of the peat dome.

C. View to the top of the peat dome from the spring run/ditch to the west. Note invasion of shrubs (buckthorn, red-osier dogwood), reed canary grass, and common reed grass. The peat dome represented by Well Nest 1B has been hydrologically altered by tiling, ditching, and probable excavation along the western flank.

Site Photographs, Hydrologic Investigations SFWC CFC Area 1: Well Nest 1B
Phase 1 Characterization: Seminary Fen Wetland Complex
Carver County, MN
Figure 5.5



	2PZA1	2WTA1
Type	Piezometer	Water Table
Location (UTM NAD83 M: X,Y)	455136.8, 4961860.5	455135.9, 4961860.6
Material	1.25-inch Sch. 80, flush threaded	2-inch Sch. 40 PVC; Glued Couplings
Screen Type	Johnson 1.25-inch wound stainless steel 10-slot drive point	Johnson 2-inch Sch. 40 10-slot PVC
Installation	Driven	Set in underfit Augered hole
Installation Date	08/09/05	08/09/05
Data Logger	2005: Solinst #41374	2005: Solinst #44490
MDH Number	5382.0	5383.0
Chemistry	Yes	Yes
Top-of-Casing (fASL)	749.6	747.5
Ground Surface (fASL)	746.1	746.1
Bottom of Well (fASL)	733.6	741.7
Screened Interval (fASL)	733.6 - 734.6	744.1 - 746.1
Depth-to-Sand	14 feet (732.1 fASL)	14 feet (732.1 fASL)
Notes	Transient depression in piezometer water level represents a purge of water. Recovery is rapid.	

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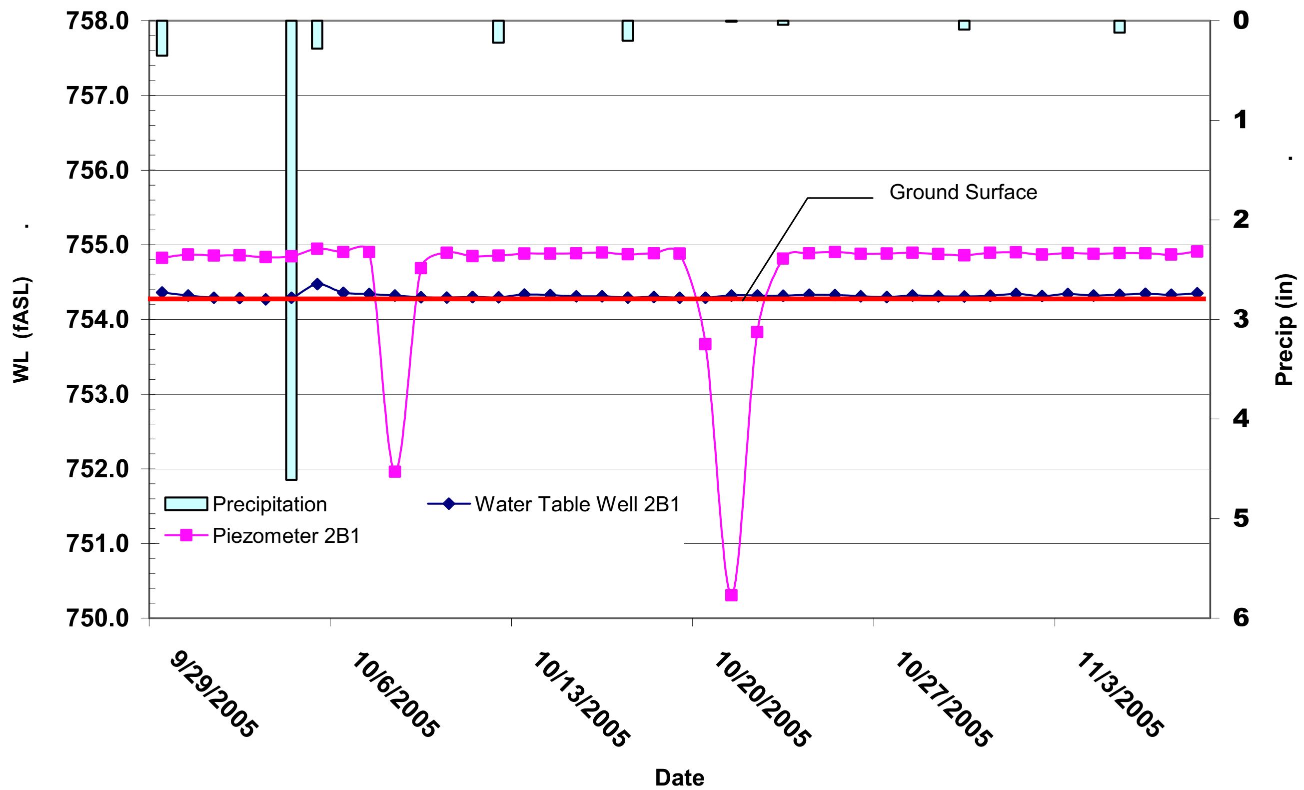
Seminary Fen 2005 Well Nest Hydrographs
SFWC CFC Area 2: Well Nest 2A
Phase 1 Characterization: Seminary Fen Wetland Complex, Carver County, MN
Figure 5.6

PEC Project No. 2005-031



	2PZB1	2WTB1
Type	Piezometer	Water Table
Location (UTM NAD83 M: X,Y)	455142.2, 4962049.1	455143.1, 4962048.5
Material	1.25-inch Sch. 80, flush threaded	2-inch Sch. 40 PVC; Glued Couplings
Screen Type	Johnson 1.25-inch wound stainless steel 10-slot drive point	Johnson 2-inch Sch. 40 10-slot PVC
Installation	Driven	Set in underfit Augered hole
Installation Date	09/27/05	09/27/05
Data Logger	2005: Solinst #41117	2005: Solinst #41059
MDH Number	5384.0	5385.0
Chemistry	Yes	Yes
Top-of-Casing (fASL)	758.6	755.8
Ground Surface (fASL)	754.7	754.4
Bottom of Well (fASL)	737.8	750.1
Screened Interval (fASL)	737.8 - 738.8	752.4 - 754.4
Depth-to-Sand	>20 feet (> 734.7 fASL)	>20 feet (> 734.7 fASL)
Notes	Transient depression in piezometer water level represents a purge of water. Recovery is relatively slow due to completion in probable lacustrine material.	

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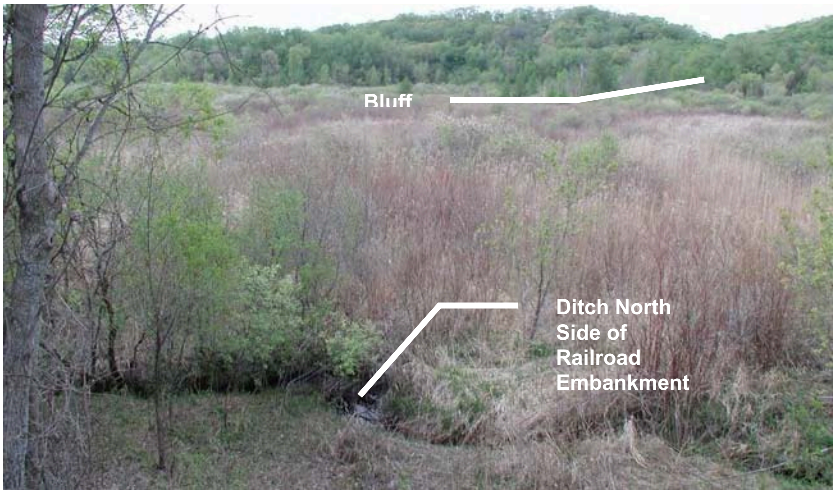
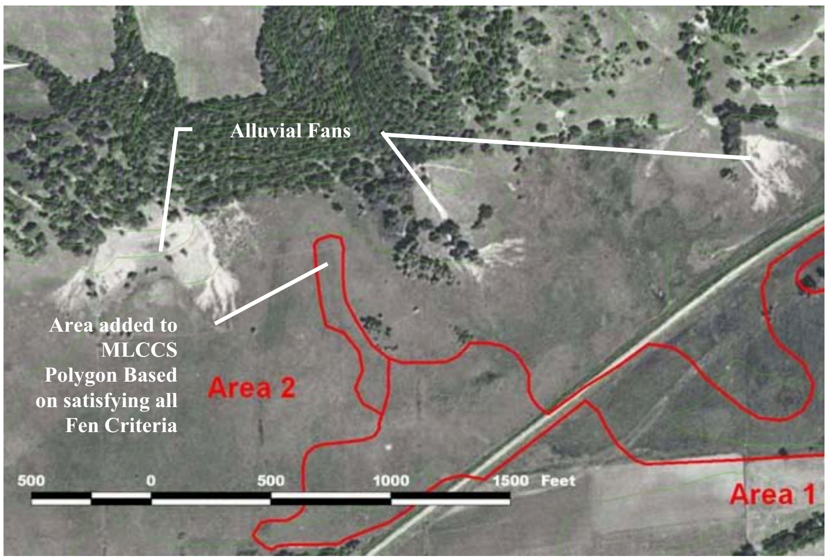
Seminary Fen 2005 Well Nest Hydrographs
SFWC CFC Area 2: Well Nest 2B
Phase 1 Characterization: Seminary Fen Wetland Complex, Carver County, MN
Figure 5.7

PEC Project No. 2005-031



A. Photo of SFWC Area 2 from the railroad embankment. Area 2 is hydrologically isolated form Area 1 by the railroad embankment which diverts surface flows through a ditch on the north side of the embankment. Upland consisting of a coarse textured terrace deposit is to the immediate south. No culverts allow surface water to pass through the embankment until well west of Area 2.



B. The northern part of the SFWC north of CFC Area 2 contains several alluvial fans deposited from intermittent drainageways in the bluff coulees (1940 photo). These alluvial fans are elevated well above the surrounding wetland and regularly receive floodwater. The alluvial fans could act as a recharge area for discharge wetlands downslope, including Area 2. Note the presence of the railroad grade separating CFC Area 1 from CFC Area 2. Contour (green) interval is 10 feet.

B. Detail of a coulee o the north of CFC Area 2. These coulees are actively down cutting and deliver large sediment loads and floodwater to the alluvial fans on the north edge of the SFWC.

A. The terrace feature that lies between the north and south components of the SFWC is an upland that is used for agriculture. The photo was taken from the railroad embankment looking east. Assumption Creek is flowing through the forested area to the right of the photo.

B. The terrace feature that lies between the north and south components of the SFWC is an dominated by Estherville soils (Sandy, mixed, mesic Typic Hapludolls) that are coarse textured and have a sand and gravel substrate (see Figure 2.6).

A. Assumption Creek well nest at time of installation October 6, 2005. The white pipe is a water table well. The grey pipe is a piezometer screened at 730 to 731 fASL. The surface of the streambed is at 733.0 fASL. Limited flow was observed at the time of installation.

B. Assumption Creek upstream of well nest during a period of no flow observed in June. Piezometer and stage gauge data (see Part A above indicates that this reach of Assumption Creek is a losing stream that recharges the watertable under the terrace.

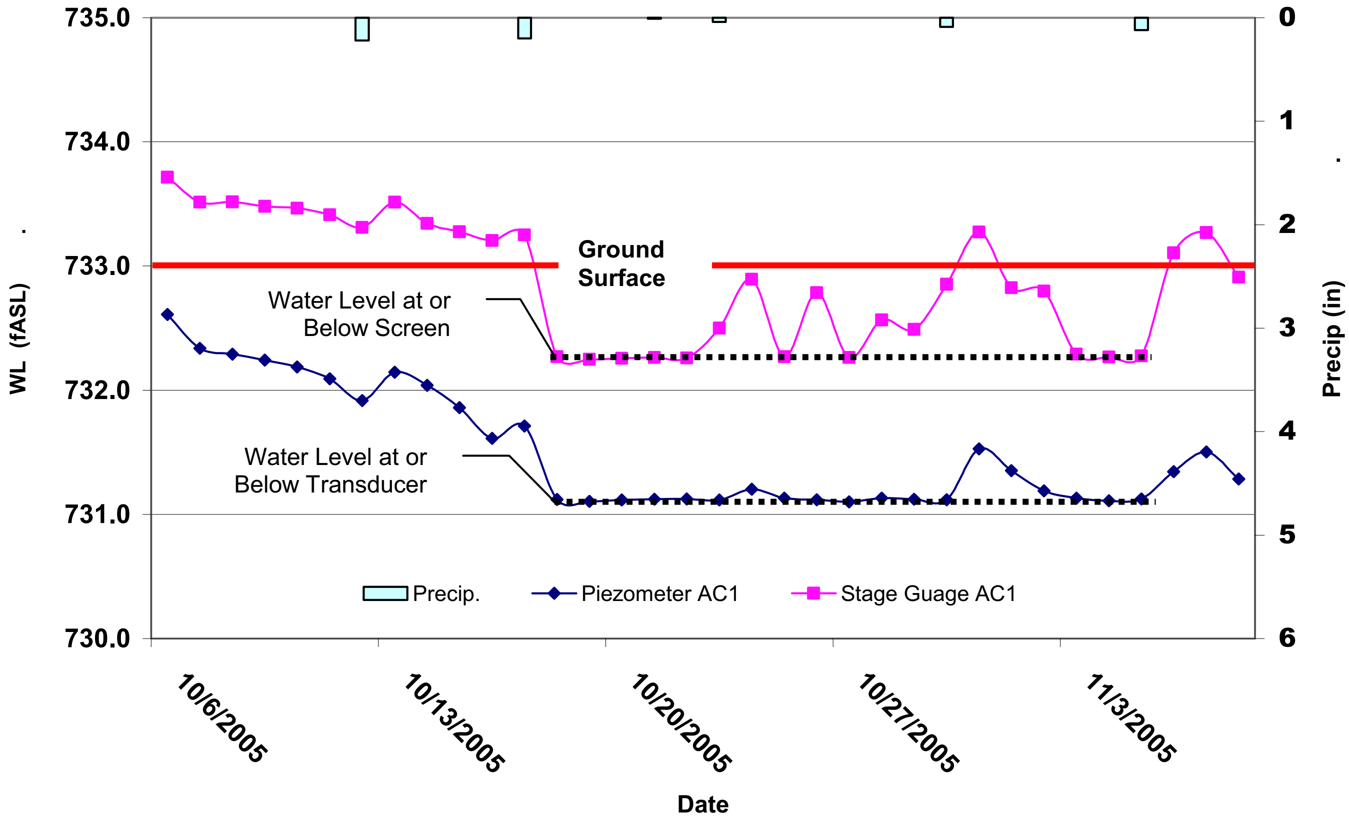
C. Stilling well driven into the bed of Assumption Creek just upstream of TH 212. The casing was 2-inch 10-slot well screen screened for 4-feet of its length. In spite of the fact that about 4 inches of well screen was above the water surface, the water rose to the top of the well and overflowed through the vent hole. A significant upward gradient indicates that this portion of Assumption Creek is a gaining stream receiving groundwater discharge from the terrace feature

Site Photographs, Assumption Creek Mid-terrace Well Nest and Stilling Well Near TH 212

Phase 1 Characterization: Seminary Fen Wetland Complex

Carver County, MN

Figure 5.10



	ACPZ1	ACSG1
Type	Piezometer	Water Table/Stage Guage Stilling Well
Location (UTM NAD83 M: X,Y)	455612.2, 4961801.5	455612.5, 4961802.1
Material	1.25-inch Sch. 80, flush threaded	2-inch Sch. 40 PVC; Glued Couplings
Screen Type	Johnson 1.25-inch wound stainless steel 10-slot drive point	Johnson 2-inch Sch. 40 10-slot PVC
Installation	Driven	Driven
Installation Date	10/05/05	10/05/05
Data Logger	2005: Solinst #40286	2005: Solinst #41062
MDH Number	NA	NA
Chemistry	No	No
Top-of-Casing (fASL)	736.2	736.1
Ground Surface (fASL)	733.1	733.0
Bottom of Well (fASL)	730.0	730.3
Screened Interval (fASL)	730.03 - 731.03	732.3 - 734.3
Depth-to-Sand	2.5 feet (730.6 fASL)	2.5 feet (730.6 fASL)
Notes	Stage Guage constructed with solid casing for the bottom two feet, nad 10-slot screen from 2-4 feet from bottom of well. Piezometer was driven to refusal.	

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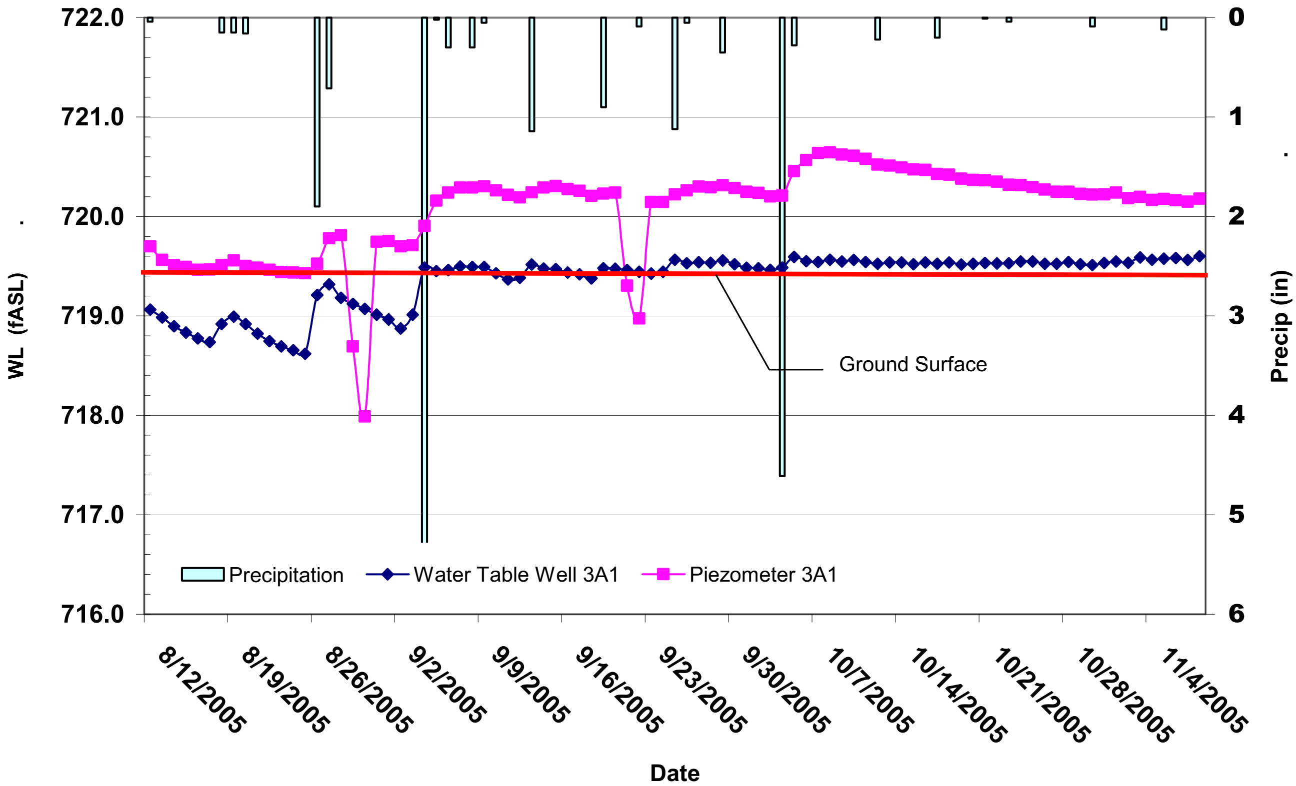
Seminary Fen 2005 Well Nest Hydrographs
Assumption Creek Terrace Piezometer and Stage Guage
Phase 1 Characterization: Seminary Fen Wetland Complex, Carver County, MN
Figure 5.11

PEC Project No. 2005-031



	3PZA1	3WTA1
Type	Piezometer	Water Table
Location (UTM NAD83 M: X,Y)	455888.8, 4961668.8	455890.3, 4961669.1
Material	1.25-inch Sch. 80, flush threaded	2-inch Sch. 40 PVC; Glued Couplings
Screen Type	Johnson 1.25-inch wound stainless steel 10-slot drive point	Johnson 2-inch Sch. 40 10-slot PVC
Installation	Driven	Set in underfit Augered hole
Installation Date	08/09/05	08/09/05
Data Logger	2005: Solinst #40284	2005: Solinst #40278
MDH Number	5380.0	5381.0
Chemistry	Yes	Yes
Top-of-Casing (fASL)	723.4	720.8
Ground Surface (fASL)	719.6	719.5
Bottom of Well (fASL)	707.4	715.2
Screened Interval (fASL)	707.4 - 708.4	717.5 - 719.5
Depth-to-Sand	11 feet (708.6 fASL)	11 feet (708.6 fASL)
Notes	Transient depression in piezometer water level represents a purge of water. Recovery is rapid.	

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Seminary Fen 2005 Well Nest Hydrographs
SFWC CFC Area 3:Well Nest 3A
Phase 1 Characterization: Seminary Fen Wetland Complex, Carver County, MN
Figure 5.12

PEC Project No. 2005-031

A. CFC Area 3 is a strongly sloping peatland near the floodplain of the Minnesota River. Note the presence of a thick stand of common reed grass in the background of the picture. The photo was taken near Well Nest 3A. The flag indicates an area of "quaking ground" that is indicative of focused groundwater discharge.

B. Thick stands of common reed grass were observed in elevated portions of the sloping fen, and are likely establishing themselves in response to disturbance associated with the construction and maintenance of the radio tower.

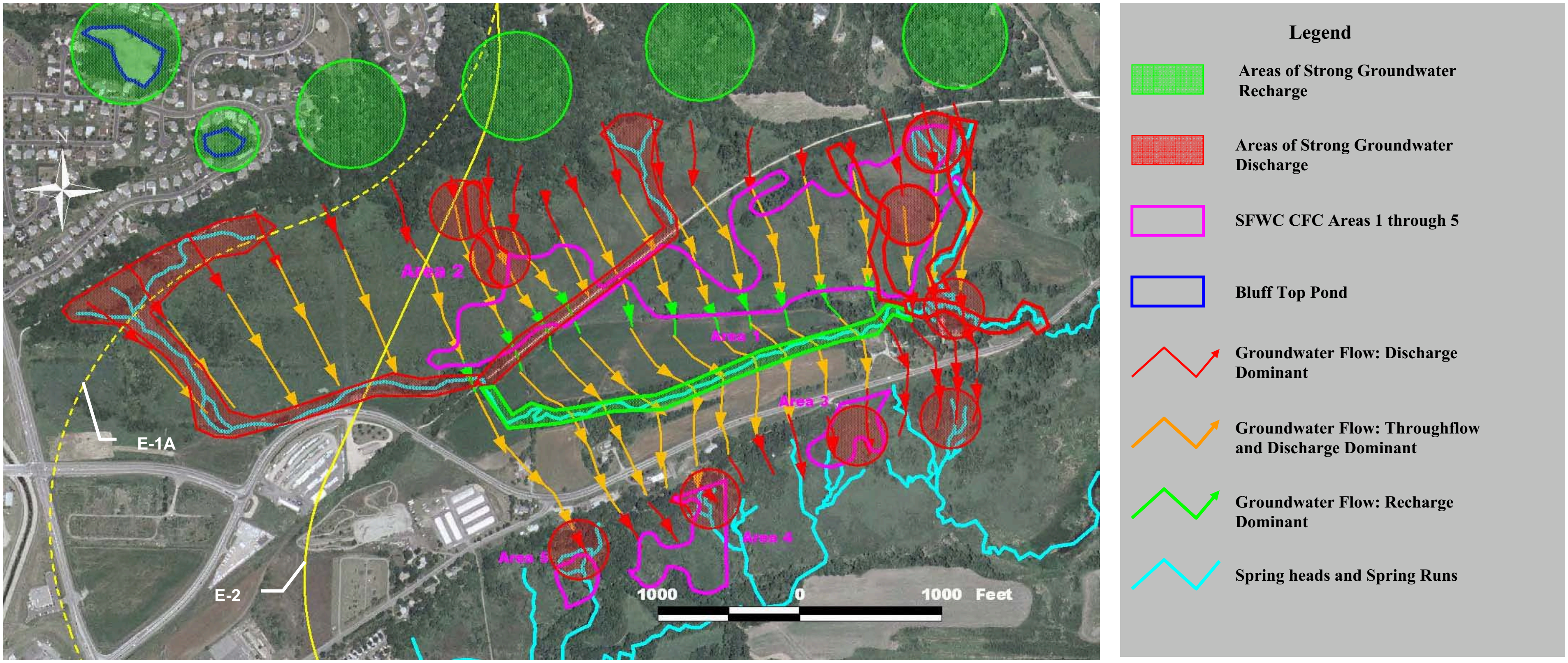
C. The radio tower utility hut has been sandbagged as protection from flooding from the Minnesota River. Calcareous fens usually do not develop in areas that receive periodic flooding as the disturbance and nutrients associated with the sediment preclude the maintenance of a species-rich nutrient poor environment.

A. Spring head near the toe-of-slope position on the north side of SFWC CFC Area 4. Large volumes of discharge were observed I the area which rapidly coalesced into a significant deeply incised spring run. Vegetation was dominated by reed canary grass, cattails, and marsh marigold.

B. The north part of CFC Area 4 had several, deeply incised spring runs.

A. Numerous Spring head and spring runs rapidly coalesce to form a significant, unnamed creek within the CFC Area 5. Abandoned spring runs result in deep incision into the surrounding peat.

B. A spring run photo taken approximately 30 feet from the spring head at the foot of the terrace slope.



Theoretical Model of Groundwater Flow: Seminary Fen Wetland Complex

- Groundwater recharge occurs on bluff-top wetlands and uplands north of the bluff escarpment. Head gradients are large and can drive downward groundwater movement through unconsolidated glacial sediment as well as the underlying bedrock.
- Groundwater discharge is primarily associated with spring heads and diffuse seepage areas at toe-of-slope positions at the base of the bluff and associated alluvial fans.
- Localized areas of discharge are also associated with areas further from the base of the bluff that are shallow to sand or that do not contain fine textured substrates.
- Throughflow dominates in the middle portions of the SFWC that are sloping peatlands with a gradient to the south. However, at any given point, weak upward gradients are also observed.
- Groundwater recharge occurs at the northern edge of the terrace feature and in losing reaches of Assumption Creek.
- Groundwater flow under the terrace feature is to the south and east and occurs as throughflow.
- Extensive groundwater discharge is observed as spring heads and spring runs at the toe-of-slope positions for the terrace feature in the southern unit of the SFWC.

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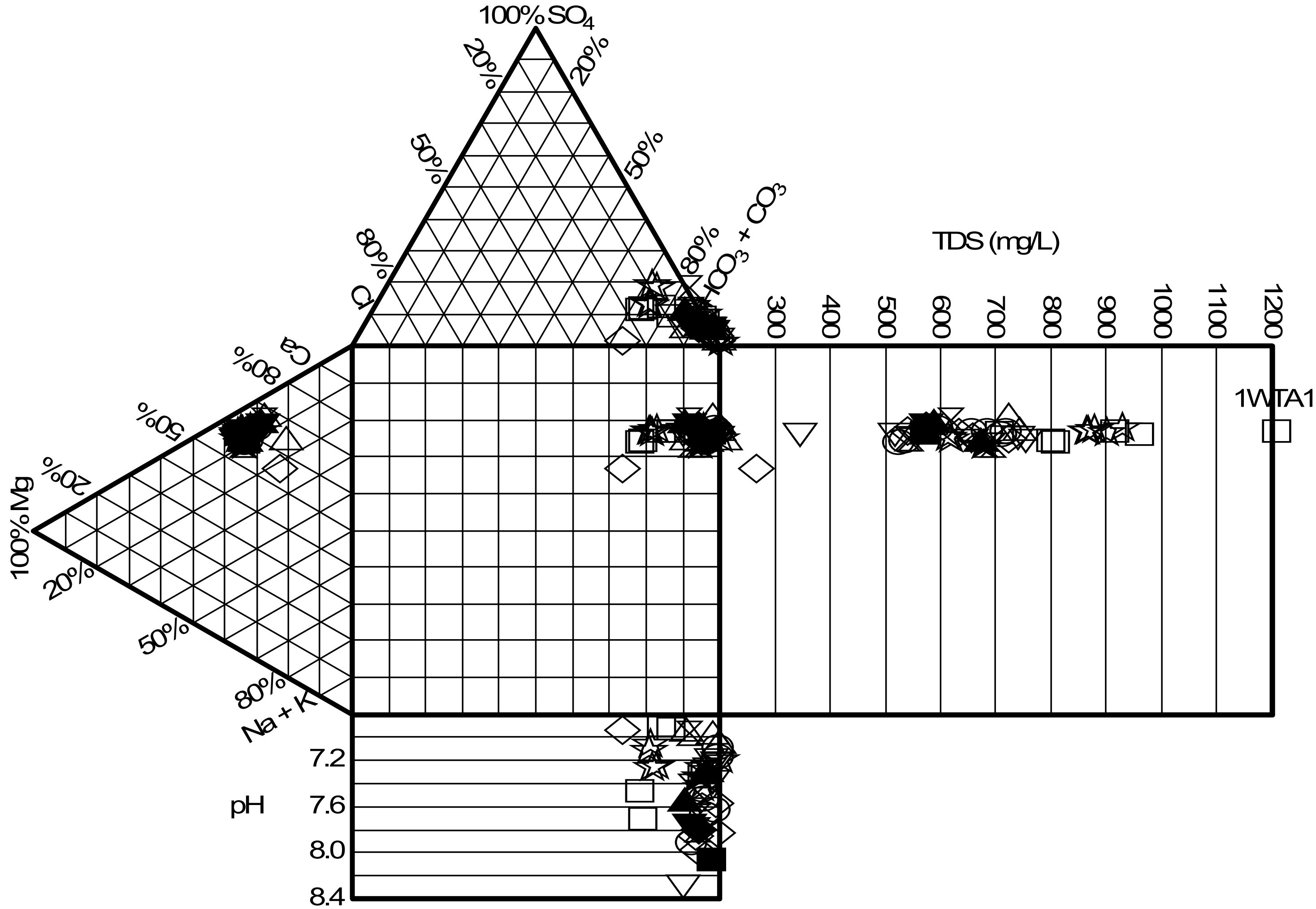
Theoretical Model of Groundwater Flow

Phase 1 Characterization: Seminary Fen Wetland Complex, Carver County MN

FIGURE 5.16

PEC Project No. 2003-031



Durov Diagram Summarizing Major Ion Water Chemistry, All Samples
Phase 1 Characterization: Seminary Fen Wetland Complex
Carver County, Minnesota
Figure 5.17

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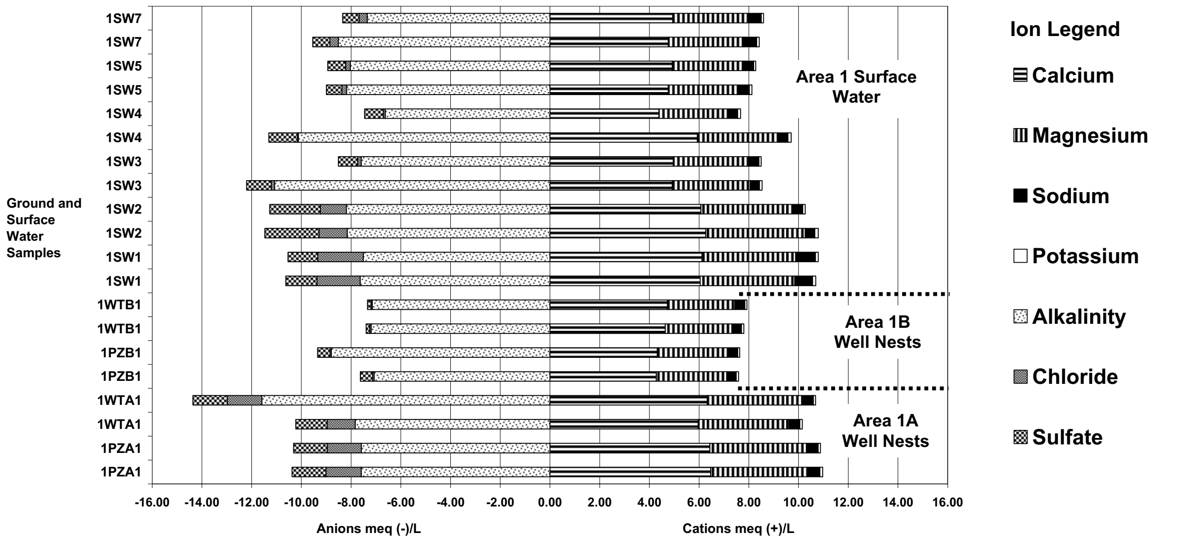
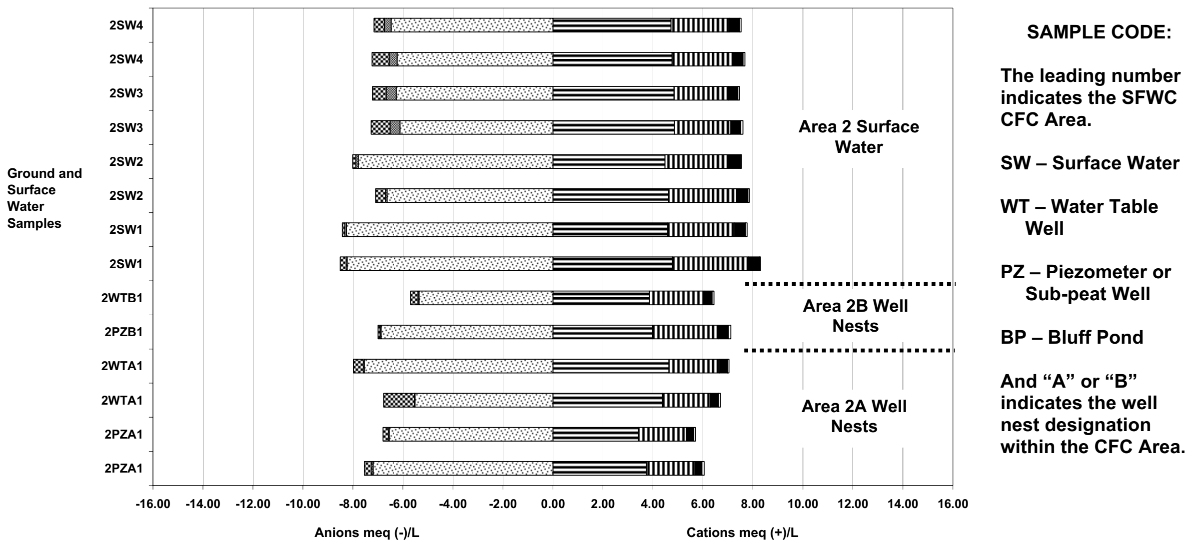
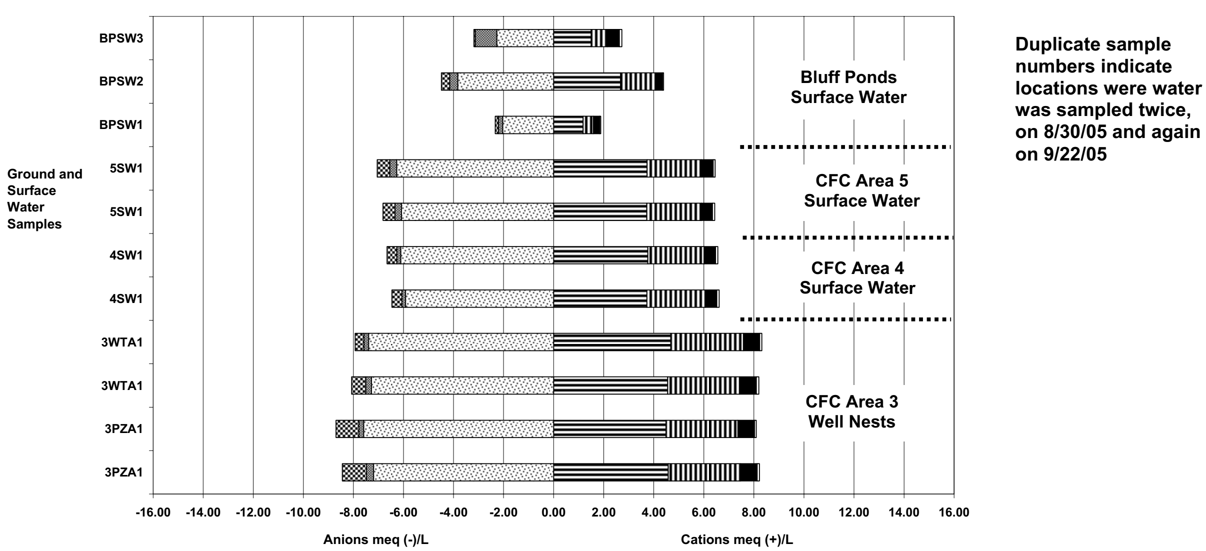
PEC Project No. 2005-031



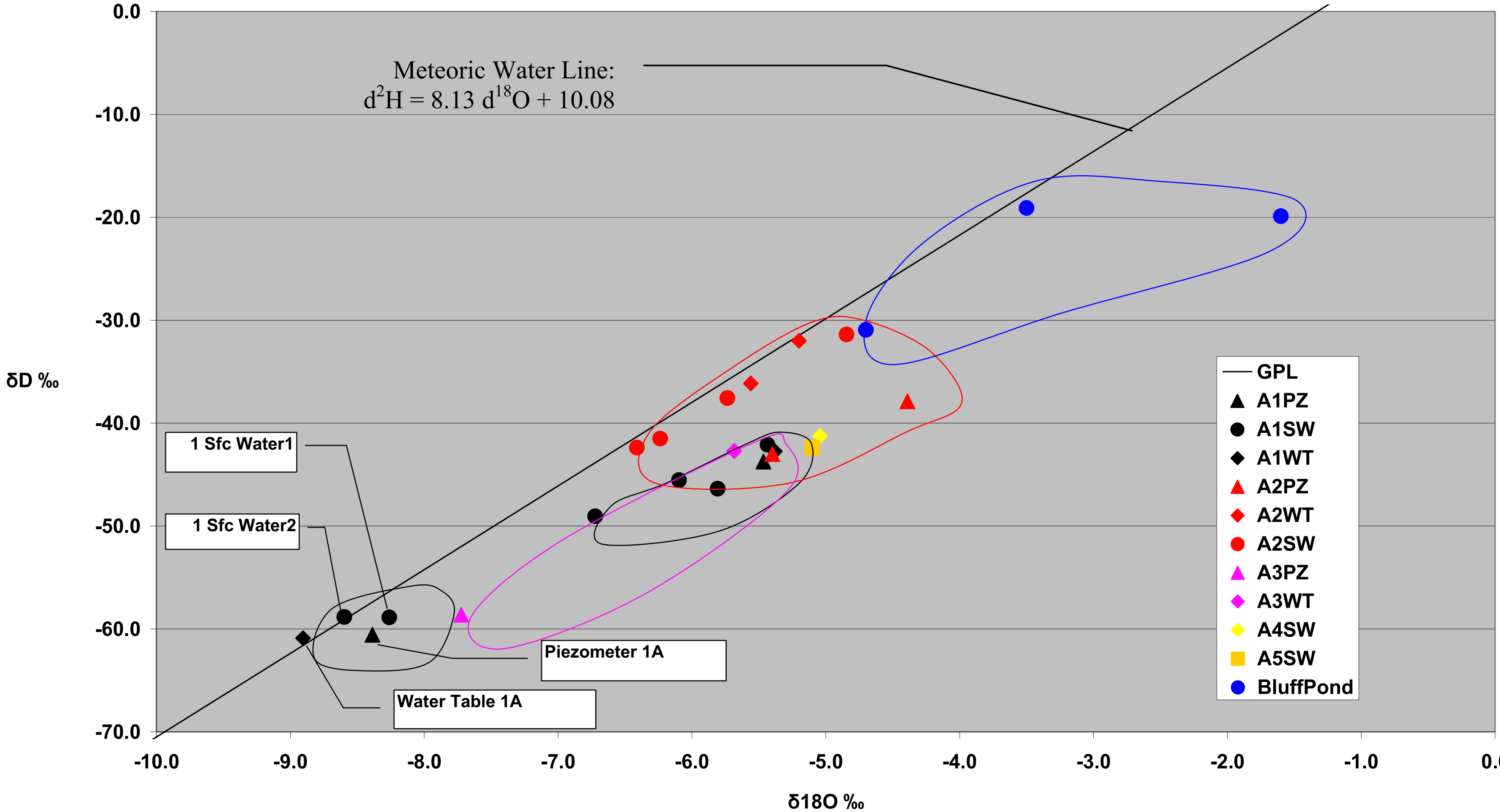
A. SFWC CFC Area 1



B. SFWC CFC Area 2



C. SFWC Areas 3, 4, 5, and in bluff top ponds.



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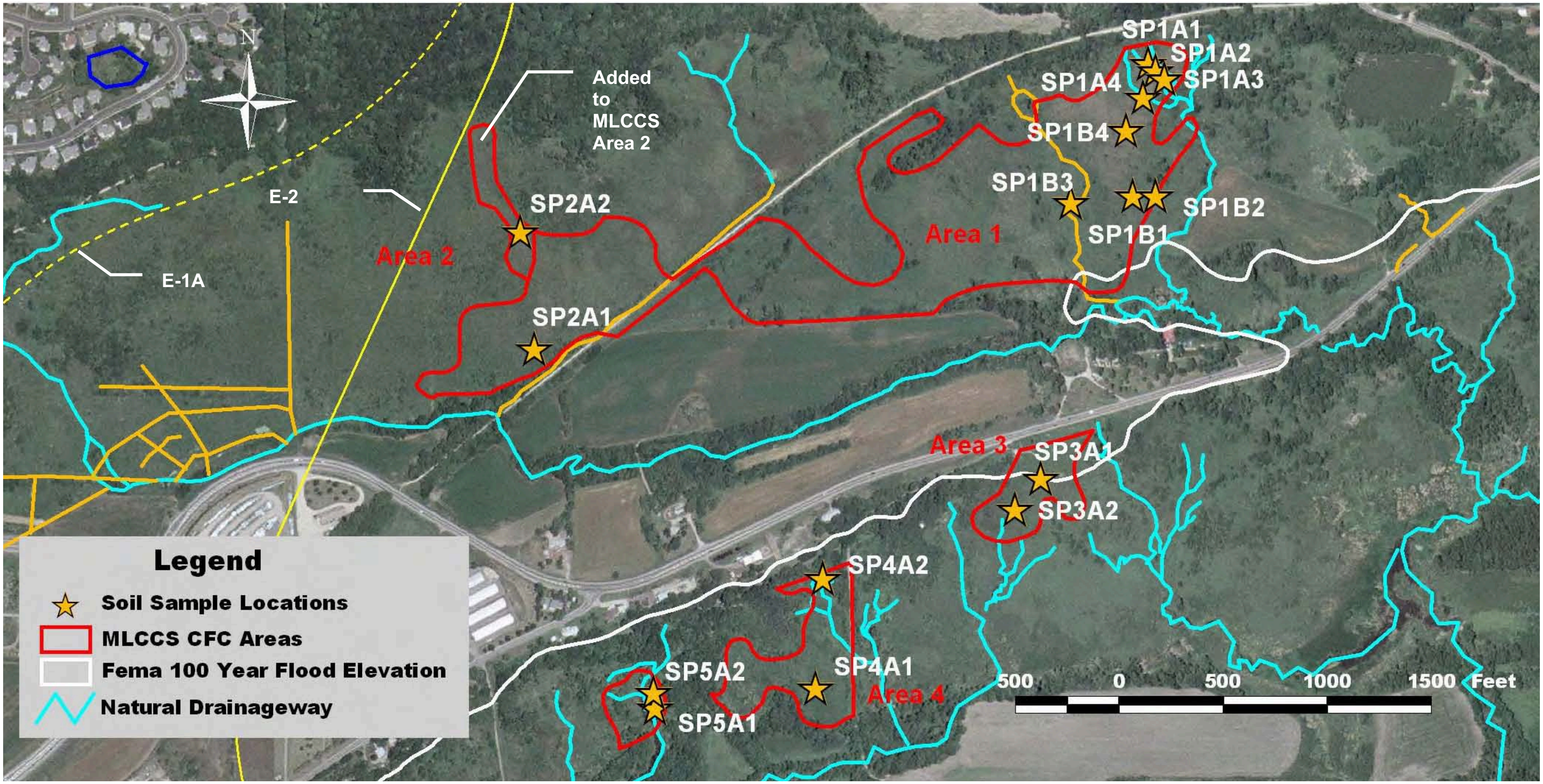
Oxygen and Hydrogen Isotope Data In Water Samples
Phase 1 Characterization: Seminary Fen Wetland Complex
Carver County, Minnesota
Figure 5.19

PEC Project No. 2005-031



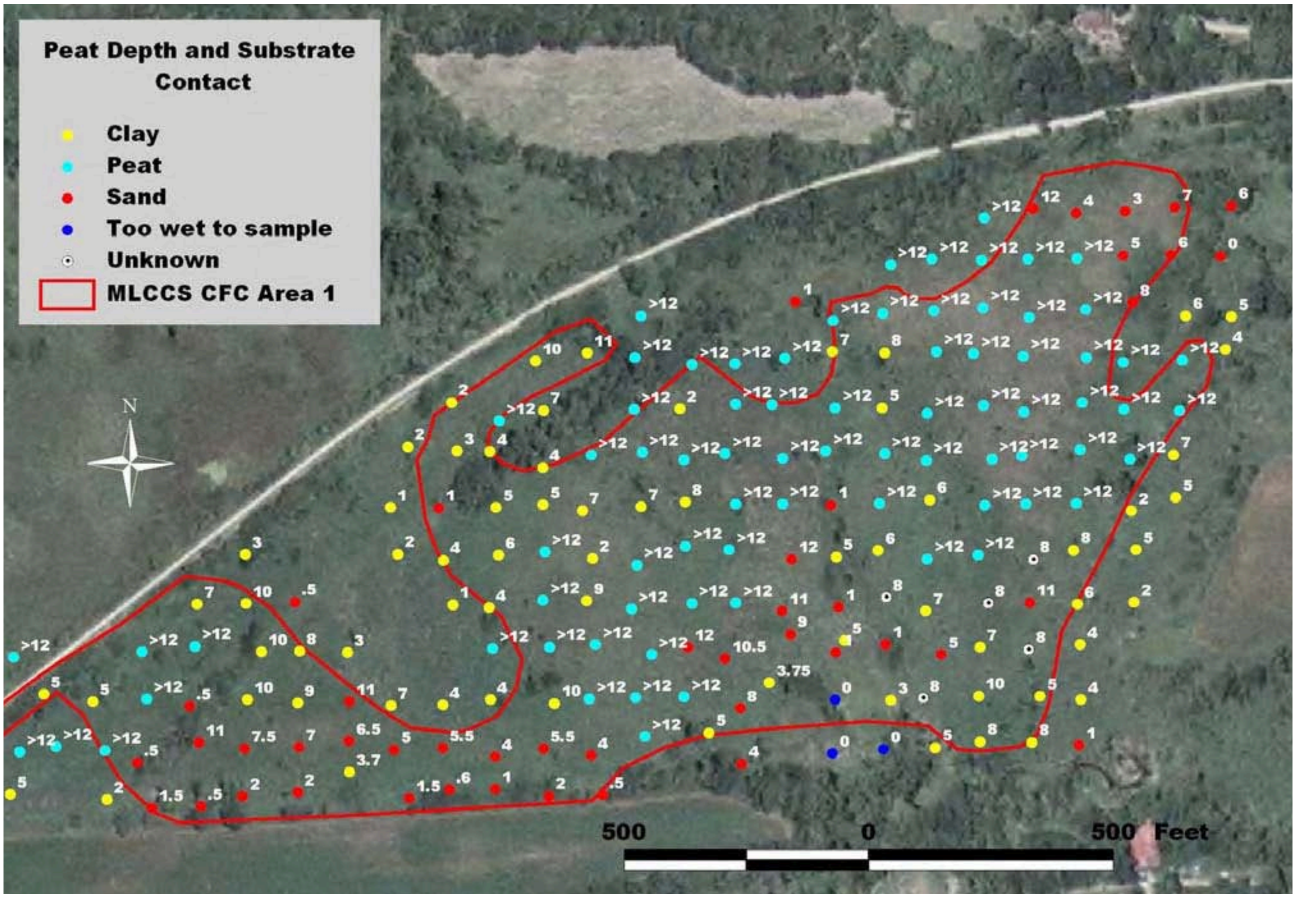
Peterson Environmental Consulting, Inc.

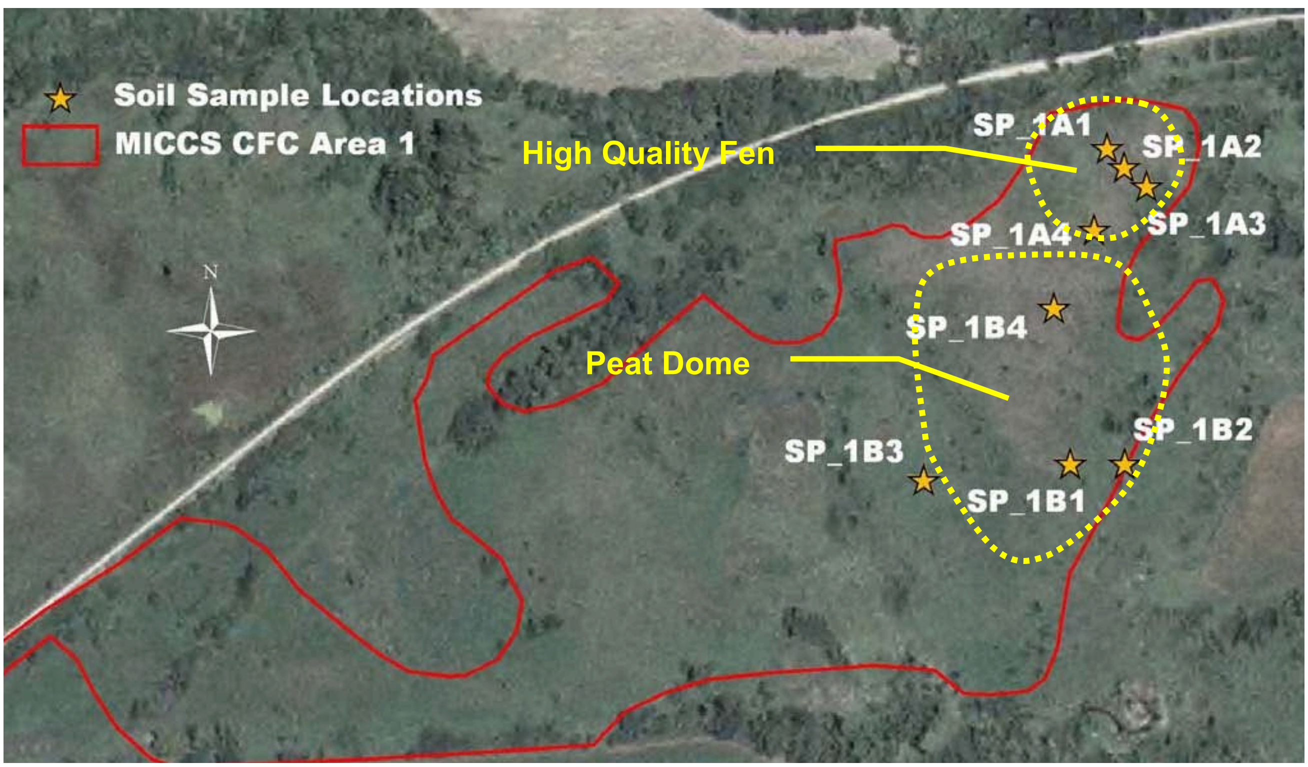
Soil Description and Sampling Locations

Phase 1 Characterization: Seminary Fen Wetland Complex, Carver County MN

FIGURE 5.20

PEC Project No. 2003-031





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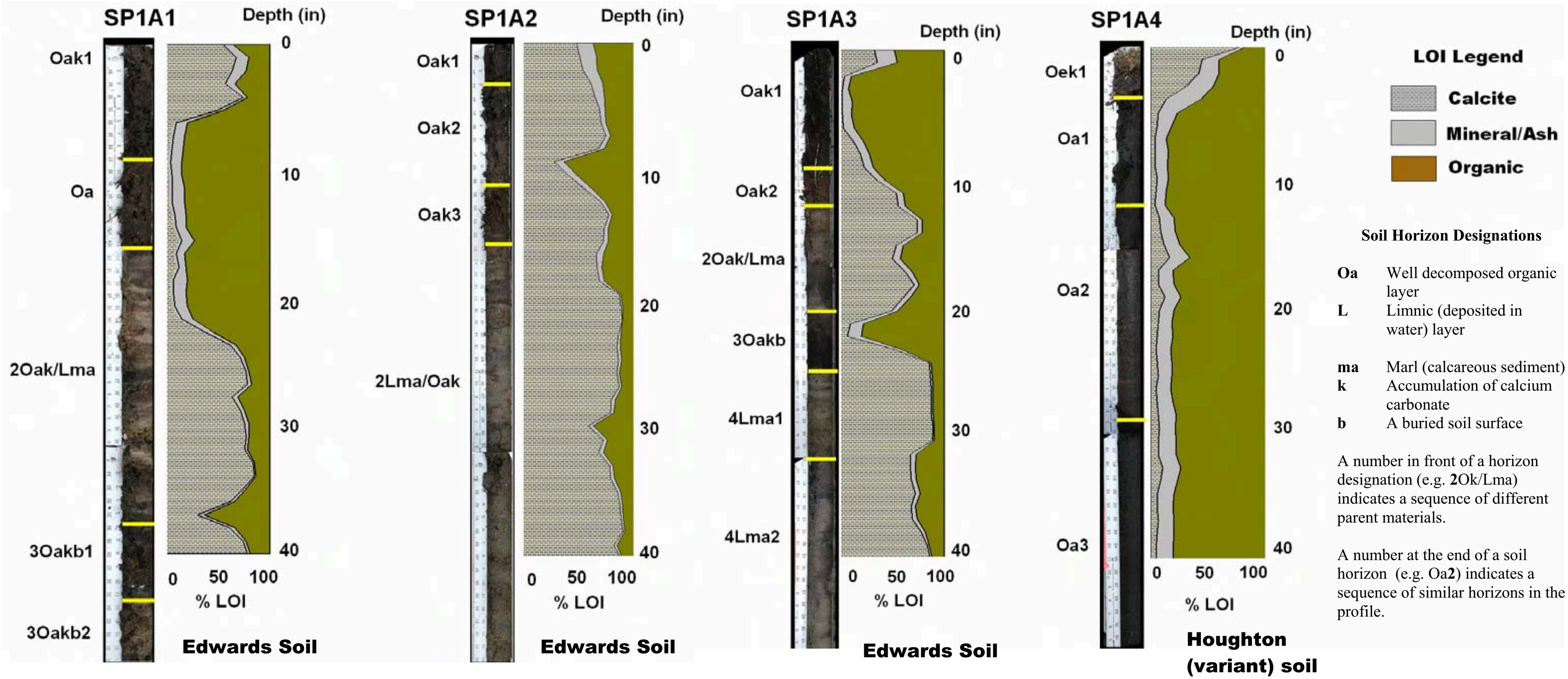
Peat Depth and Soil Sampling Locations: CFC-SFWC Area 1
Phase 1 Characterization: Seminary Fen Wetland Complex
Carver County, Minnesota
FIGURE 5.21

PEC Project No. 2005-031



USDA Soil Horizons are indicated to the left of the profile. Loss-on-Ignition (LOI) data are graphically presented to the right of each profile and correspond to the depth sampled (40 inches). All profiles collected along Transect 1A meet calcareous fen soils criteria (Leete et al., 2005). All profiles contain histic epipedons with significant amounts of included calcium carbonate. Stratification observed in Profiles 1A1 through 1A3 are probably abandoned flarks, spring runs, or spring heads that represented surface flows associated with the discharge of groundwater that is supersaturated with calcium carbonate. Elevated calcium carbonate contents in the surface of Profile 1A4 likely reflect evapotranspiration concentrating calcium carbonate at and near the soil surface.

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Soil Profiles Description and Loss-on-Ignition Data Collected Along Transect 1A, CFC-SFWC Area 1

Phase 1 Characterization: Seminary Fen Wetland Complex

Carver County, Minnesota

FIGURE 5.22

PEC Project No. 2005-052

A. Soil transect 1A was collected in a short stature, high-quality, sloping calcareous fen area that presents classic calcareous fen characteristics, including spring heads and runs, high point calciphiles, and tufa at the surface.

B. Deposit of virtually pure calcium carbonate at the soil surface is called "tufa" and is deposited by continuous discharge and evaporation of calcite saturated groundwater..

C. Stratified deposits of marl, organic matter, and coprogenous earth (sedimentary peat) indicates deposition in a water environment. Such sediments are call "Limnic" and may be precipitated in spring heads, along spring runs, and in shallow lake pools.

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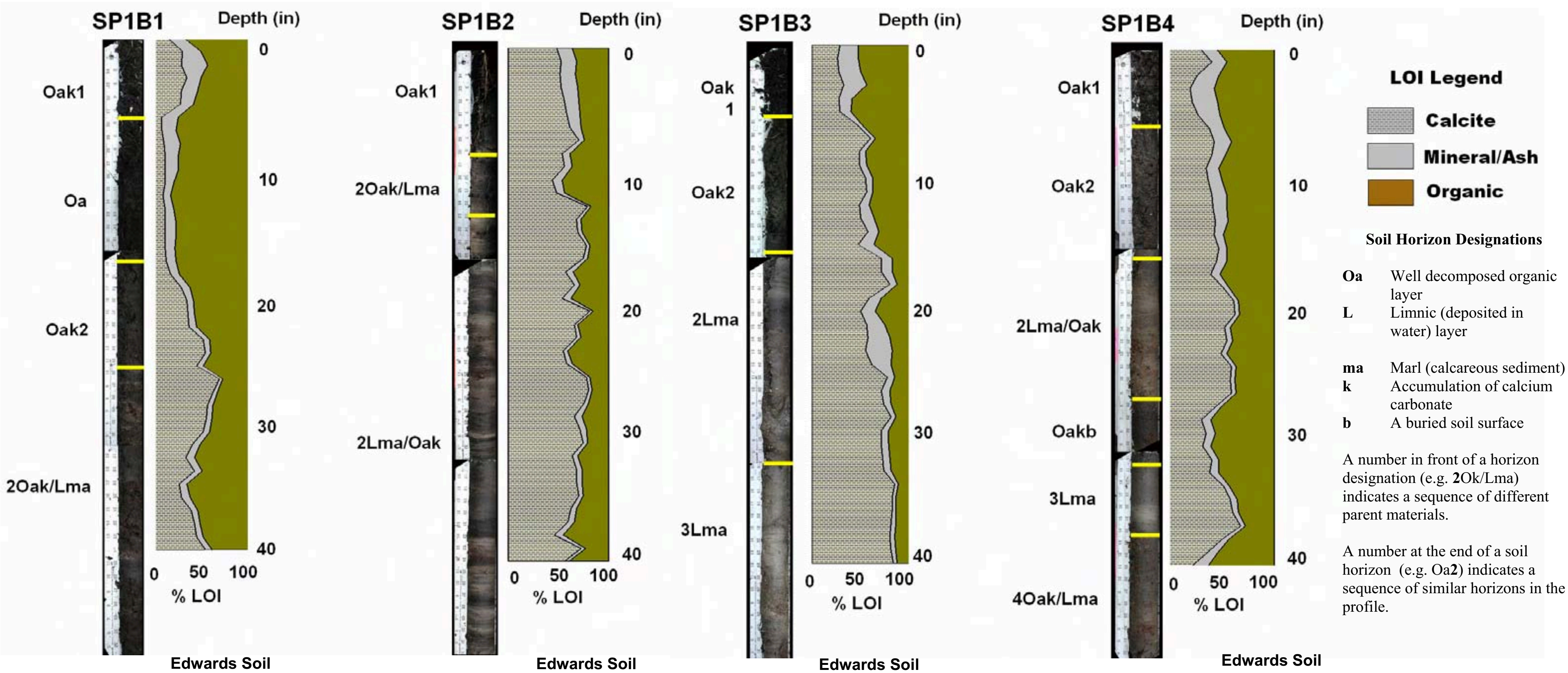
Site Photographs, Soil Investigations, SFWC CFC Area 1: Transect 1A
Phase 1 Characterization: Seminary Fen Wetland Complex
Carver County, MN
Figure 5.23

PEC Project No. 2005-031



USDA Soil Horizons are indicated to the left of the profile. Loss-on-Ignition (LOI) data are graphically presented to the right of each profile and correspond to the depth sampled (40 inches). All profiles collected along Transect 1B meet calcareous fen soils criteria (Leete et al., 2005). All profiles contain histic epipedons with significant amounts of included calcium carbonate. Stratification observed in Profiles 1B2 through 1B4 are probably abandoned flarks, spring runs, or spring heads that represented surface flows associated with the discharge of groundwater that is supersaturated with calcium carbonate. Profile 1B1 was collected on top of the peat dome and is a deep histosol that lacks the stratification observed in Profiles 1B2 through 1B4.

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Soil Profile Descriptions and Loss-on-Ignition Data Collected Along Transect 1B, CFC-SFWC Area 1

Phase 1 Characterization: Seminary Fen Wetland Complex

Carver County, Minnesota

FIGURE 5.24

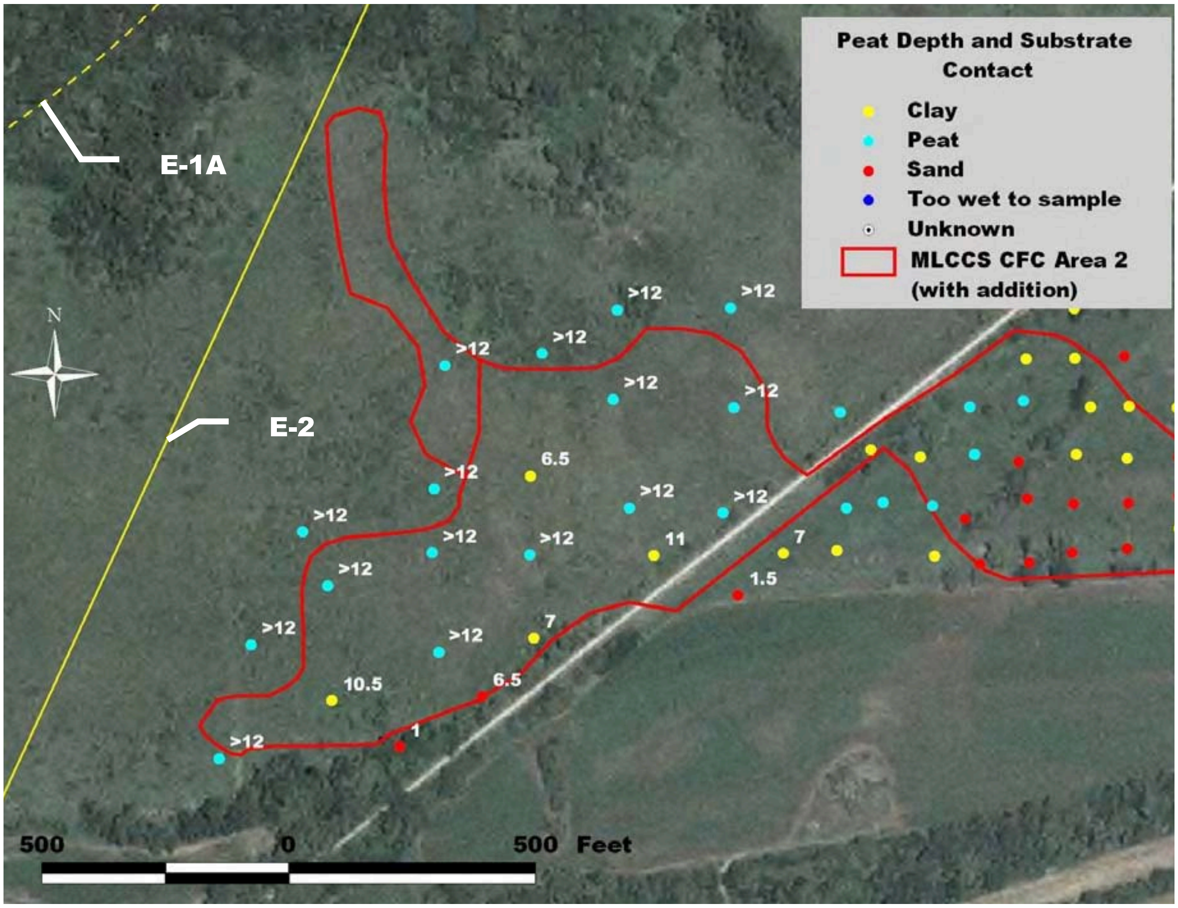
PEC Project No. 2005-052

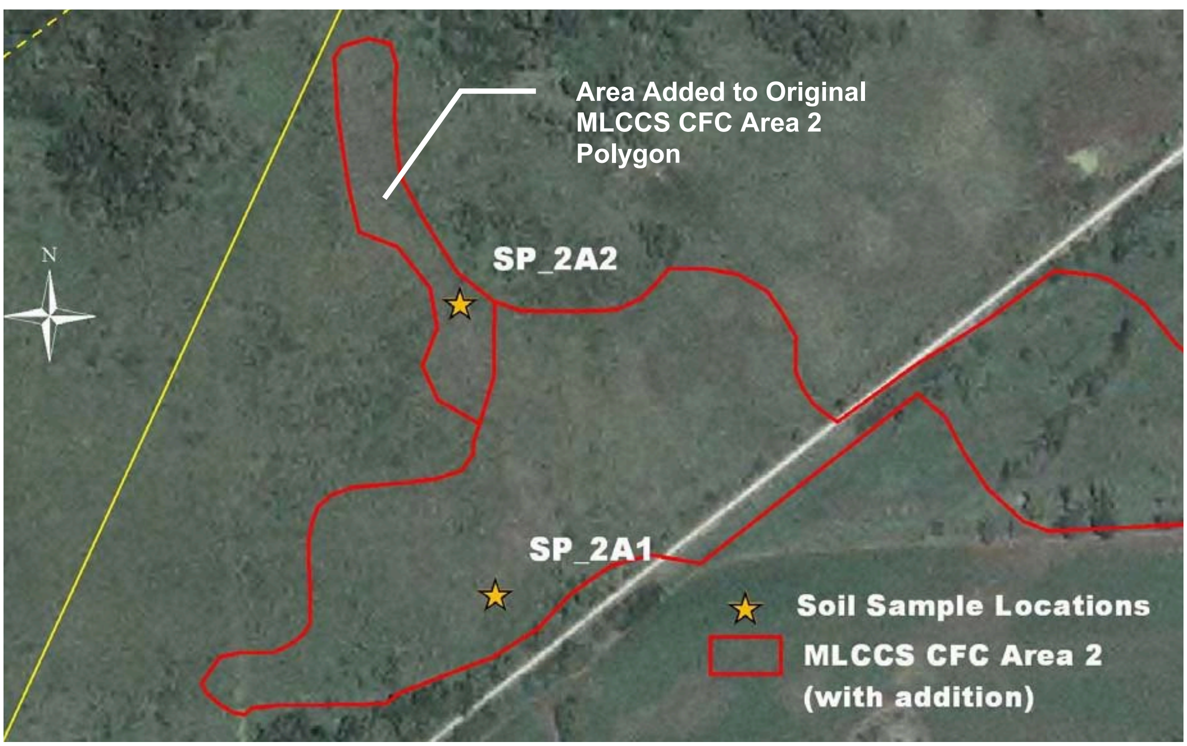
A. Soil transect 1B was collected on the flanks and top of a significant peat dome in Area 1. Relief from the top of the peat dome to the surrounding wetland is approximately 10-12 feet. Historic aerial photos indicate that the peat dome has been extensively tiled. As a result, buckthorn, common reed grass, and reed canary grass are invading the area.

B. Tile discharge observed on the flank of the peat dome. The white material in the discharge pool is calcium carbonate. The dominant vegetation in the discharge area is a reed canary grass monotype. The soil profile shown in part C, below was collected just a short distance from this tile discharge area.

C. Stratified deposits of marl, organic matter, and coprogenous earth (sedimentary peat) indicates deposition in a water environment. Such sediments are call "limnic" and may be precipitated in spring heads, along spring runs, flarks, and in shallow lake pools. We believe that this area was historically high quality calcareous fen with significant potential for restoration

Site Photographs, Soil Investigations, SFWC CFC Area 1: Transect 1B
Phase 1 Characterization: Seminary Fen Wetland Complex
Carver County, MN
Figure 5.25





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Peat Depth and Soil Sampling Locations: SFWC-CFC Area 2
Phase 1 Characterization: Seminary Fen Wetland Complex
Carver County, Minnesota
FIGURE 5.26

PEC Project No. 2005-031

A. Soil sampling points 2A1 and 2A2 were located on the north and south sides of CFC Area 2, respectively. No peat mounds were observed. The morphology is a sloping peatland with a gentle downhill grade from north to south. Shrubs are invading the area and substantial portions are dominated by common reed grass. Soil sample point 2A2 (shown) is located between two alluvial fans resulting from deposition of sediment eroded from nearby coulees. These areas could be acting as recharge to the downslope fen areas.

B. Two high point calciphiles were observed in the immediate area of soil sample point 2A2. the blue flower is *Lobelia Kalmii* (25 calciphile points) and *Parnassia glauca* (25 calciphile points). A walkover of the area indicated that these plants were sparingly but generally distributed but showed no areas of high population densities. MLCCS CFC Area 2 was extended in this area based on the presence of positive soil, hydrology, and vegetation calcareous fen indicators.

C. Peat depth at soil sampling points 2A1 and 2A2 was greater than 12 feet. The soil profiles did not exhibit stratification and the presence of limnic sediments found at other locations. However, both profiles presented snail shells throughout (white flecks). Snail shells are composed of calcium carbonate, and their presence in the profile indicates that the groundwater is saturated with calcium carbonate.

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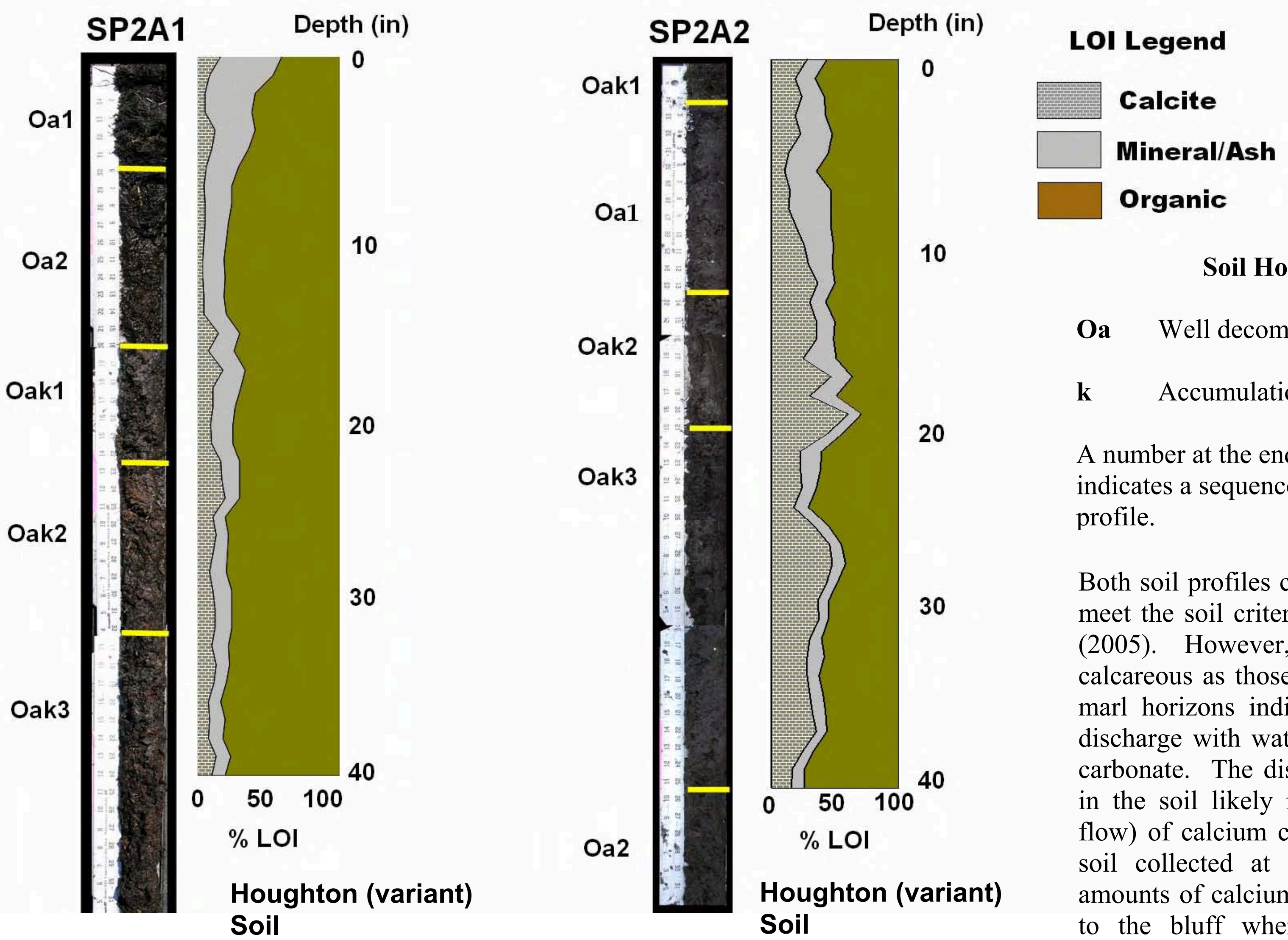
Site Photographs, Soil Investigations, SFWC CFC Area 2: Transect 2A
Phase 1 Characterization: Seminary Fen Wetland Complex
Carver County, MN
Figure 5.27

PEC Project No. 2005-031



Soil Horizon Designations

Oa Well decomposed organic layer

k Accumulation of calcium carbonate

A number at the end of a soil horizon (e.g. Oa**2**) indicates a sequence of similar horizons in the profile.

Both soil profiles collected in CFC-SFWC Area 2 meet the soil criteria for calcareous fens in Leete (2005). However, the soils are not as strongly calcareous as those in Area 1, and do not present marl horizons indicative of intense groundwater discharge with water supersaturated with calcium carbonate. The distribution of calcium carbonate in the soil likely represents throughflow (lateral flow) of calcium carbonate saturated water. The soil collected at location 2A2 presents higher amounts of calcium carbonate because it is closes to the bluff where more intense groundwater discharge would be expected.

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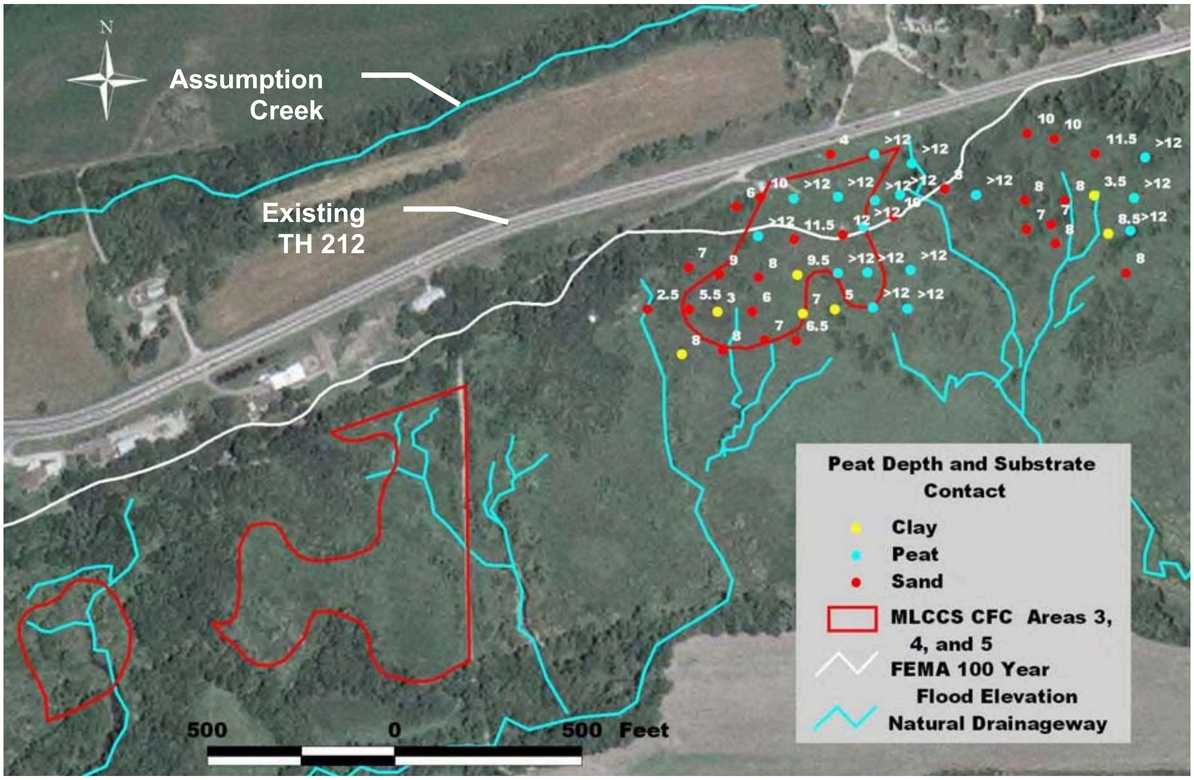
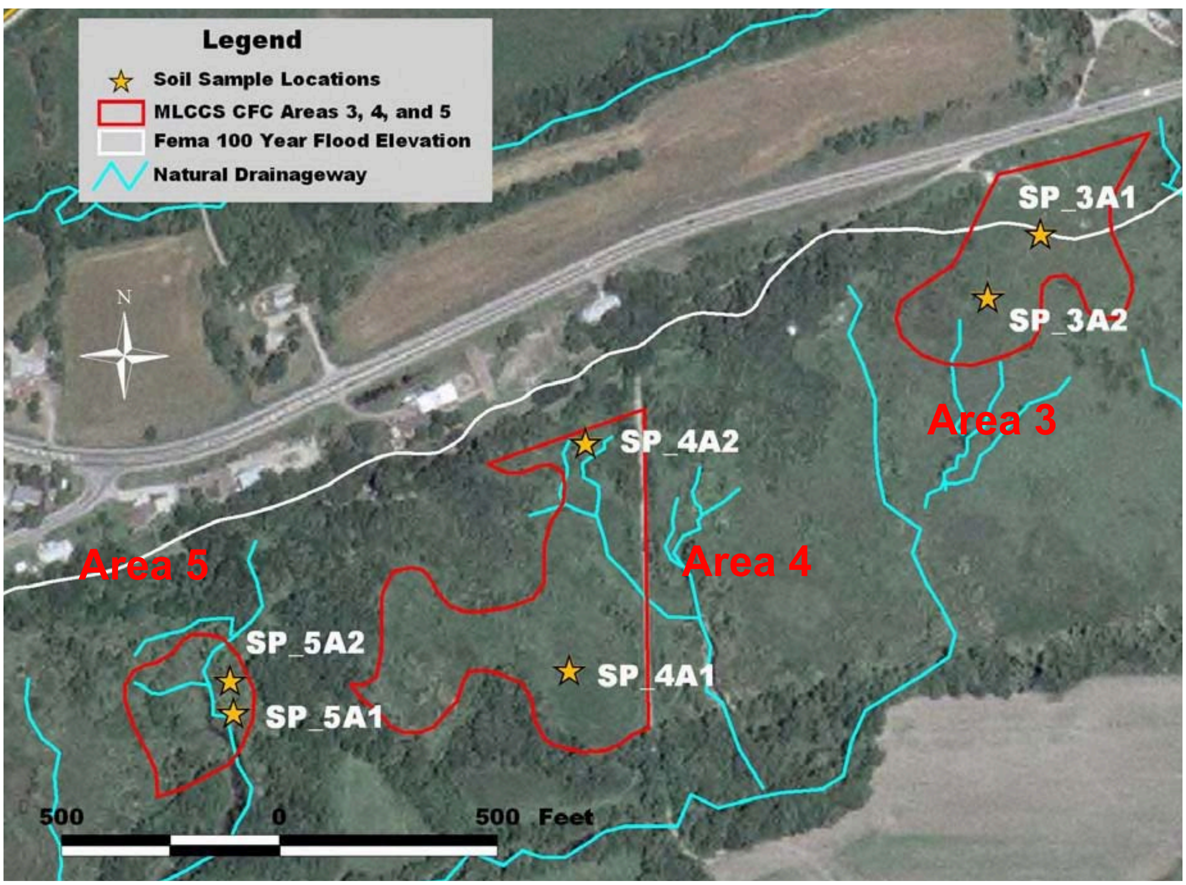
Soil Profile and Loss-on-Ignition Data Collected Along Transect 2A, CFC-SFWC Area 2
Phase 1 Characterization: Seminary Fen Wetland Complex
Carver County, Minnesota
Figure 5.28





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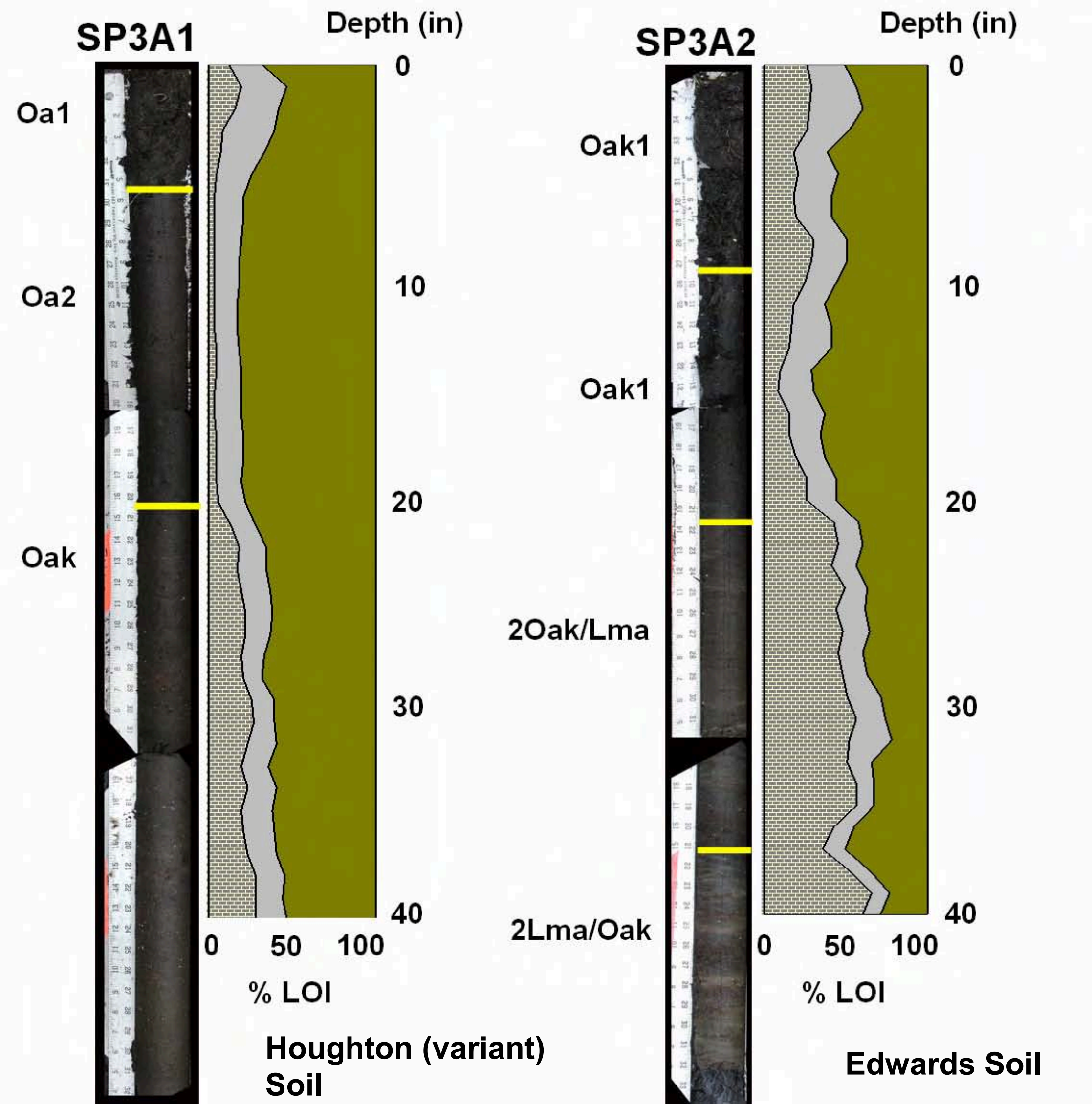
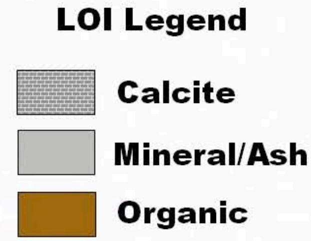
Peat Depth and Soil Sampling Locations: SFWC-CFC Area 3, 4, and 5
Phase 1 Characterization: Seminary Fen Wetland Complex
Carver County, Minnesota
FIGURE 5.29

PEC Project No. 2005-031





Soil Horizon Designations

Oa	Well decomposed organic layer
L	Limnic (deposited in water) layer
ma	Marl (calcareous sediment)
k	Accumulation of calcium carbonate
b	A buried soil surface

A number in front of a horizon designation (e.g. **2**Ok/Lma) indicates a sequence of different parent materials.

A number at the end of a soil horizon (e.g. Oa**2**) indicates a sequence of similar horizons in the profile.

Both soil profiles collected in CFC-SFWC Area 3 meet the soil criteria for calcareous fens in Leete (2005). However, the soils are not as strongly calcareous as those in Area 1. Soil 3A2 presents marl horizons indicative of intense groundwater discharge with water supersaturated with calcium carbonate. The distribution of calcium carbonate in the soil likely represents the discharge of calcium carbonate saturated water originating in CFC Area 1 that has recharged the groundwater under the eastern part of the terrace feature, a subsequently discharged south of existing TH 212.

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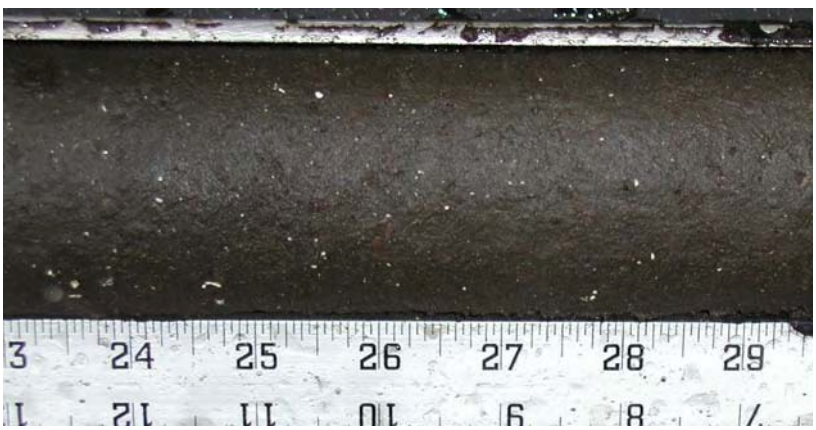
Soil Profile and Loss-on-Ignition Data Collected Along Transect 3A, CFC-SFWC Area 3
Phase 1 Characterization: Seminary Fen Wetland Complex
Carver County, Minnesota

Figure 5.30

PEC Project No. 2005-031

A. Soil sampling points 3A1 and 3A2 were located on the north and south sides of CFC Area 3, respectively. The morphology is that of a sloping peatland with a downhill grade from north to south. Shrubs are invading and substantial portions are dominated by common reed grass. The area has received disturbance from construction of a short-wave radio tower facility. The northern portion was likely filled during construction of existing TH 212.



B. The plant community is not strongly calcareous. Flarks, spring heads and spring runs are absent; however, an area of quaking ground indicated at least one area of strong focused groundwater discharge. Most of the discharge appears to be diffuse across the surface and through the peat. The soil at sampling point 3A1 (shown) had snail shells distributed throughout the profile but was weakly calcareous above 20 inches, suggesting that the groundwater is saturated with calcium carbonate.

C. The soil at sampling point 3A2 presented marl and coprogenous earth stratification in the subsoil. The subsoil zone was strongly calcareous indicating that the area may have been more representative of a classic calcareous fen presenting flarks, spring heads and spring runs in the past. However, the calcareous deposits could also have been deposited in a shallow post glacial lake.

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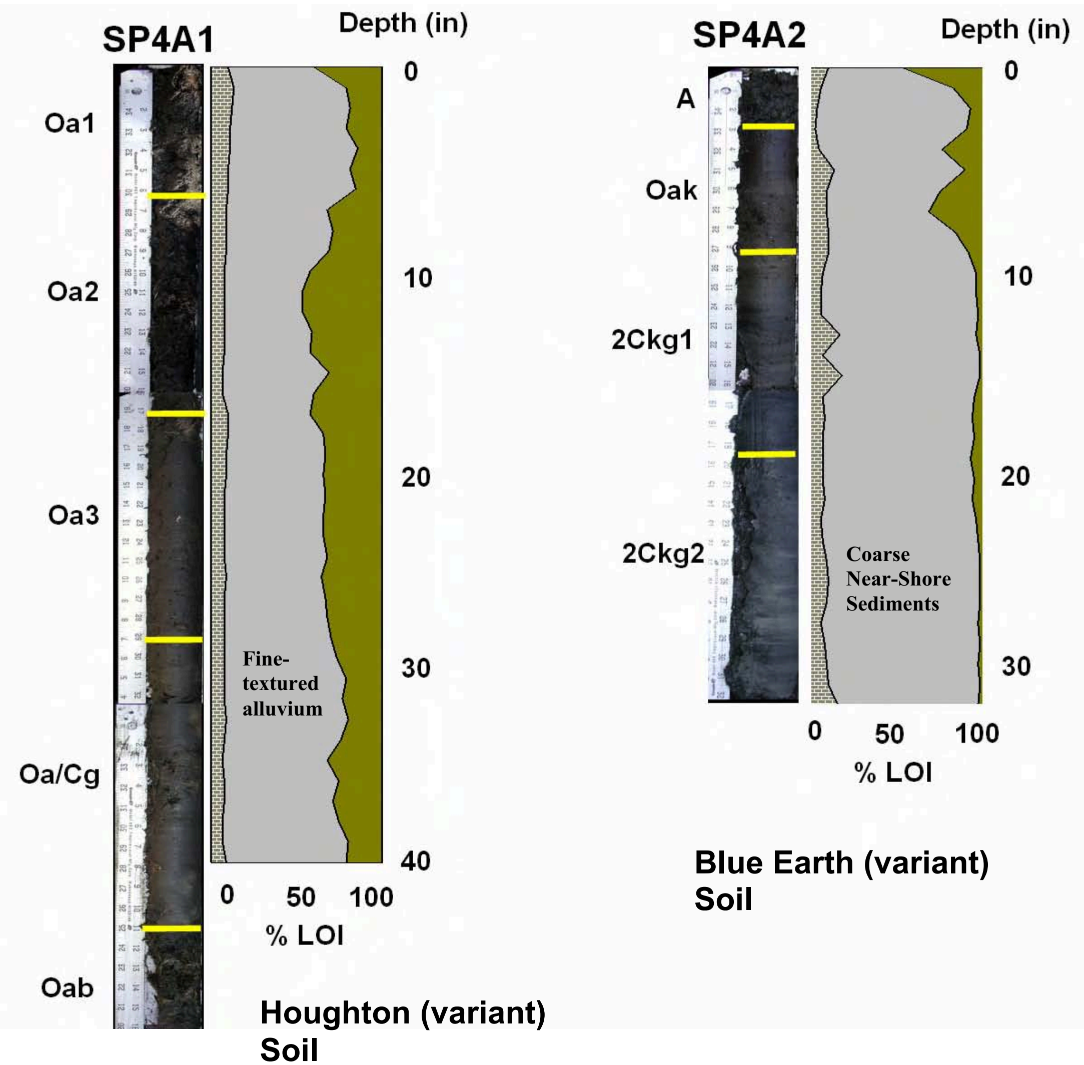
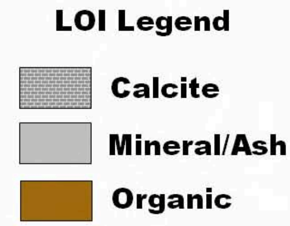
Site Photographs, Soil Investigations, SFWC CFC Area 3: Transect 3A
Phase 1 Characterization: Seminary Fen Wetland Complex
Carver County, MN
Figure 5.31

PEC Project No. 2005-031





Soil Horizon Designations

Oa	Well decomposed organic layer
L	Limnic (deposited in water) layer
k	Accumulation of calcium carbonate
b	A buried soil surface

A number in front of a horizon designation (e.g. **2**Ok/Lma) indicates a sequence of different parent materials.

A number at the end of a soil horizon (e.g. Oa**2**) indicates a sequence of similar horizons in the profile.

Both soil profiles collected in CFC-SFWC Area 3 meet the soil criteria for calcareous fens in Leete (2005). However, the soils are not as strongly calcareous as those in Area 1. Soil 3A2 presents marl horizons indicative of intense groundwater discharge with water supersaturated with calcium carbonate. The distribution of calcium carbonate in the soil likely represents the discharge of calcium carbonate saturated water originating in CFC Area 1 that has recharged the groundwater under the eastern part of the terrace feature, a subsequently discharged south of existing TH 212.

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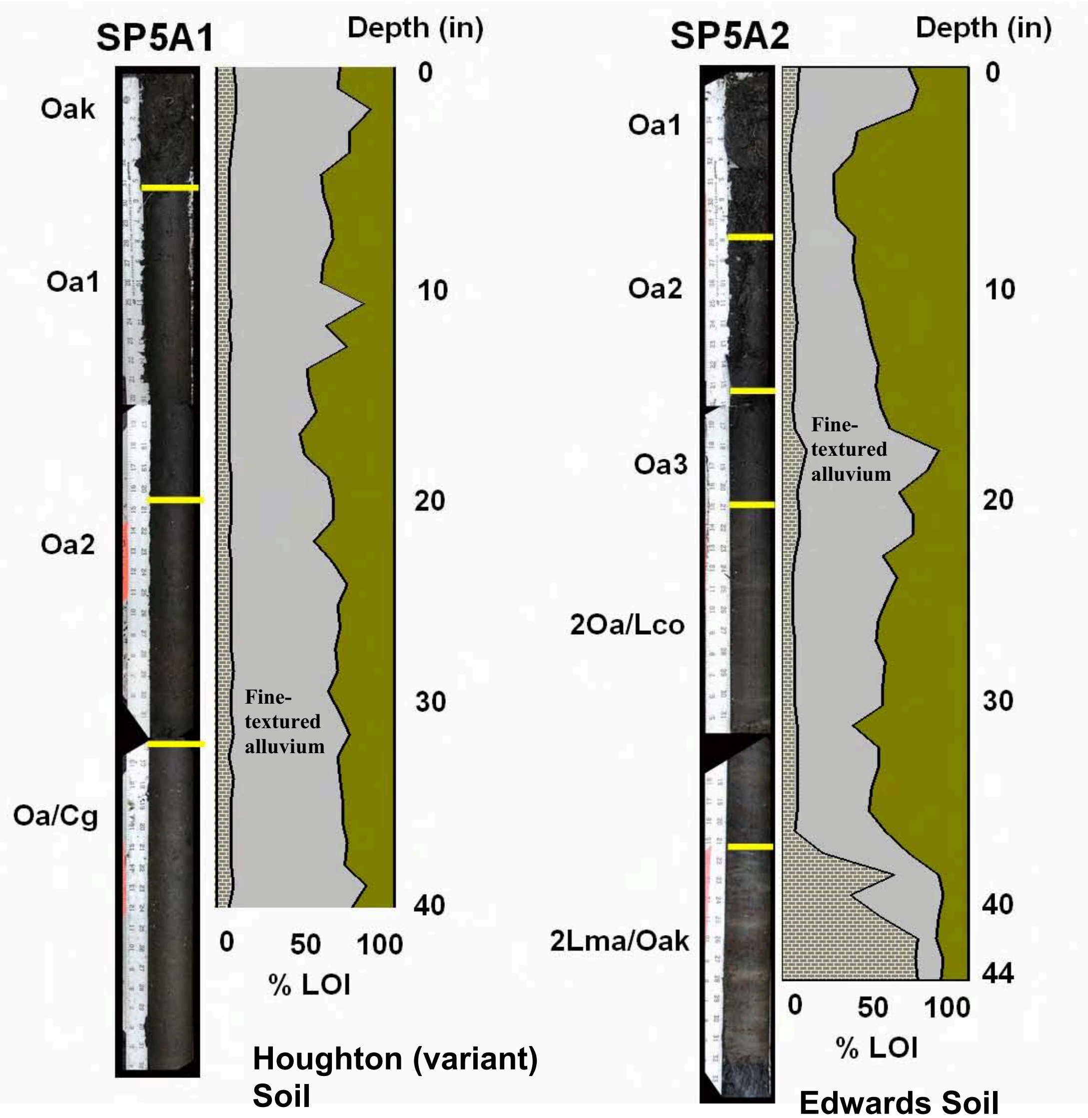
Soil Profile and Loss-on-Ignition Data Collected Along Transect 4A, CFC-SFWC Area 4
Phase 1 Characterization: Seminary Fen Wetland Complex
Carver County, Minnesota
Figure 5.32

PEC Project No. 2005-031



Soil Horizon Designations

Oa Well decomposed organic layer
L Limnic (deposited in water) layer

k Accumulation of calcium carbonate

A number in front of a horizon designation (e.g. **2**Ok/Lma) indicates a sequence of different parent materials.

A number at the end of a soil horizon (e.g. Oa**2**) indicates a sequence of similar horizons in the profile.

Both soil profiles collected in CFC-SFWC Area 5 meet the soil criteria for calcareous fens in Leete (2005). However, the soils are non-calcareous to weakly calcareous.

Substantial amounts of non-calcareous mineral matter in the soils is the result of the deposition of alluvium from periodic flooding by the Minnesota River.

Soil 5A2 presents a marl subsoil indicative of post-glacial, calcite supersaturated groundwater discharge. However, the absence of calcium carbonate in the surface of both soils indicates that conditions favorable for calcareous fens no longer exist at this location.

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Soil Profile and Loss-on-Ignition Data Collected Along Transect 5A, CFC-SFWC Area 5
Phase 1 Characterization: Seminary Fen Wetland Complex
Carver County, Minnesota
Figure 5.33

PEC Project No. 2005-031

A. Soil sampling points 4A1 and 4A2 were located on the north and south sides of CFC Area 4, respectively. The morphology is that of a sloping peatland with a downhill grade from north to south. The site is dissected by spring runs originating as toe-of-slope springhead discharge in the north portion of the area. Shrubs are invading, and substantial portions are dominated by common reed grass and other tall, rank vegetation. CFC Area 4 is entirely within the floodplain of the Minnesota River. Soils exhibited the deposition of fine-textured sediment within the peat.

B. The soil at sampling point 4A1 is well within the 100-year floodplain of the Minnesota River. The texture of the mineral material within the profile is fine, indicating deposition in a backswamp or backwater environment. Because periodic additional of floodwater sediment introduces relatively high nutrient levels in addition to disturbance, it is unlikely that floodplain positions will support calcareous fens, even though the site would meet soil, hydrology, and chemistry criteria.

C. The soil at sampling point 4A2 consisted of thin peat over loamy stratified material. The site is very near several large spring heads that coalesce to form a spring run. The subsoil zone was weakly calcareous indicating that the groundwater discharge is saturated with calcium carbonate. The stratification and relatively coarse-texture of the sediments at location 4A2 suggests that the material was deposited in a near-shore environment of a shallow post-glacial lake.

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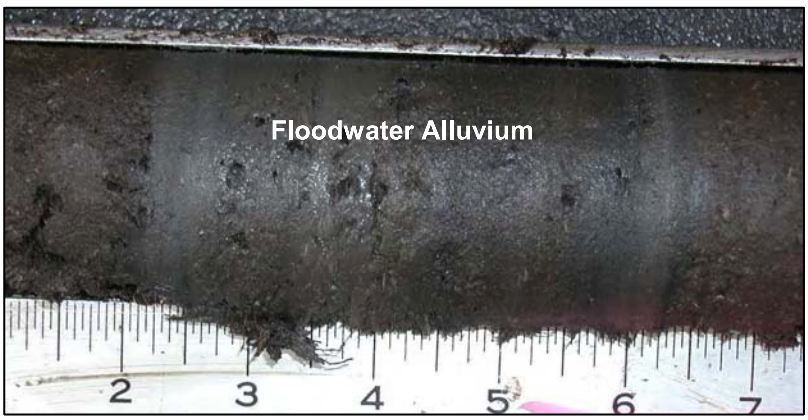
Site Photographs, Soil Investigations, SFWC CFC Area 4: Transect 4A
Phase 1 Characterization: Seminary Fen Wetland Complex
Carver County, MN
Figure 5.34

PEC Project No. 2005-031

A. Soil sampling points 5A1 and 5A2 were located on the north and south sides of CFC Area 5, respectively. The morphology is a sloping peatland with a downhill grade from north to south that has been dissected by numerous spring runs originating as toe-of-slope springhead discharge on the north portion of the area. Substantial portions are dominated by common reed grass and other tall, rank vegetation. Soil profiles were collected on a large peat dome feature on the east side of a significant spring run. CFC Area 4 is entirely within the floodplain of the Minnesota River. Soils exhibited the deposition of fine-textured sediment within the peat.



B. The soil at sampling point 5A1 is well within the 100-year floodplain of the Minnesota River. The texture of the mineral material within the profile is fine, indicating deposition in a backswamp or backwater environment. Because periodic additional of floodwater sediment introduce relatively high nutrient levels in addition to disturbance it is unlikely that floodplain positions will support calcareous fens, even though the site would meet soil, hydrology, and chemistry criteria.

C. The soil at sampling point 5A2 consisted of weakly calcareous peat over a stratified highly calcareous marl and coprogenous earth substrate. The stratification and calcareous nature of the sediments at location 5A2 suggests that the area possibly supported calcareous fen vegetation in the distance past. However, the weakly calcareous nature of the surface peat combined with the evidence of regular flooding and deposition of nutrient rich sediments indicates that the area is no longer a calcareous fen.

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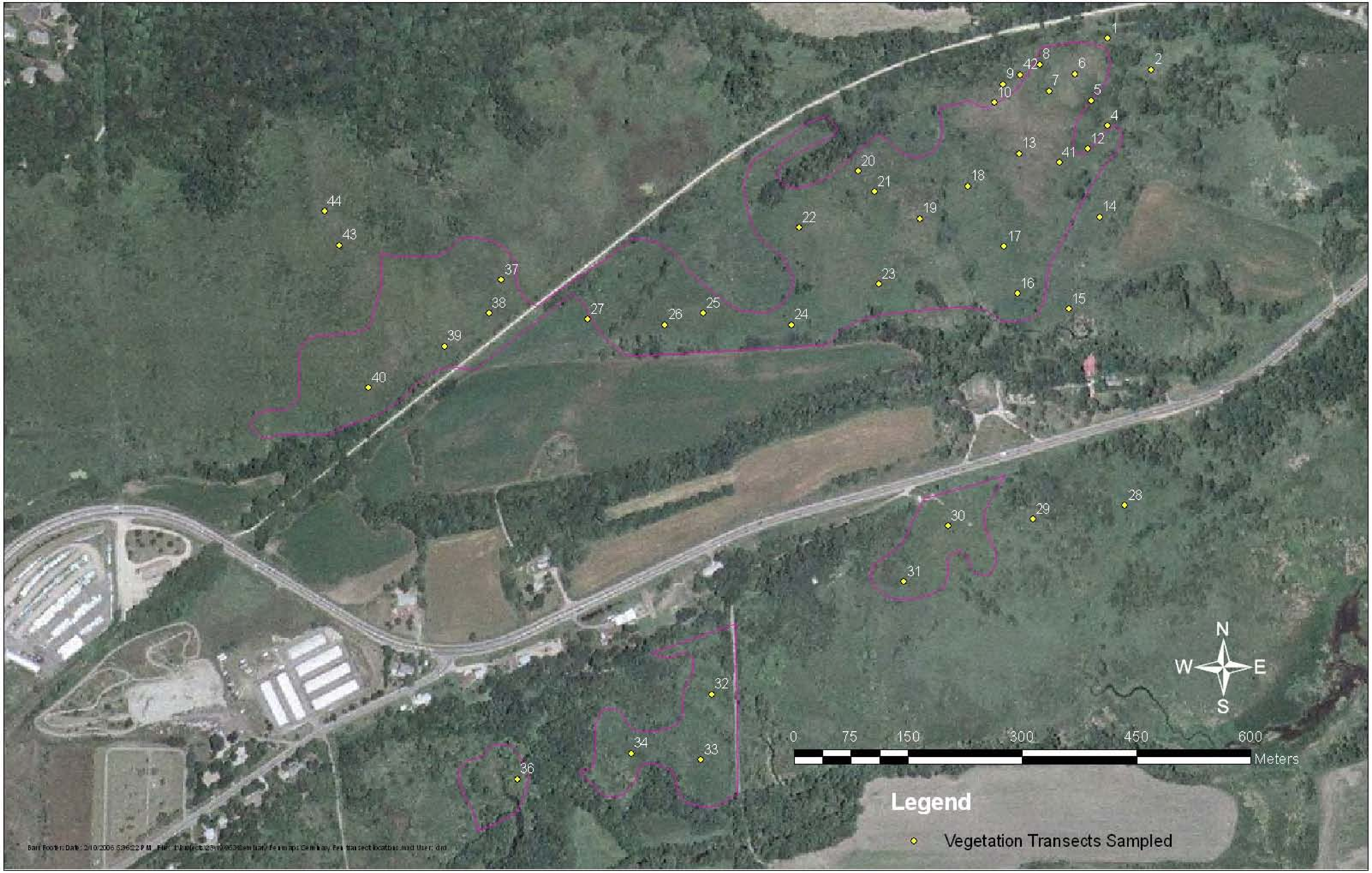
Site Photographs, Soil Investigations, SFWC CFC Area 5: Transect 5A
Phase 1 Characterization: Seminary Fen Wetland Complex
Carver County, MN
Figure 5.35

PEC Project No. 2005-031



Peterson Environmental Consulting, Inc.

Locations of Vegetation Transects
Phase 1 Characterization Seminary Fen Wetland Complex
City of Chaska, Carver County, Minnesota
FIGURE 5.36

PEC Project No. 2005-031

June 14, 2005

September 9, 2005

Site Photograph: Vegetation Transect 6
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.37

PEC Project No. 2005-031

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June 15, 2005

September 9, 2005

Site Photograph: Vegetation Transect 10
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.38

PEC Project No. 2005-031

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June 15, 2005

September 9, 2005

Site Photograph: Vegetation Transect 1
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.39

PEC Project No. 2005-031

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June 16, 2005

September 9, 2005

Site Photograph: Vegetation Transect 9
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.40

PEC Project No. 2005-031

Peterson Environmental Consulting, Inc.

June 16, 2005

September 12, 2005

Site Photograph: Vegetation Transect 18
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.41

PEC Project No. 2005-031

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June 16, 2005

September 13, 2005

Site Photograph: Vegetation Transect 42
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.42

PEC Project No. 2005-031

Peterson Environmental Consulting, Inc.

June 14, 2005

September 9, 2005

Site Photograph: Vegetation Transect 4
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.43

PEC Project No. 2005-031

Peterson
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Consulting, Inc.

June 14, 2005

September 12, 2005

Site Photograph: Vegetation Transect 7
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.44

PEC Project No. 2005-031

Peterson Environmental Consulting, Inc.

June 15, 2005

September 12, 2005

Site Photograph: Vegetation Transect 15
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.45

PEC Project No. 2005-031

Peterson Environmental Consulting, Inc.

June 15, 2005

September 9, 2005

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Site Photograph: Vegetation Transect 41
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.46

PEC Project No. 2005-031

June 15, 2005

September 9, 2005

Site Photograph: Vegetation Transect 12
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.47

PEC Project No. 2005-031

Peterson Environmental Consulting, Inc.

June 15, 2005

September 12, 2005

Site Photograph: Vegetation Transect 16
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.48

PEC Project No. 2005-031

Peterson Environmental Consulting, Inc.

June 16, 2005

September 13, 2005

Site Photograph: Vegetation Transect 25
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.49

PEC Project No. 2005-031

Peterson Environmental Consulting, Inc.

June 16, 2005

September 13, 2005

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Site Photograph: Vegetation Transect 26
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.50

PEC Project No. 2005-031

June 16, 2005

September 13, 2005

Peterson Environmental Consulting, Inc.

Site Photograph: Vegetation Transect 27
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.51

PEC Project No. 2005-031

June 16, 2005

September 12, 2005

Site Photograph: Vegetation Transect 21
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.52

PEC Project No. 2005-031

Peterson Environmental Consulting, Inc.

June 16, 2005

September 12, 2005

Site Photograph: Vegetation Transect 22
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.53

PEC Project No. 2005-031

Peterson Environmental Consulting, Inc.

June 16, 2005

September 12, 2005

Site Photograph: Vegetation Transect 23
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.54

PEC Project No. 2005-031

Peterson Environmental Consulting, Inc.

June 15, 2005

September 13, 2005

Site Photograph: Vegetation Transect 14
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.55

PEC Project No. 2005-031

Peterson Environmental Consulting, Inc.

September 12, 2005

Site Photograph: Vegetation Transect 2
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.56

PEC Project No. 2005-031

Peterson Environmental Consulting, Inc.

June 16, 2005

September 12, 2005

Site Photograph: Vegetation Transect 19
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.57

PEC Project No. 2005-031

Peterson Environmental Consulting, Inc.

June 16, 2005

Site Photograph: Vegetation Transect 8
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.58

PEC Project No. 2005-031

Peterson Environmental Consulting, Inc.

June 15, 2005

September 9, 2005

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Consulting, Inc.

Site Photograph: Vegetation Transect 13
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.59

PEC Project No. 2005-031

June 16, 2005

September 12, 2005

Site Photograph: Vegetation Transect 17
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.60

PEC Project No. 2005-031

Peterson Environmental Consulting, Inc.

June 16, 2005

September 12, 2005

Site Photograph: Vegetation Transect 24
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.61

PEC Project No. 2005-031

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June 14, 2005

September 9, 2005

Site Photograph: Vegetation Transect 5
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.62

Peterson Environmental Consulting, Inc.

PEC Project No. 2005-031

June 15, 2005

September 13, 2005

Site Photograph: Vegetation Transect 40
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.63

PEC Project No. 2005-031

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September 13, 2005

Site Photograph: Vegetation Transect 43
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.64

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PEC Project No. 2005-031

September 13, 2005

Site Photograph: Vegetation Transect 44
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.65

PEC Project No. 2005-031

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June 15, 2005

Site Photograph: Vegetation Transect 37
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.66

PEC Project No. 2005-031

Peterson Environmental Consulting, Inc.

June 15, 2005

September 13, 2005

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Site Photograph: Vegetation Transect 38
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.67

PEC Project No. 2005-031

June 15, 2005

September 13, 2005

Site Photograph: Vegetation Transect 39
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.68

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PEC Project No. 2005-031

September 14, 2005

Site Photograph: Vegetation Transect 28
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.69

PEC Project No. 2005-031

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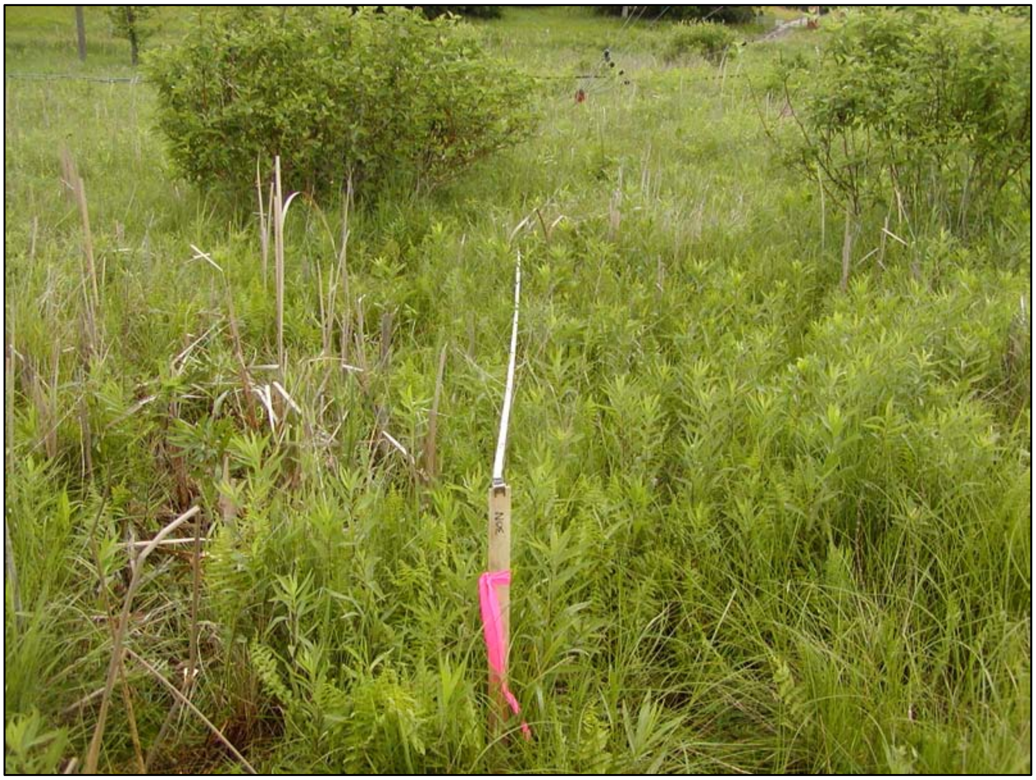
June 14, 2005

September 14, 2005

Site Photograph: Vegetation Transect 29
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.70

PEC Project No. 2005-031

Peterson Environmental Consulting, Inc.



June 14, 2005

September 14, 2005

Peterson
Environmental
Consulting, Inc.

Site Photograph: Vegetation Transect 30
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.71

PEC Project No. 2005-031

June 14, 2005

September 14, 2005

Peterson Environmental Consulting, Inc.

Site Photograph: Vegetation Transect 31
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.72

PEC Project No. 2005-031

June 14, 2005

September 14, 2005

Site Photograph: Vegetation Transect 32
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.73

PEC Project No. 2005-031

Peterson Environmental Consulting, Inc.

June 14, 2005

September 14, 2005

Site Photograph: Vegetation Transect 33
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.74

PEC Project No. 2005-031

Peterson Environmental Consulting, Inc.

June 14, 2005

September 14, 2005

Site Photograph: Vegetation Transect 34
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.75

PEC Project No. 2005-031

Peterson Environmental Consulting, Inc.

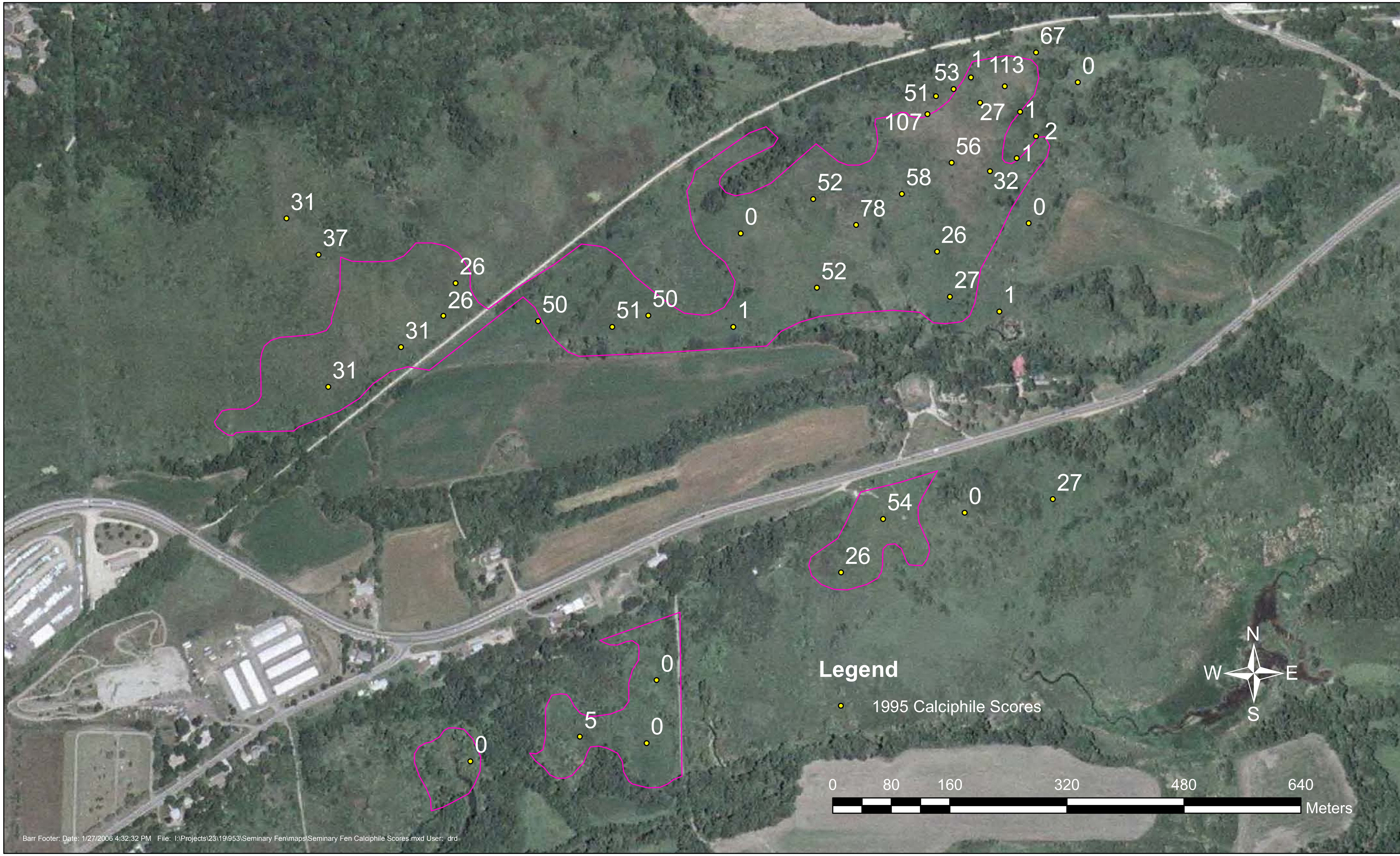
June 14, 2005

September 14, 2005

Peterson Environmental Consulting, Inc.

Site Photograph: Vegetation Transect 36
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.76

PEC Project No. 2005-031



Peterson Environmental Consulting, Inc.

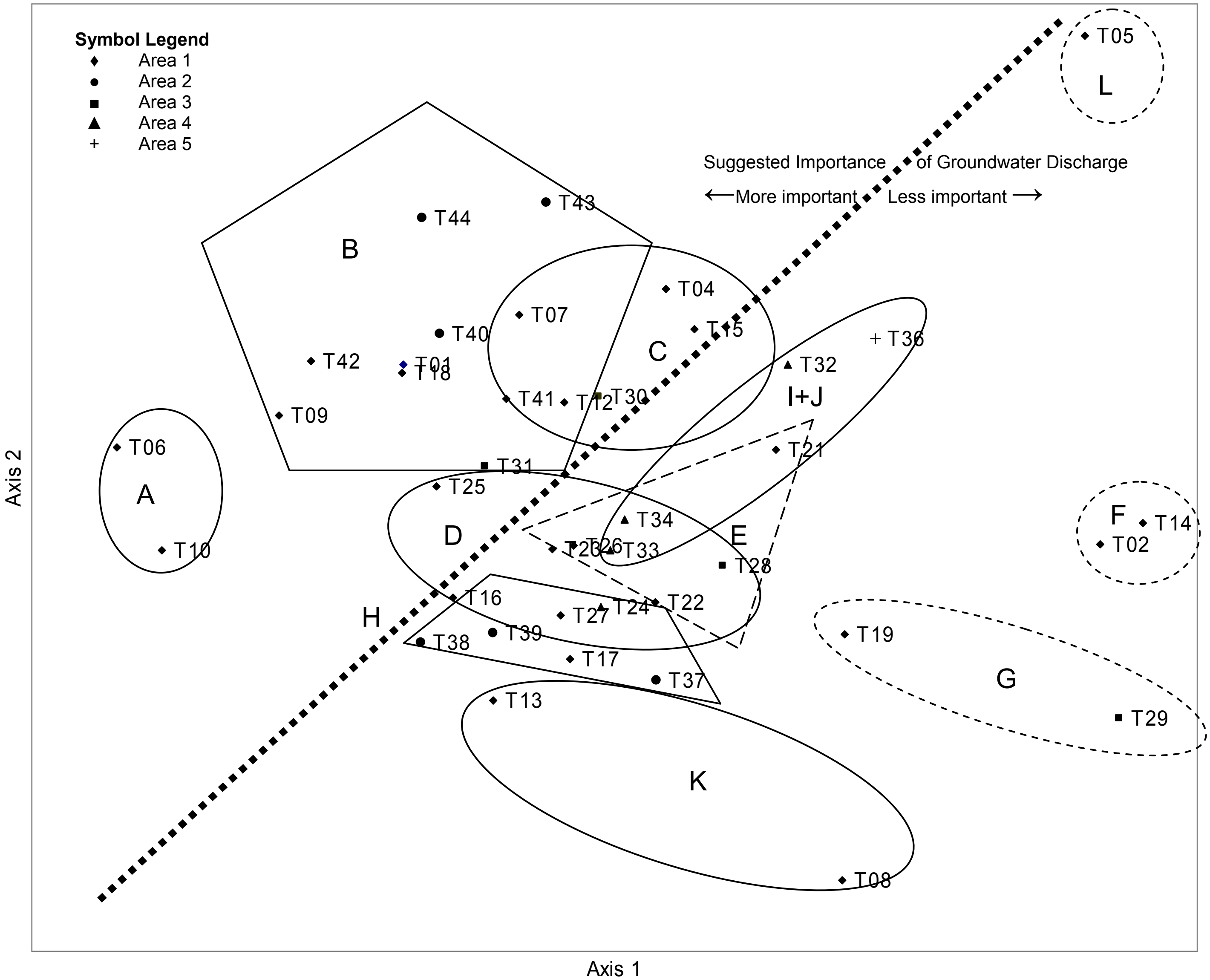
2005 Botanical Survey Calciphile Scores Using 1995 Technical Guidelines
Phase 1 Characterization Seminary Fen Wetland Complex
City of Chaska, Carver County, Minnesota
FIGURE 5.77

PEC Project No. 2005-031

Peterson Environmental Consulting, Inc.

2005 Botanical Survey Calciphile Scores Using 2005 Technical Guidelines
Phase 1 Characterization Seminary Fen Wetland Complex
City of Chaska, Carver County, Minnesota
FIGURE 5.78

PEC Project No. 2005-031



The axes of the graph represent the first two axes from multivariate ordination of importance values of 83 vascular plant species on 41 transects throughout the SFWC. Transects are labeled as "T##." Polygons represent the arrangement of transects into ecotopes. Dashed polygons represent the most ecologically disturbed ecotopes. Ecotopes are as follows:

Label	Ecotope
A	Short sedge fen
B	Tall sedge fen
C	*Carex stricta* seep/spring run
D	*Carex-Thalictrum* meadow
E	*Carex-Solidago* meadow
F	*Phalaris arundinacea*

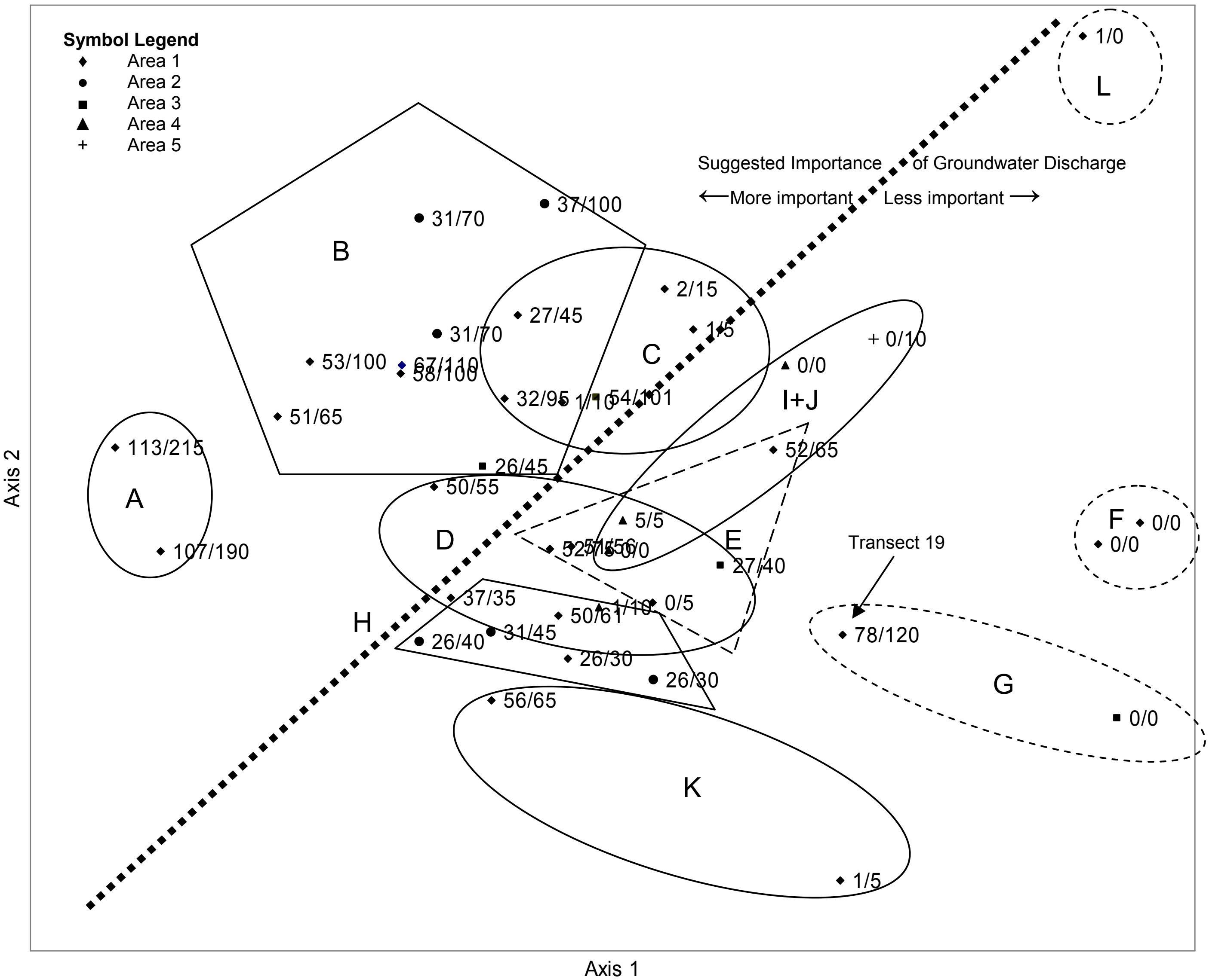
Label	Ecotope
G	*Phalaris-Typha*
H	*Carex lacustris*
I	*Carex lacustris-Acorus americanus*
J	*Acorus americanus-Sparganium eurycarpum*
K	*Typha*
L	*Rhamnus*

The high degree of overlap of ecotopes in the center of the figure reflects the many wetland species that are shared among the ecotopes, even though dominant species vary by ecotope. The heavy dotted line represents a hypothesized division between ecotopes that are highly dependent on groundwater discharge versus ecotopes with less dependence on groundwater.

Peterson Environmental Consulting, Inc.

Multivariate Ordination Results of Vegetation Data
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.79

PEC Project No. 2005-031

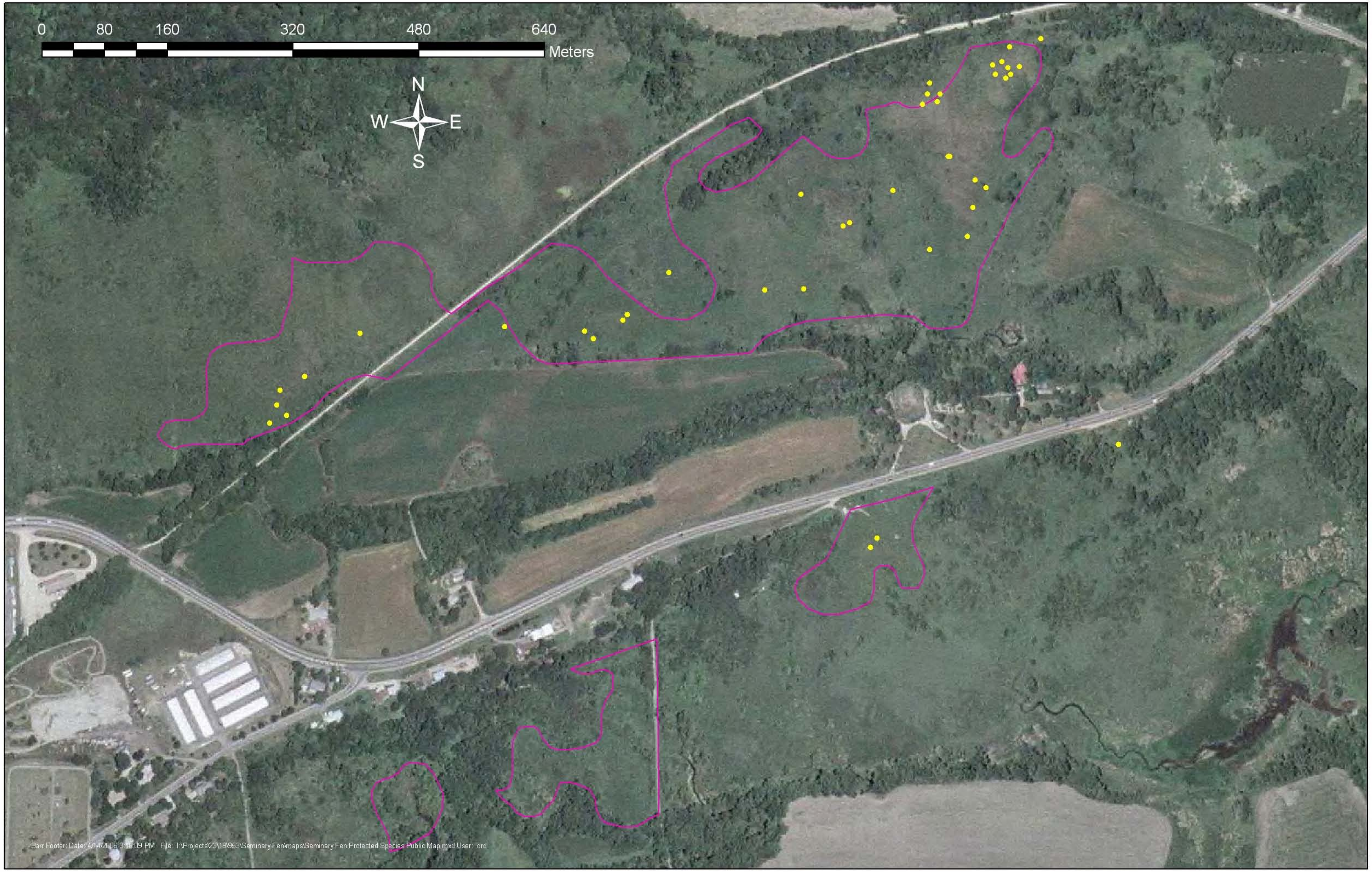


The axes of the graph represent the first two axes from multivariate ordination of importance values of 83 vascular plant species on 41 transects throughout the SFWC. Transects are labeled with vicinity calciphile scores. The first value uses 1995 guidelines, and the second score uses 2005 draft guidelines. Polygons represent the arrangement of transects into ecotopes. Dashed polygons represent the most ecologically disturbed ecotopes. Ecotopes are as follows:

Label	Ecotope
A	Short sedge fen
B	Tall sedge fen
C	*Carex stricta* seep/spring run
D	*Carex-Thalictrum* meadow
E	*Carex-Solidago* meadow
F	*Phalaris arundinacea*

Label	Ecotope
G	*Phalaris-Typha*
H	*Carex lacustris*
I	*Carex lacustris-Acorus americanus*
J	*Acorus americanus-Sparganium eurycarpum*
K	*Typha*
L	*Rhamnus*

The high degree of overlap of ecotopes in the center of the figure reflects the many wetland species that are shared among the ecotopes, even though dominant species vary by ecotope. The heavy dotted line represents a hypothesized division between ecotopes that are highly dependent on groundwater discharge versus ecotopes with less dependence on groundwater. Transect 19 is indicated because of unexpectedly high scores (see text).



Peterson Environmental Consulting, Inc.

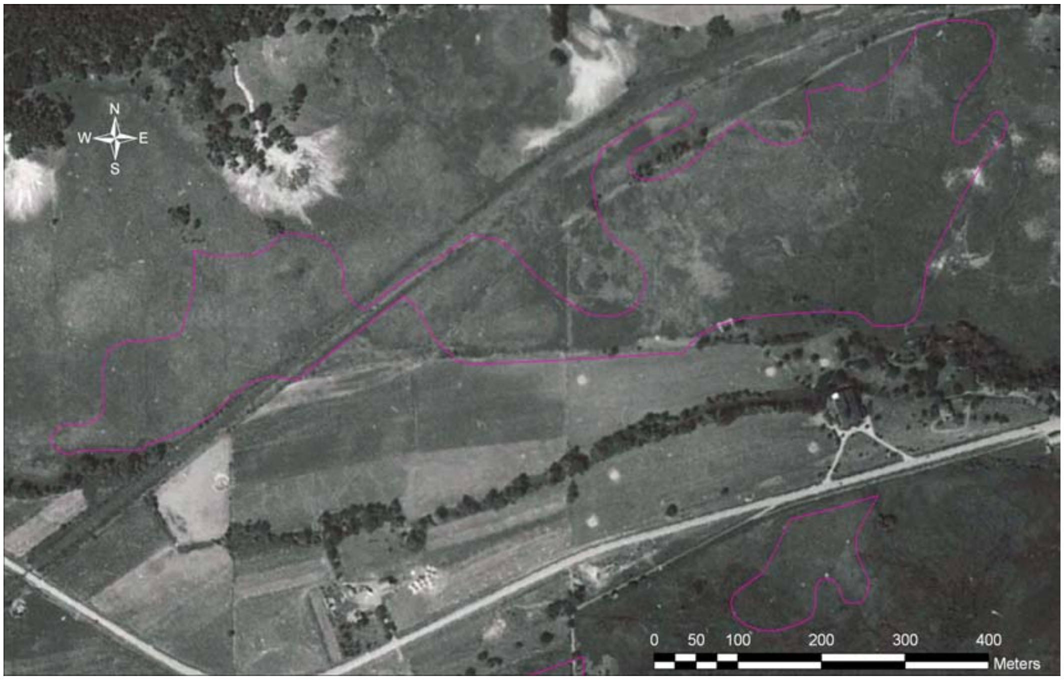
Locations of State Protected Plant Species: 1995 and 2005

Phase 1 Characterization Seminary Fen Wetland Complex

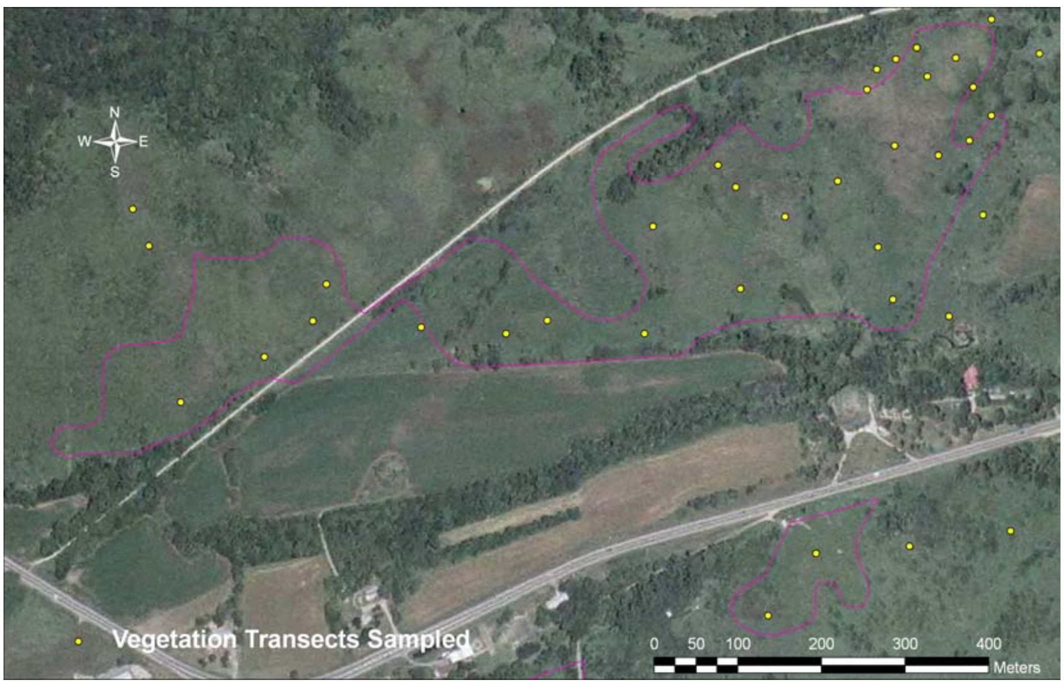
City of Chaska, Carver County, Minnesota

FIGURE 5.81

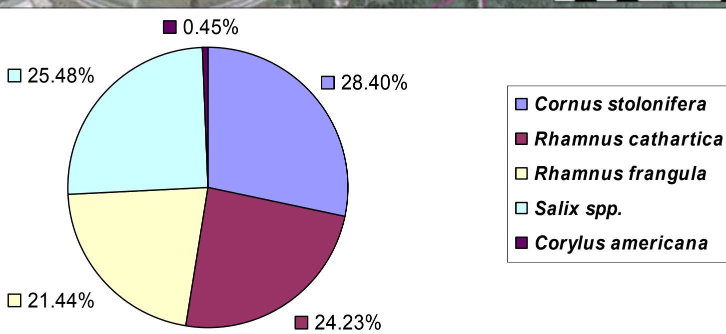
PEC Project No. 2005-031



A. 1937 Aerial photograph of Areas 1-3. Very little tree and shrub growth is found in the Seminary Fen Wetland Complex.



B. 2003 Aerial photograph of Areas 1-3. Woody vegetation has become common throughout the wetland complex. Shrub cover on vegetation transects averages 15.96% ± 4.64% (SE). Judging by the placement of transects, this value likely underestimates the total extent of shrub cover.



C. The relative coverage of shrub species. Almost half of the cover consists of exotic, invasive buckthorns (*Rhamnus* spp.)

Peterson Environmental Consulting, Inc.

Woody Vegetation in Areas 1-3
Phase 1 Characterization: Seminary Fen Wetland Complex
City of Chaska, Carver County, MN
Figure 5.82

PEC Project No. 2005-031

Appendix 1: Vegetation Data

Seminary Fen Vegetation Data 2005

Data are maximum cover classes in plots along transects for each species.
An "x" in a "V" column indicates a species was present in the vicinity of a transect but cover was not estimated.

Transect:	1						2						4						5						6					
Plot:	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5
Acer saccharinum																														
Acorus americanus																														
Agalinus paupercula																									x					
Agrostis stolonifera	x												x																	
Amorpha fruticosa																														
Andropogon gerardii	x																									3				3
Angelica atropurpurea																														
Apocynum cannabinum																														
Asclepias incarnata																														
Aster borealis		2																							x		3	2	2	2
Aster firmus														2	2															
Aster novae-angliae																														
Aster spp.																														
Aster umbellatus														1		2	3										2	3		5
Betula papyrifera																														
Bidens spp.																														
Boehmeria cylindrica																														
Bromus ciliatus	x				1								x	2																
Calamagrostis spp.													x																	
Calamagrostis stricta																														
Caltha palustris	x												x																	
Campanula aparinoides																														
Cardamine bulbosa													x																	
Carex aquatilis	x				3																									
Carex buxbaumii																														
Carex granularis	x		2																	2				1						
Carex hystericina	x				3								x		2															
Carex interior	x		4																											
Carex lacustris																														
Carex lasiocarpa																														
Carex oligosperma																														
Carex prairea	x					2																								
Carex sartwellii																														
Carex spp.	x					2																								
Carex sterilis																									x					
Carex stipata																														
Carex stricta	x	5	2			2							x	4	5	5	4	5												
Carex tetanica													x												x	1				
Chelone glabra	x												x																	
Cicuta bulbifera																														
Cicuta maculata																														
Cirsium muticum	x																2								x	1		3	2	
Cladium mariscoides																									x					
Clematis virginiana																														
Convolvulus arvensis																														

Transect:	7						8						9						10						12						13					
Plot:	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5
Acer saccharinum																																				
Acorus americanus																																				
Agalinus paupercula																			x																	
Agrostis stolonifera																											2									
Amorpha fruticosa																																				
Andropogon gerardii																				4	5	5	2	4	x						x					
Angelica atropurpurea																																				
Apocynum cannabinum																															x					
Asclepias incarnata																									x											
Aster borealis	x												x	1					x				1		x		2				x					
Aster firmus		2																									1	2	2		x					
Aster novae-angliae																																				
Aster spp.																	2																			
Aster umbellatus																			x							3	3	2	3	2						
Betula papyrifera																																				
Bidens spp.																																				
Boehmeria cylindrica																																				
Bromus ciliatus	x												x	3	4				x	4					x		2				x			2		
Calamagrostis spp.																																				
Calamagrostis stricta																																				
Caltha palustris	x			3		3	x		3																											
Campanula aparinoides																																				
Cardamine bulbosa	x	1	2		1		x																													
Carex aquatilis																																				
Carex buxbaumii														5											x	1	3									
Carex granularis																									x	3	3				x					
Carex hystericina	x			2									x																							
Carex interior																																				
Carex lacustris																																				
Carex lasiocarpa							x																													
Carex oligosperma																																				
Carex prairea	x	5	6			3							x					4													x					
Carex sartwellii																									x											
Carex spp.															5	4	3																			1
Carex sterilis													x								1										x			4		
Carex stipata																																				
Carex stricta	x	3	3	5	6	6	x						x			2									x		2	2	3	5						
Carex tetanica													x											2												
Chelone glabra																																				2
Cicuta bulbifera	x	1																																		
Cicuta maculata	x																																			
Cirsium muticum	x												x								2		2	2	x		1	2	3	1						2
Cladium mariscoides																																				
Clematis virginiana																																				
Convolvulus arvensis																									x		2									

Seminary Fen Vegetation Data 2005

Data are maximum cover classes in plots along transects for each species.

An "x" in a "V" column indicates a species was present in the vicinity of a transect but cover was not estimated.

Transect:	1						2						4						5						6						7						8						9						10						12						13					
Plot:	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5
Cornus stolonifera																																					x																													
Cuscuta spp.																																																																		
Cypripedium candidum																																																																		
Cypripedium parviflorum																																																																		
Echinocystis lobata									2																																																									
Eleocharis erythropoda																																																																		
Eleocharis rostellata	x																								x	4	3																						x																	
Eleocharis spp.																																																							x											
Elymus canadensis																																																																		
Epilobium spp.																																															2																			
Equisetum pratense																			x		2																																													
Eriophorum angustifolium																																																																		
Eupatorium maculatum	x	1	2	2	1	3	x						x		2										x		2		1		x	2		1			x						x				2	2	x			2			x						x	3	2		2	2
Eupatorium perfoliatum						1							x		2		2	2													x					2							x																							
Euthamia graminifolia																											3	2																										2				2			x					
Galium boreale																																																																		
Galium labradoricum																																											x	1	1	1		2																		
Gentianopsis procera	x																								x																								x																	
Glyceria striata																																					x																								x			2		2
Helenium autumale																																																																		
Helianthus giganteus	x													2		3	3	2																																						2	2									
Helianthus grosseserratus							x																								x																									2	2	1								
Helianthus spp																														1														2		2				2	2			2		3		1								3
Hierchloe odorata																																																																		
Humulus lupulus																																																																		
Hypoxis hirsuta																									x		2																						x			1			x											
Impatiens capensis	x		2	2	2	2																									x				1	2	x		2	2	1	2																								
Iris versicolor																																																																		
Juncus alpino-articulatus	x																																																																	
Juncus dudleyi																																																																		
Larix decidua																																																																		
Lathyrus palustris																															x																																			
Leersia oryzoides																																																																		
Liatris ligulistylis	x	2		2	2																				x																								x		2			1							x					
Lilium michiganense																																																																		
Lilium philadelphicum																																																																		
Liparis loeselii																									x																																									
Lobelia kalmii																									x																								x																	
Lobelia siphilitica	x												x																		x																								x											
Lycopus americanus			2	2									x																														x																2		x					
Lycopus uniflorus		2	2		2								x		1	2															x		1	2										1	2	2	1	2	x	1	1	2									x	1	1			2
Lysimachia ciliata																																					x																													
Lysimachia quadriflora																																											x																				2			
Lysimachia spp.															2										x																																										
Lysimachia thyrsifolia																																																																		

Seminary Fen Vegetation Data 2005

Data are maximum cover classes in plots along transects for each species.

An "x" in a "V" column indicates a species was present in the vicinity of a transect but cover was not estimated.

Transect:	1						2						4						5						6					
Plot:	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5
Lythrum salicaria																														
Mentha canadensis																														
Muhlenbergia glomerata																														
Muhlenbergia racemosa		3		2																						1	3			
Muhlenbergia richardsonis																														
Muhlenbergia spp.						2																								
Onoclea sensibilis																														
Panicum spp.																														
Parnassia glauca	x																								x	1				
Pedicularis lanceolata		1			3																					1				
Phalaris arundinacea	x							6	6	6	6	6	x		2															
Phragmites australis																														
Pilea fontana																														
Poa pratensis	x																													
Poa spp.																														
Polygonum spp.																														
Populus deltoides																														
Prenanthes alba																														
Pycnanthemum virginianum																														
Ranunculus spp.																														
Rhamnus cathartica																														
Rhamnus frangula	x												x												x					
Rorippa nasturtium-aquaticum																														
Rubus pubescens																														
Rubus strigosus																			x			1								
Rumex orbiculatus													x																	
Sagittaria latifolia																														
Salix bebbiana																														
Salix candida	x																													
Salix nigra																														
Salix spp.																														
Scirpus acutus	x					2																						2	2	2
Scirpus fluviatilis																														
Scirpus pungens																									x					
Scirpus validus						3																								
Scleria verticillata																									x	3				
Scutellaria galericulata																														
Senecio pseudaureus	x		1																						x	2	2	2	2	2
Silphium perfoliatum																														
Sium suave																														
Smilacina stellata																														
Solidago canadensis									2		3	2																		
Solidago gigantea								2		3						2	2	2												
Solidago riddellii																														
Solidago spp.																														

Transect:	7						8						9						10						12						13					
Plot:	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5
Lythrum salicaria																																				
Mentha canadensis																																				
Muhlenbergia glomerata																																				
Muhlenbergia racemosa																																				
Muhlenbergia richardsonis																																				
Muhlenbergia spp.														2						4	5	5	5	5								2	3	3	3	2
Onoclea sensibilis																																				
Panicum spp.																									x	2	2									
Parnassia glauca																			x		1			2												
Pedicularis lanceolata																																				
Phalaris arundinacea																																				
Phragmites australis																																				
Pilea fontana																																				
Poa pratensis																																				
Poa spp.							x																													
Polygonum spp.																																				
Populus deltoides																															x					
Prenanthes alba																									x											
Pycnanthemum virginianum																			x						x											
Ranunculus spp.																																				
Rhamnus cathartica													x																							
Rhamnus frangula													x																		x					
Rorippa nasturtium-aquaticum	x		2			1																														
Rubus pubescens																																				
Rubus strigosus																																				
Rumex orbiculatus								2											x	1																
Sagittaria latifolia																																				
Salix bebbiana																																				
Salix candida																															x					
Salix nigra																																				
Salix spp.																																				
Scirpus acutus	x	1											x	2					x	3	2	2														
Scirpus fluviatilis																																				
Scirpus pungens	x																																			
Scirpus validus	x														2																					
Scleria verticillata																			x																	
Scutellaria galericulata																																				
Senecio pseudaureus							x					1							x	1			2	2	x											
Silphium perfoliatum																																				
Sium suave																																				
Smilacina stellata							x																													
Solidago canadensis													x												x	2			2	2	x			3		
Solidago gigantea																												2	2							
Solidago riddellii																																				
Solidago spp.																																				

Seminary Fen Vegetation Data 2005

Data are maximum cover classes in plots along transects for each species.

An "x" in a "V" column indicates a species was present in the vicinity of a transect but cover was not estimated.

Transect:	1						2						4						5					
Plot:	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**
Sparganium eurycarpum																								
Spartina pectinata																								
Stellaria spp.																								
Taraxacum officinale																			x				1	
Thalictrum dasycarpum																								
Thylepteris palustris	x																							
Triglochin maritima																								
Triglochin palustris																								
Typha angustifolia																								
Typha latifolia							x																	
Ulmus americana																								
unidentified forb		4	2											2							1			
unidentified grass	x																			4				2
Urtica dioica							x																	
Verbena hastata																								
Viola nephrophylla	x	2	1		2	2																		
Zizia aurea																								

Transect:	6						7						8						9					
Plot:	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**
Sparganium eurycarpum																								
Spartina pectinata																								
Stellaria spp.																								
Taraxacum officinale																								
Thalictrum dasycarpum													x											
Thylepteris palustris																			x					
Triglochin maritima	x	2	3			2																		
Triglochin palustris	x																							
Typha angustifolia													x	2	4	4	2	3						
Typha latifolia							x																	
Ulmus americana																								
unidentified forb																		2		1	1			
unidentified grass			3	5	4	5																		
Urtica dioica																								
Verbena hastata																								
Viola nephrophylla	x		1																x					
Zizia aurea							x		2														1	

Transect:	10						12						13					
Plot:	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**
Sparganium eurycarpum																		
Spartina pectinata																		
Stellaria spp.																		
Taraxacum officinale																		
Thalictrum dasycarpum							x	3	4	2	2	2						
Thylepteris palustris																		
Triglochin maritima	x																	
Triglochin palustris	x																	
Typha angustifolia							x						x	4	4		4	3
Typha latifolia																		
Ulmus americana																		
unidentified forb					1													
unidentified grass	x																	
Urtica dioica																		
Verbena hastata																		
Viola nephrophylla	x																	
Zizia aurea																		

Seminary Fen Vegetation Data 2005

Data are maximum cover classes in plots along transects for each species.

An "x" in a "V" column indicates a species was present in the vicinity of a transect but cover was not estimated.

Transect:	14						15						16						17						18						19					
Plot:	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5
Acer saccharinum																																				
Acorus americanus																																				
Agalinus paupercula																																				
Agrostis stolonifera																															x					
Amorpha fruticosa																																				
Andropogon gerardii							x							2											x											
Angelica atropurpurea																									x											
Apocynum cannabinum		2	4		1								x																							
Asclepias incarnata																																				
Aster borealis																															x					
Aster firmus										2	2			2		3	2	3						3			2	2		2						
Aster novae-angliae																																				
Aster spp.																																				
Aster umbellatus																	3						3					3				4				
Betula papyrifera																																				
Bidens spp.																																				
Boehmeria cylindrica																																				
Bromus ciliatus													x	2			2	2	x						x						x					
Calamagrostis spp.																				3	3	3	2													
Calamagrostis stricta																																				
Caltha palustris																			x		3	2														
Campanula aparinoides							x			1															x	1		1	1							
Cardamine bulbosa							x		2																x						x					
Carex aquatilis																																				
Carex buxbaumii																																				
Carex granularis													x						x																	
Carex hystericina													x												x						x					
Carex interior																																				
Carex lacustris																			x	4	2	2														
Carex lasiocarpa													x																							
Carex oligosperma																																				
Carex prairea																									x	2	5	5	2		x					
Carex sartwellii													x						x		3	2			x	3				2	x					
Carex spp.																																				
Carex sterilis																2	2	2	x						x						x					
Carex stipata																																				
Carex stricta							x	5	5	5	5	6													x				4	4						
Carex tetanica																									x											
Chelone glabra																									x											
Cicuta bulbifera																																				
Cicuta maculata							x																													
Cirsium muticum	x																		x												x					
Cladium mariscoides																																				
Clematis virginiana																																				
Convolvulus arvensis	x												x		2			1	x																	

Transect:	21						22						23						24						25					
Plot:	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5
Acer saccharinum																														
Acorus americanus																														
Agalinus paupercula																														
Agrostis stolonifera	x																													
Amorpha fruticosa																														
Andropogon gerardii																											2			3
Angelica atropurpurea													x																	
Apocynum cannabinum	x						x	1		1	1																			
Asclepias incarnata							x						x																	
Aster borealis																														
Aster firmus		1							1	3	3	3			2		1		x	1	1						2	3	3	4
Aster novae-angliae																														
Aster spp.																														
Aster umbellatus			2	1					2		1																2			
Betula papyrifera																														
Bidens spp.																														
Boehmeria cylindrica																														
Bromus ciliatus	x						x						x	2					x											
Calamagrostis spp.																														
Calamagrostis stricta																														
Caltha palustris	x						x	3	2	3			x	4		5	3	3	x	5	3	6								
Campanula aparinoides													x	1																
Cardamine bulbosa	x												x	2	2	1			x											
Carex aquatilis																														
Carex buxbaumii																									x				2	
Carex granularis	x		3	2																										
Carex hystericina													x																	
Carex interior	x												x												x	2				
Carex lacustris																			x	4	5	3	5	6						
Carex lasiocarpa																														
Carex oligosperma																									x					1
Carex prairea	x												x												x	2	2	3	3	
Carex sartwellii							x			2			x	2		1	3	4							x		2	3	3	4
Carex spp.	x		2	2			x		2		2	3																		
Carex sterilis	x												x												x	2			2	
Carex stipata																														
Carex stricta													x		2		2								x	3	2			2
Carex tetanica																														
Chelone glabra																									x					
Cicuta bulbifera													x																	
Cicuta maculata																														
Cirsium muticum	x		2				x																		x					
Cladium mariscoides																														
Clematis virginiana							x																							
Convolvulus arvensis																														

Seminary Fen Vegetation Data 2005

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Transect:	14						15						16						17						18					
Plot:	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5
Cornus stolonifera																														
Cuscuta spp.																														
Cypripedium candidum																														
Cypripedium parviflorum																														
Echinocystis lobata																														
Eleocharis erythropoda																														
Eleocharis rostellata																														
Eleocharis spp.																			x						x					
Elymus canadensis																														
Epilobium spp.																									x					
Equisetum pratense																														
Eriophorum angustifolium																														
Eupatorium maculatum		2			2		x		4		1								x	2	2		2	3	x		2			
Eupatorium perfoliatum																			x											
Euthamia graminifolia																2														
Galium boreale																														
Galium labradoricum																														
Gentianopsis procera																									x					
Glyceria striata																			x						x					
Helenium autumale																									x					
Helianthus giganteus																3	2								x					
Helianthus grosseserratus	x							3		2		2									2					1				
Helianthus spp														2		2	2	2			2									
Hierchloe odorata																														
Humulus lupulus																														
Hypoxis hirsuta													x		1										x					
Impatiens capensis																			x		2	2	2	2						
Iris versicolor																														
Juncus alpino-articulatus																														
Juncus dudleyi																			x											
Larix decidua																														
Lathyrus palustris																														
Leersia oryzoides																														
Liatris ligulistylis													x												x					
Lilium michiganense																														
Lilium philadelphicum																														
Liparis loeselii																														
Lobelia kalmii																														
Lobelia siphilitica													x																	
Lycopus americanus													x		1	2														
Lycopus uniflorus													x	2			2	2	x	2		2			x				2	2
Lysimachia ciliata																									x				2	
Lysimachia quadriflora																														
Lysimachia spp.																														
Lysimachia thyrsifolia																														

Transect:	19						21						22						23						24						25					
Plot:	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5
Cornus stolonifera																																				
Cuscuta spp.																																				
Cypripedium candidum																																				
Cypripedium parviflorum																																				
Echinocystis lobata																																				
Eleocharis erythropoda																																				
Eleocharis rostellata	x																																			
Eleocharis spp.							x																													
Elymus canadensis																																				
Epilobium spp.																																				
Equisetum pratense	x													2																						
Eriophorum angustifolium																																				
Eupatorium maculatum	x				2	1	x						x						x	4		2	2	2	x	3	3	4			x		3		2	
Eupatorium perfoliatum																																				
Euthamia graminifolia							x												x																	
Galium boreale							x																													
Galium labradoricum																																				
Gentianopsis procera																			x																	
Glyceria striata	x												x																							
Helenium autumale							x																													
Helianthus giganteus																2																1		3		
Helianthus grosseserratus				2				1						2				3	x	2					x	2							1			
Helianthus spp			2												2	3	2															3				
Hierchloe odorata																																				
Humulus lupulus																									x			2								
Hypoxis hirsuta																																				
Impatiens capensis																			x		2	1	2	2	x	3	1		2	2						
Iris versicolor																																				
Juncus alpino-articulatus																																				
Juncus dudleyi																																				
Larix decidua																																				
Lathyrus palustris														2																						
Leersia oryzoides																																				
Liatris ligulistylis																															x			1		
Lilium michiganense																			x																	
Lilium philadelphicum																																				
Liparis loeselii																																				
Lobelia kalmii	x																																			
Lobelia siphilitica																															x					
Lycopus americanus	x						x	2	2				x	2					x				3													
Lycopus uniflorus	x	2					x		2				x	1		2			x			3	2	1		1	2				x	2	2	2	1	1
Lysimachia ciliata													x					3	x																	
Lysimachia quadriflora													x																							
Lysimachia spp.																							2													
Lysimachia thyrsifolia																			x																	

Seminary Fen Vegetation Data 2005

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Transect:	14						15						16						17					
Plot:	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**
Lythrum salicaria																								
Mentha canadensis																								
Muhlenbergia glomerata																								
Muhlenbergia racemosa																								
Muhlenbergia richardsonis														3		2	3	3						
Muhlenbergia spp.																				3	2	2		
Onoclea sensibilis																								
Panicum spp.																								
Parnassia glauca																								
Pedicularis lanceolata																								
Phalaris arundinacea	x	6	6	6	6	6													x					
Phragmites australis																			x			3	2	3
Pilea fontana																								
Poa pratensis																								
Poa spp.													x											
Polygonum spp.																								
Populus deltoides																								
Prenanthes alba							x																	
Pycnanthemum virginianum																								
Ranunculus spp.																								
Rhamnus cathartica																								
Rhamnus frangula	x																							
Rorippa nasturtium-aquaticu																								
Rubus pubescens																								
Rubus strigosus																								
Rumex orbiculatus																								
Sagittaria latifolia																								
Salix bebbiana																								
Salix candida																								
Salix nigra																								
Salix spp.																								
Scirpus acutus																								
Scirpus fluviatilis																								
Scirpus pungens																								
Scirpus validus													x											
Scleria verticillata																								
Scutellaria galericulata																								
Senecio pseudaureus																								
Silphium perfoliatum																								
Sium suave																								
Smilacina stellata							x				3	3							x	2	2			3
Solidago canadensis	x						x			2	2	2	x	3	2			3						
Solidago gigantea	x				2			3																
Solidago riddellii																								
Solidago spp.																					3			

Transect:	18						19						21						22					
Plot:	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**
Lythrum salicaria																								
Mentha canadensis																								
Muhlenbergia glomerata																								
Muhlenbergia racemosa	x																							
Muhlenbergia richardsonis																								
Muhlenbergia spp.	x		2	2	1		x							1	4	3					2		3	
Onoclea sensibilis																								
Panicum spp.																								
Parnassia glauca																								
Pedicularis lanceolata	x																							
Phalaris arundinacea							x	5	5	5	4	6					1	1						
Phragmites australis																								
Pilea fontana																								
Poa pratensis																								
Poa spp.																			x					
Polygonum spp.																								
Populus deltoides																								
Prenanthes alba													x											
Pycnanthemum virginianum	x																							
Ranunculus spp.																								
Rhamnus cathartica													x											
Rhamnus frangula	x												x											
Rorippa nasturtium-aquaticu																								
Rubus pubescens																								
Rubus strigosus																								
Rumex orbiculatus																								
Sagittaria latifolia																								
Salix bebbiana																								
Salix candida	x																							
Salix nigra																								
Salix spp.							x																	
Scirpus acutus							x																	
Scirpus fluviatilis																								
Scirpus pungens																								
Scirpus validus					2	2	x																	
Scleria verticillata																								
Scutellaria galericulata																								
Senecio pseudaureus	x			2																				
Silphium perfoliatum													x											
Sium suave																								
Smilacina stellata																								
Solidago canadensis							x	2		2			x	2	3	2	4		x	3			2	3
Solidago gigantea							x			2			x	3		2			x	1	3			3
Solidago riddellii							x																	
Solidago spp.																								

Transect:	23						24						25					
Plot:	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**
Lythrum salicaria																		
Mentha canadensis	x																	
Muhlenbergia glomerata																		
Muhlenbergia racemosa																		
Muhlenbergia richardsonis														3	2			
Muhlenbergia spp.				3						2								
Onoclea sensibilis																		
Panicum spp.																		
Parnassia glauca																		
Pedicularis lanceolata																		
Phalaris arundinacea	x																	
Phragmites australis																		
Pilea fontana																		
Poa pratensis																		
Poa spp.																		
Polygonum spp.																		
Populus deltoides																		
Prenanthes alba													x					
Pycnanthemum virginianum																		
Ranunculus spp.																		
Rhamnus cathartica																		
Rhamnus frangula																		
Rorippa nasturtium-aquaticu																		
Rubus pubescens																		
Rubus strigosus																		
Rumex orbiculatus	x																	
Sagittaria latifolia																		
Salix bebbiana																		
Salix candida																		
Salix nigra																		
Salix spp.																		
Scirpus acutus	x	2																
Scirpus fluviatilis																		
Scirpus pungens																		
Scirpus validus		1																
Scleria verticillata																		
Scutellaria galericulata																		
Senecio pseudaureus	x					2												
Silphium perfoliatum										2								
Sium suave																		
Smilacina stellata																		
Solidago canadensis	x												x		2	3	1	
Solidago gigantea																		
Solidago riddellii													x					
Solidago spp.																		

Seminary Fen Vegetation Data 2005

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Transect:	14						15						16						17						18						19						21						22						23						24						25					
Plot:	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5
Sparganium eurycarpum																																																																		
Spartina pectinata																																							4	4																										
Stellaria spp.																																																																		
Taraxacum officinale																																																																		
Thalictrum dasycarpum													x	2	3	3	3	3	x					4							x						x						x												x								3			
Thylepteris palustris																																																	x																	
Triglochin maritima																									x																																									
Triglochin palustris																																																																		
Typha angustifolia																			x	3											x	3	2	2	3	2	x						x	1	2	3		2	x	3	5	4	2	2												
Typha latifolia													x												x																														x											
Ulmus americana																																																																		
unidentified forb																												2																2						1		2		2												
unidentified grass																																					x																													
Urtica dioica																																																																		
Verbena hastata																																																																		
Viola nephrophylla																									x	2	2			2																																				
Zizia aurea																			x						x	2											x						x						x																	

Seminary Fen Vegetation Data 2005

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An "x" in a "V" column indicates a species was present in the vicinity of a transect but cover was not estimated.

Transect:	26						27						28						29						30						31						32						33						34						36						37					
Plot:	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5
Acer saccharinum																																																							0											
Acorus americanus																																					x		4	3	4	5	x	2					x	3	2	4	3	3	x	6			3	3						
Agalinus paupercula																																																																		
Agrostis stolonifera																																																																		
Amorpha fruticosa													x												x												x																		x											
Andropogon gerardii	x																								x																																									
Angelica atropurpurea																																																																		
Apocynum cannabinum																																																																		
Asclepias incarnata																																																																		
Aster borealis																															x																																			
Aster firmus		2		2	1			2			3		x	3												1				2		2		2																					x											
Aster novae-angliae																									x																																									
Aster spp.																																																																		
Aster umbellatus	x						x						x												x											1																														
Betula papyrifera																																																																		
Bidens spp.																																																							x											
Boehmeria cylindrica														1																								1																					3	1						
Bromus ciliatus							x						x				1	2							x						x																								x											
Calamagrostis spp.								6	5	6	3	4		2				2																3	2	3																														
Calamagrostis stricta								2	4	4		2																																																						
Caltha palustris							x						x			2	2		x				1		x						x																														x					
Campanula aparinoides																																				1																									x					
Cardamine bulbosa	x												x												x						x	2																													x					
Carex aquatilis																															x																								x											
Carex buxbaumii	x																																																																	
Carex granularis																									x																																									
Carex hystericina													x												x																																									
Carex interior							x																		x																																									
Carex lacustris													x	4	3	3	4	3													x	4	5	4	3	4	x			2	3	3	x	5	6	5	6	6	x	6	4	2	3	3	x						x	5	5	3	5	6
Carex lasiocarpa	x																																																																	
Carex oligosperma																																																																		
Carex prairea	x						x						x												x	3	4	5		4	x					2																									x					2
Carex sartwellii	x	3	4	3	4	3	x	2	4		5	2													x																																									
Carex spp.																																																																		
Carex sterilis	x					1	x																		x																																									
Carex stipata																									x												x																		x		2									
Carex stricta	x					2	x				2		x		2										x				3		x	4	3	3		3	x	4	3																											
Carex tetanica																									x																																									
Chelone glabra																																																																		
Cicuta bulbifera																																																														x					1
Cicuta maculata																																																																		
Cirsium muticum	x						x						x												x		2				x																																				
Cladium mariscoides																																																																		
Clematis virginiana																																																																		
Convolvulus arvensis													x	2																																																				

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Transect:	26						27						28						29						30						31						32						33						34						36						37					
Plot:	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5
Cornus stolonifera													x						x																		x																													
Cuscuta spp.																																																	x																	
Cypripedium candidum	x																																																																	
Cypripedium parviflorum																									x																																									
Echinocystis lobata																																																																		
Eleocharis erythropoda																									x																																									
Eleocharis rostellata																																																																		
Eleocharis spp.	x																																																						x					2						
Elymus canadensis																																																							x											
Epilobium spp.																																																									2									
Equisetum pratense				3																					x				2	1																																				
Eriophorum angustifolium	x						x																		x																																									
Eupatorium maculatum	x						x	4	3	3		4	x			4	3								x	4	2	3			x	2		2	2	1	x				2		x	4		3	2				3		2	3	x											
Eupatorium perfoliatum																																																																		
Euthamia graminifolia																																																																		
Galium boreale																																																							x											
Galium labradoricum													x												x						x	3	2	3	2	2																														
Gentianopsis procera																									x																																									
Glyceria striata	x						x																		x																																									
Helenium autumale							x																		x													2																	x											
Helianthus giganteus																																						x																												
Helianthus grosseserratus			3	3	2			2	3							3		2							x								3	1																																
Helianthus spp		3	3	2	2							2																																																						
Hierchloe odorata																									x																																									
Humulus lupulus																																																																		
Hypoxis hirsuta	x																																																																	
Impatiens capensis													x	1				2	x				2								x		1	1		1							x	1																	x	1	2	2	2	1
Iris versicolor																																					x																		x											
Juncus alpino-articulatus																																																																		
Juncus dudleyi																																																																		
Larix decidua																																																																		
Lathyrus palustris													x					5							x																																									
Leersia oryzoides																																								3																2	4	5	2	2						
Liatris ligulistylis																																																																		
Lilium michiganense																																																																		
Lilium philadelphicum													x				2								x																																									
Liparis loeselii																																																																		
Lobelia kalmii																									x																																									
Lobelia siphilitica																									x																																									
Lycopus americanus	x	2	1				x						x	3		2									x				1								x	2	2				x			1											2									
Lycopus uniflorus	x	1		2			x	2		2	1		x	1			1									1	3		3	3	x	1		2	2	2	x		2		3	2	x	2			3		x			2	2	2	x			2			x			2		
Lysimachia ciliata																															x	2	1																																	
Lysimachia quadriflora																									x																																									
Lysimachia spp.																																																									2			2		2		2	2	2
Lysimachia thyrsifolia																																					x		1	2			x		2	2		2	x	2	2		2		x				2		x					

Seminary Fen Vegetation Data 2005

Data are maximum cover classes in plots along transects for each species.

An "x" in a "V" column indicates a species was present in the vicinity of a transect but cover was not estimated.

Transect:	26						27						28						29						30						31						32						33						34						36						37					
Plot:	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5	V	1	2	3	4	5
Lythrum salicaria																																					x			2	2		x						x		1	2			x			2	2							
Mentha canadensis																																																																		
Muhlenbergia glomerata																																																																		
Muhlenbergia racemosa																													2			2				2																														
Muhlenbergia richardsonis																																																																		
Muhlenbergia spp.																																																																		
Onoclea sensibilis																																					x																														
Panicum spp.																																																																		
Parnassia glauca																																																																		
Pedicularis lanceolata																																																																		
Phalaris arundinacea													x						x	6	6	6	6	6													x	3	3				x												x											
Phragmites australis																			x		2				x																																				x	3	3	3	2	2
Pilea fontana																																					x	2			2														x	1		2	4	5						
Poa pratensis																									x																																									
Poa spp.																									x																																									
Polygonum spp.																																																							x		2									
Populus deltoides																																																																		
Prenanthes alba	x	1																																																																	
Pycnanthemum virginianum													x	1		2	2								x						x			1	2		x			2	1								x				1		x		2	2	3	2						
Ranunculus spp.																																																									3									
Rhamnus cathartica																																																																		
Rhamnus frangula																																																																		
Rorippa nasturtium-aquaticu																			x																																				x											
Rubus pubescens																																																																		
Rubus strigosus																																																																		
Rumex orbiculatus													x						x												x																3		x						x		2				x			1		
Sagittaria latifolia																																												4	4	4	2	3							x		2	2								
Salix bebbiana																																											x																							
Salix candida																																																	x																	
Salix nigra																																																							x											
Salix spp.																																					x												x																	
Scirpus acutus													x												x						x	3	1		2	2																			x											
Scirpus fluviatilis																																																3							x											
Scirpus pungens																																																																		
Scirpus validus						2	x											2							x																														x											
Scleria verticillata																																																																		
Scutellaria galericulata																																																								3			2							
Senecio pseudaureus																									x																																									
Silphium perfoliatum																									x																																									
Sium suave																																																							x			2								
Smilacina stellata													x	3	2	2	2	2							x																																									
Solidago canadensis	x	4	3	4	4	3	x	3	3		3		x	2	1		4								x	3	5	4	1																																					
Solidago gigantea													x	2	2	3	2	2							x		2																																							
Solidago riddellii																									x																																									
Solidago spp.															2		2	2																																																

Seminary Fen Vegetation Data 2005

Data are maximum cover classes in plots along transects for each species.

An "x" in a "V" column indicates a species was present in the vicinity of a transect but cover was not estimated.

Transect:	26						27						28						29						30						31						32						33						34						36						37					
Plot:	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**
Sparganium eurycarpum																															x												x												x		2	3	3		x			2		
Spartina pectinata																																																																			
Stellaria spp.																															x	2																																		
Taraxacum officinale																																																																		
Thalictrum dasycarpum	x	3	3	2	2	3	x						x		4	6	4	6							x																																									
Thylepteris palustris																									x	4	3	3	2	3							x																													
Triglochin maritima																																																																		
Triglochin palustris																																																																		
Typha angustifolia							x				2									4	3				x				2								x						x										1								x					
Typha latifolia	x										2		x		1																x												x						x																	
Ulmus americana																																																							x											
unidentified forb																																																																	1	2
unidentified grass																										2			3											2																										
Urtica dioica																																					x																													
Verbena hastata																																																	x																	
Viola nephrophylla																									x							1																																		
Zizia aurea							x																		x																																				x					

Seminary Fen Vegetation Data 2005

Data are maximum cover classes in plots along transects for each species.

An "x" in a "V" column indicates a species was present in the vicinity of a transect but cover was not estimated.

Transect:	38						39						40						41						42						43						44					
Plot:	**0**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**
Acer saccharinum																																										
Acorus americanus																																										
Agalinus paupercula																																										
Agrostis stolonifera																																										
Amorpha fruticosa																																										
Andropogon gerardii																	3	2													x											
Angelica atropurpurea																																										
Apocynum cannabinum																			x																							
Asclepias incarnata																			x																							
Aster borealis						2	x												x						x						x						x					
Aster firmus		2	1	1	2			2		2	2	1		3	3	2	1	3		2	2		2			1				2	x							1	2	2	3	1
Aster novae-angliae	x																																									
Aster spp.																																										
Aster umbellatus	x	3						2											x						x						x						x					
Betula papyrifera																															x											
Bidens spp.																																										
Boehmeria cylindrica																																										
Bromus ciliatus	x												x		2			1	x						x									2			x					
Calamagrostis spp.																																										
Calamagrostis stricta																																										
Caltha palustris	x						x		1	2		1	x												x																	
Campanula aparinoides	x		1										x	1			1								x		1							1								
Cardamine bulbosa	x						x						x												x																	
Carex aquatilis																																										
Carex buxbaumii																																										
Carex granularis																																										
Carex hystericina																			x						x										2							
Carex interior							x					2	x																													
Carex lacustris	x	4	2	3	4	5	x	3	3		4	2																					2									
Carex lasiocarpa																									x																	
Carex oligosperma																																										
Carex prairea	x		4				x			3	3	4	x	2		2		6							x	5	5	3	4	4		2		3		4		2	3	4	4	3
Carex sartwellii	x	3		4	3		x					2																														
Carex spp.																																										
Carex sterilis																			x						x																	
Carex stipata																																										
Carex stricta	x						x						x	4	4	5	5		x	3	5	4	4	4	x									2	4			3	3	3		
Carex tetanica													x					1	x																							
Chelone glabra																			x						x												x					
Cicuta bulbifera					3		x	1																																		
Cicuta maculata																																										
Cirsium muticum													x						x	2			1		x																	
Cladium mariscoides																																										
Clematis virginiana													x																													
Convolvulus arvensis																																										

Seminary Fen Vegetation Data 2005

Data are maximum cover classes in plots along transects for each species.
An "x" in a "V" column indicates a species was present in the vicinity of a transect but cover was not estimated.

Transect:	38						39						40						41						42						43						44					
Plot:	**0**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**
Cornus stolonifera													x												x																	
Cuscuta spp.							x																																			
Cypripedium candidum													x																													
Cypripedium parviflorum																																										
Echinocystis lobata																																										
Eleocharis erythropoda																																										
Eleocharis rostellata																																										
Eleocharis spp.																																										
Elymus canadensis																																										
Epilobium spp.																																										
Equisetum pratense							x												x		2																					
Eriophorum angustifolium													x																													
Eupatorium maculatum	x						x						x		3		2		x		2	3	2	3	x		2	2			x			1	1						1	
Eupatorium perfoliatum	x						x						x												x						x											
Euthamia graminifolia																																										
Galium boreale																																										
Galium labradoricum	x				2		x				2	2	x																													
Gentianopsis procera																			x						x		1				x						x					
Glyceria striata							x						x			2									x																	
Helenium autumale																															x											
Helianthus giganteus																												2	1									1				
Helianthus grosseserratus	x						x						x														1				x						x					
Helianthus spp			2					2													2		2	2			2	3		2												
Hierchloe odorata																																										
Humulus lupulus																																										
Hypoxis hirsuta													x												x																	
Impatiens capensis							x	2	2		1	1													x			2														
Iris versicolor																																										
Juncus alpino-articulatus																																										
Juncus dudleyi																																										
Larix decidua																																					x					
Lathyrus palustris	x																																									
Leersia oryzoides																																										
Liatris ligulistylis																			x						x																	
Lilium michiganense																																										
Lilium philadelphicum																																										
Liparis loeselii																																										
Lobelia kalmii																			x						x						x										1	
Lobelia siphilitica																			x						x																	
Lycopus americanus							x						x			3			x																	2						
Lycopus uniflorus	x	2	2	2		2	x	1	2				x		1			1	x	1			2		x																	1
Lysimachia ciliata							x																																			
Lysimachia quadriflora																			x	2																						
Lysimachia spp.																																										
Lysimachia thyrsifolia	x						x																																			

Seminary Fen Vegetation Data 2005

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An "x" in a "V" column indicates a species was present in the vicinity of a transect but cover was not estimated.

Transect:	**38**						**39**						**40**						**41**						**42**						**43**						**44**					
Plot:	**0**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**
Lythrum salicaria																																										
Mentha canadensis																																										
Muhlenbergia glomerata																																						5		3	1	2
Muhlenbergia racemosa																												2	2						3							
Muhlenbergia richardsonis																																										
Muhlenbergia spp.																2				3	3			2				3														
Onoclea sensibilis																																										
Panicum spp.																																										
Parnassia glauca																			x												x											
Pedicularis lanceolata																													2													
Phalaris arundinacea																																	3									
Phragmites australis	x						x																																			
Pilea fontana																																										
Poa pratensis																																										
Poa spp.																3									x																	
Polygonum spp.																																										
Populus deltoides																																										
Prenanthes alba	x												x																													
Pycnanthemum virginianum																			x																							
Ranunculus spp.																																										
Rhamnus cathartica																																										
Rhamnus frangula																																										
Rorippa nasturtium-aquaticu																																										
Rubus pubescens																																2		2	1	2			1			2
Rubus strigosus																																										
Rumex orbiculatus																																										
Sagittaria latifolia																																										
Salix bebbiana																																										
Salix candida							x						x																		x						x					
Salix nigra																																										
Salix spp.							x																		x																	
Scirpus acutus	x												x	1	2	1				2					x			2	2	2												
Scirpus fluviatilis																																										
Scirpus pungens																																										
Scirpus validus	x													3		2			x							1		2	2	2	x	2						2		4	2	3
Scleria verticillata																																										
Scutellaria galericulata																																										
Senecio pseudaureus																									x																	
Silphium perfoliatum																																										
Sium suave																																										
Smilacina stellata																																										
Solidago canadensis													x		2				x	2			2																			
Solidago gigantea																																										
Solidago riddellii																															x											
Solidago spp.																																										

Seminary Fen Vegetation Data 2005

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An "x" in a "V" column indicates a species was present in the vicinity of a transect but cover was not estimated.

Transect:	**38**						**39**						**40**						**41**						**42**						**43**						**44**					
Plot:	**0**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**	**V**	**1**	**2**	**3**	**4**	**5**
Sparganium eurycarpum							x			2	3																							2	3							
Spartina pectinata																																										
Stellaria spp.																																										
Taraxacum officinale																																										
Thalictrum dasycarpum																			x																							
Thylepteris palustris													x																			2		2	3	3		3				3
Triglochin maritima																																										
Triglochin palustris																																										
Typha angustifolia		2			2				2				x																		x						x					
Typha latifolia							x						x												x																	
Ulmus americana																																										
unidentified forb			1											2			1				2																					
unidentified grass																		1																								
Urtica dioica																																										
Verbena hastata																																										
Viola nephrophylla							x	1					x		1				x			1			x		1		1													
Zizia aurea																									x																	

Appendix 2: Bryophyte Report

Extract of 'BRYOPHYTES OF CARVER COUNTY MINNESOTA': Seminary Fen sites 2349, 6643 to 6646

Update December 2005

Joannes A. Janssens

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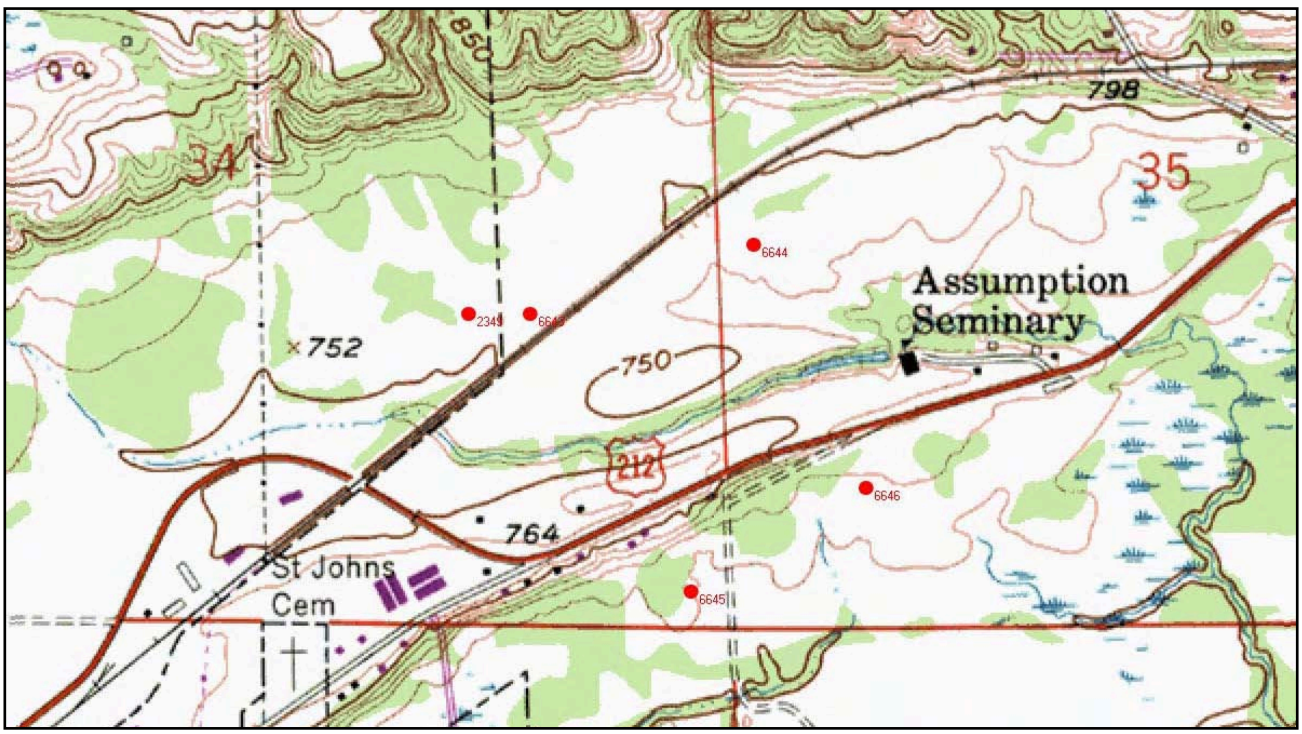
SITES 2349 & 6643-6646 (Seminary Fen)

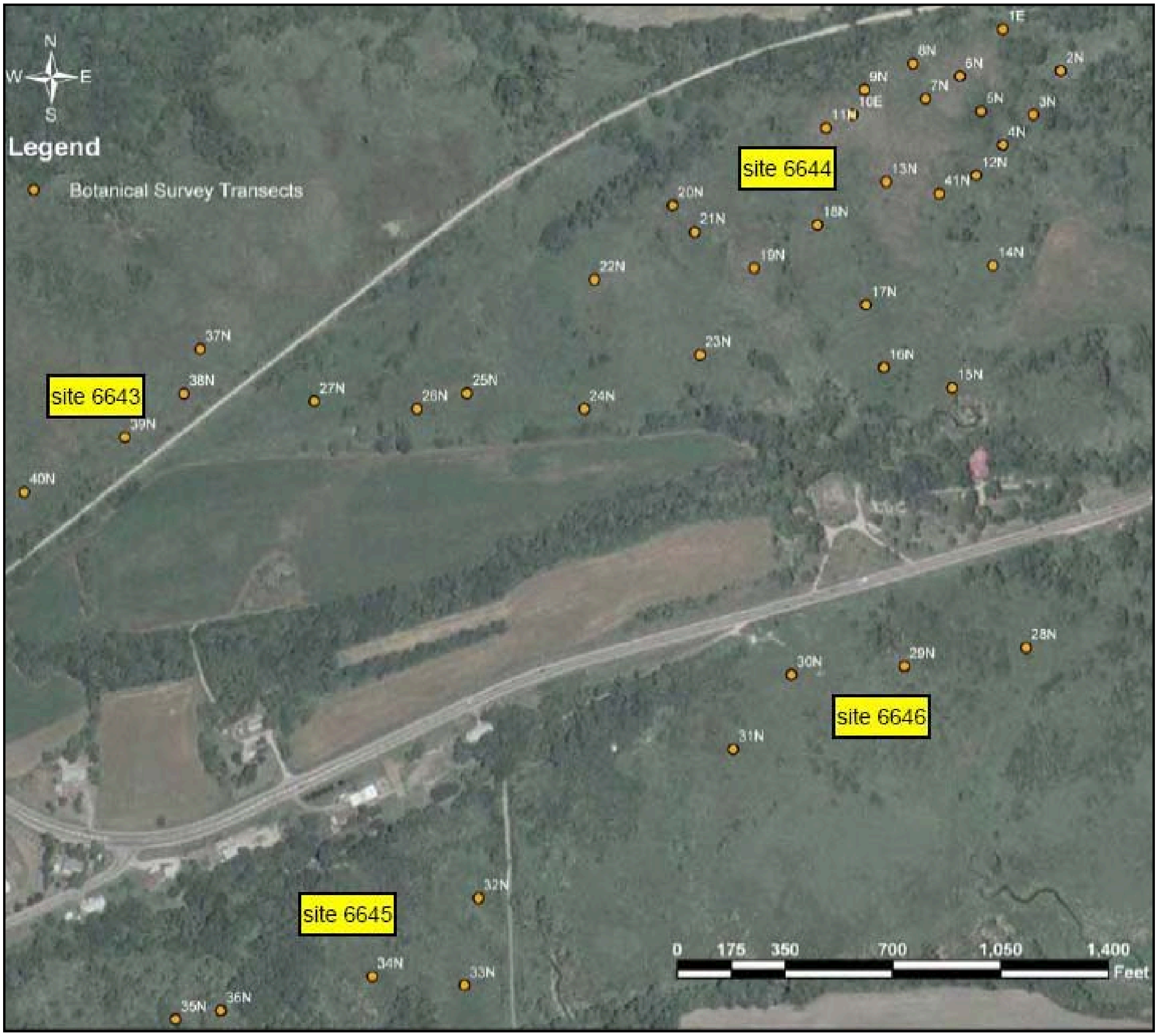
Chaska Area: Seminary Fen, site 2349 = 110 m NW of old railroad grade, 1.9 km north of Nyssens Lake, 3.6 km NE of Chaska, 44° 48' 35" N, 93° 34' 00" W, 229 m; site 6643 = midpoint of number of collection sites just north of railroad, 3.6 km NE of Chaska, 44° 48' 35" N, 93° 33' 55" W, 234 m; site 6644 = midpoint of number of collection sites just south of railroad, 3.9 km NE of Chaska, 44° 48' 39" N, 93° 33' 37" W, 244 m; site 6645 = midpoint of number of collection sites just south of state highway 212, 3.5 km NE of Chaska, 44° 48' 19" N, 93° 33' 42" W, 224 m; and site 6646 = midpoint of number of collection sites just south of state highway 212, 3.9 km NE of Chaska, 44° 48' 25" N, 93° 33' 28" W, 226 m (see topographic-map extract for site midpoints and aerial photo for botanical transect associated with sites 6643-6646).



Site 2349 & 6643-6646 locations. Topographic map extract from the 1:24,000 Shakopee quad.

Ecotope Delineation

Only a single ecotope can be analyzed at the moment: 2349A. Ecotopes are not yet delineated for the sites 6643 to 6646. The bryophyte assemblages of these sites are based on the analysis of a number of different point-intercept transect samples (see Janssens 2002 for detailed methods) by Daniel R Dejoode in June 2005 (see aerial photo) and will be grouped in ecotopes when the vascular plant data have been analyzed.



Site 6643-6646 botanical transect. Aerial-photo extract (Peterson Environmental Consulting, Inc.) with the location of the botanical transect of sites 6643-6646.

Ecotope 2349A

Classification: Southern Seepage Meadow/Carr (WMs83), based on distance of nearest classified DNR relevé 5037 within 0.001° lat/long (bryophyte assemblage fits better with WMs83 than OPp93 as suggested by the other nearby relevé 5036, Janssens 2005). Ecotope 2349A has 6 calcareous-fen indicator species, with a total indicator-species score of 263 (rank 24th out of 93) and should be considered a calcareous fen based on the bryophyte criterion (Janssens 2005). The score obtained with the old method equals 181, and the site ranked 21st of 60 calcareous fens state wide or 8th out of 14 for the Boreal & Central region (Janssens 2004).

Water chemistry: pH 7.96 and $K^{20°C}_{corr}$ 1020 µScm^{-1} (sample type: stagnant water in small depression or hollow), provided by J.H. Leete.

Bryophytes: Surveyed by J.A. Janssens on September 25, 2002. Vouchers *Janssens 47434-47475* !JAJ, see Appendix.

Bryophyte composition: Bryophyte cover was estimated using a 15-m point-intercept line (*Janssens 47452-47475)*. The table below presents the species composition of ecotope 2349A based on the analysis of these transect-line data, and the identification of bryophyte vouchers of both the point-intercepts and the general collections made in the immediate area within the ecotope 2349A (*Janssens 47434-47451).*

Table 2349A. Bryophytes identified from transect and general collections in ecotope 2349A, represented by relevé 2349AA (near DNR relevé 5037). The number of vouchers (n) are the total number of vouchers deposited for each species (see Appendix). The % cover is the proportional % cover calculated from the point-intercept transect line vouchers only. The 'cover (BB)' is the Braun-Blanquet cover/abundance derived from the transect % cover; the species among the general collections not found among the point-intercept samples are assigned '+'. The calcareous-fen indicator species (Janssens 2005) are marked by an '*'.

	n	% cover	cover (BB)
**Campylium polygamum*	29	35	3
Fissidens adianthoides	17	16	2
**Brachythecium rivulare*	9	9	2
**Bryum pseudotriquetrum*	7	5	2
Thuidium recognitum	4	5	2
Hypnum lindbergii	7	3	1
**Aneura pinguis*	2	1	1
**Plagiomnium ellipticum*	2	1	1
**Drepanocladus aduncus*	2	0	+
Eurhynchium hians	1	0	+
total bryophyte cover		80	

Botanical transects of sites 6643 to 6646

No ecotopes have yet been delineated within these four sites. Table 6643-6646 lists all bryophytes species recorded from the 5-m point-intercept lines surveyed as the botanical transects 1 to 42 (see aerial photo). Once the ecotopes will be delineated, their total bryophyte and individual species cover will be calculated based on their configuration of point-intercept transects. The individual transect data are stored in the Minnesota Bryophyte Database and are available on request. If the sites are considered in their entirety, three of them (6643-6645) qualify for calcareous-fen status, based on the new protocol proposed in Janssens (2005). However, no calcareous-fen validation scores are calculated, because they cannot be compared with those of other Minnesota calcareous fens, as those are configured at the ecotope level.

Table 6643-6646. Bryophytes identified from sites 6643 to 6646. The values given are the total number of vouchers deposited for each species (see Appendix) and correspond to the total number of point-intercept hits for all the botanical transect within the site. The calcareous-fen indicator species (Janssens 2005) are marked by an '*' and tallied at the bottom in the row 'total # of CF IS'. Sites with 3 or more indicator species qualify for calcareous-fen status based on the bryophyte criterion (Janssens 2005).

	6643	**6644**	**6645**	**6646**
**Amblystegium varium*	5	32	21	3
**Aneura pinguis*		4		
Aulacomnium palustre		1		
Brachythecium oedipodium		3		
Brachythecium salebrosum	4	35	1	10
**Bryum pseudotriquetrum*	2	11	1	
**Calliergonella cuspidata*		1		
**Campylium polygamum*	2	21		
**Campylium stellatum*		31		
**Drepanocladus aduncus*	2	16	2	3
Eurhynchium hians		4		2
Fissidens adianthoides	1	10		
Hypnum lindbergii		1		
Hypnum pratense		3		1
**Plagiomnium ellipticum*	3	21	5	
total # of CF IS	**5**	**8**	**4**	**2**

APPENDIX: SEMINARY FEN CHECKLIST

Site information and ecotope habitat descriptions

Site 2349: Chaska Area: Seminary Fen, 110 m NW of old railroad grade, 1.9 km north of Nyssens Lake, 3.6 km NE of Chaska, 44° 48' 35" N, 93° 34' 00" W, 229 m
ecotope 2349A: calcareous seepage fen

Site 6643: Chaska Area: Seminary Fen, midpoint of number of collection sites just north of railroad, 3.6 km NE of Chaska, 44° 48' 35" N, 93° 33' 55" W, 234 m
ecotope 6643X: potential calcareous seepage fen, SMF bot transects 37-40

Site 6644: Chaska Area: Seminary Fen, midpoint of number of collection sites just south of railroad, 3.9 km NE of Chaska, 44° 48' 39" N, 93° 33' 37" W, 244 m
ecotope 6644X: potential calcareous seepage fen, SMF bot transects 1-27, 41-42

Site 6645: Chaska Area: Seminary Fen, midpoint of number of collection sites just south of state highway 212, 3.5 km NE of Chaska, 44° 48' 19" N, 93° 33' 42" W, 224 m
ecotope 6645X: potential calcareous seepage fen, SMF bot transects 32-36

Site 6646: Chaska Area: Seminary Fen, midpoint of number of collection sites just south of state highway 212, 3.9 km NE of Chaska, 44° 48' 25" N, 93° 33' 28" W, 226 m
ecotope 6646X: potential calcareous seepage fen, SMF bot transects 28-31

Voucher lists for all bryophyte species recorded

Amblystegium varium
***ecotope* 6643X:** Dejoode, 6/17/2005, 372A1, 374A1, 388A2, 395A1, 397A1, **ecotope 6644X:** Dejoode, 6/16/2005, 75A1, 161A1, 162A2, 167A1, 168A2, 169A1, 170A1, 222A1, 223A1, 227A2, 250A2, 259A1, 269A1, 411A1, 6/17/2005, 37A1, 39A1, 122A1, 127A1, 128A1, 202A1, 211A2, 212A1, 214A1, 215A1, 216A2, 219A1, 220A1, 6/27/2005, 143A1, 145A1, 405A1, 408A1, 410A1, **ecotope 6645X:** Dejoode, 6/28/2005, 311A2, 312A1, 316A1, 317A1, 318A1, 327A1, 330A1, 334A1, 335A1, 338A1, 339A1, 340A1, 351A1, 352A1, 353A2, 354A1, 355A1, 356A2, 357A1, 359A1, 360A2, **ecotope 6646X:** Dejoode, 6/28/2005, 273A1, 274A3, 306A1

Aneura pinguis
***ecotope* 2349A:** Janssens, 9/25/2002, 47448A1, 47469A1, **ecotope 6644X:** Dejoode, 6/16/2005, 85A1, 6/27/2005, 51A1, 120A1, 160A1

Aulacomnium palustre
***ecotope* 6644X:** Dejoode, 6/16/2005, 86A1

Brachythecium oedipodium
***ecotope* 6644X:** Dejoode, 6/16/2005, 165A1, 168A1, 169A2

Brachythecium rivulare
***ecotope* 2349A:** Janssens, 9/25/2002, 47437A2, 47440A1, 47447A2, 47448A3, 47455A3, 47456A3, 47467A1, 47468A2, 47474A1

Brachythecium salebrosum
***ecotope* 6643X:** Dejoode, 6/17/2005, 371A3, 381A1, 387A1, 388A4, **ecotope 6644X:** Dejoode, 6/16/2005, 68A1, 69A1, 72A1, 80A1, 84A1, 85A3, 162A1, 164A1, 173A1, 175A2, 176A1, 177A2, 180A1, 227A1, 242A1, 243A1, 264A1, 267A1, 412A1, 413A1, 414A3, 415A4, 6/17/2005, 6A1, 7A2, 130A1, 204A1, 206A1, 207A1, 208A1, 211A1, 212A2, 216A1, 219A2, 6/27/2005, 148A1, 159A2, **ecotope 6645X:** Dejoode, 6/28/2005, 311A1, **ecotope 6646X:** Dejoode, 6/28/2005, 279A1, 298A1, 301A1, 302A1, 303A1, 304A1, 305A1, 307A1, 308A1, 310A1

Bryum pseudotriquetrum
***ecotope* 2349A:** Janssens, 9/25/2002, 47439A3, 47445A3, 47446A1, 47447A3, 47461A3, 47463A2, 47464A3, **ecotope 6643X:** Dejoode, 6/17/2005, 395A2, 396A2, **ecotope 6644X:** Dejoode, 6/16/2005, 83A2, 84A2, 242A2, 414A1, 6/17/2005, 1A2, 6/27/2005, 98A2, 112A4, 114A1, 118A2, 156A1, 404A2, **ecotope 6645X:** Dejoode, 6/28/2005, 352A2

Calliergonella cuspidata
***ecotope* 6644X:** Dejoode, 6/16/2005, 417A1

Campylium polygamum
***ecotope* 2349A:** Janssens, 9/25/2002, 47434A2, 47435A1, 47441A1, 47442A2, 47443A1, 47444A1, 47445A2, 47446A2, 47447A1, 47448A2, 47455A2, 47456A2, 47457A1, 47459A2, 47460A2, 47461A2, 47462A1, 47463A1, 47464A2, 47465A1, 47466A1, 47467A2, 47468A3, 47469A2, 47470A2, 47471A2, 47472A1, 47473A1, 47475A1, **ecotope 6643X:** Dejoode, 6/17/2005, 393A1,

396A3, **ecotope 6644X:** Dejoode, 6/16/2005, 81A2, 85A2, 243A2, 244A1, 246A1, 250A1, 414A4, 415A1, 417A5, 6/17/2005, 50A1, 6/27/2005, 52A1, 111A2, 112A2, 113A1, 114A2, 116A2, 120A2, 151A1, 152A1, 155A1, 156A2

Campylium stellatum

***ecotope* 6644X:** Dejoode, 6/16/2005, 83A1, 417A4, 6/17/2005, 33A2, 124A1, 125A1, 126A1, 6/27/2005, 51A2, 53A2, 55A1, 57A2, 60A1, 94A1, 95A1, 96A1, 97A1, 98A1, 99A1, 100A1, 111A1, 112A3, 117A2, 118A1, 119A1, 153A1, 159A1, 160A2, 401A1, 403A2, 404A1, 406A1, 407A1

Drepanocladus aduncus

***ecotope* 2349A:** Janssens, 9/25/2002, 47440A2, 47444A2, **ecotope 6643X:** Dejoode, 6/17/2005, 371A1, 388A1, **ecotope 6644X:** Dejoode, 6/16/2005, 69A2, 70A1, 81A1, 172A1, 173A3, 174A1, 177A4, 178A2, 179A1, 265A1, 413A2, 415A3, 420A1, 6/17/2005, 6A3, 212A3, 6/27/2005, 117A1, **ecotope 6645X:** Dejoode, 6/28/2005, 319A1, 360A1, **ecotope 6646X:** Dejoode, 6/28/2005, 271A1, 274A2, 309A1

Eurhynchium hians

***ecotope* 2349A:** Janssens, 9/25/2002, 47442A1, **ecotope 6644X:** Dejoode, 6/16/2005, 417A3, 6/17/2005, 1A1, 2A2, 129A1, **ecotope 6646X:** Dejoode, 6/28/2005, 273A2, 274A1

Fissidens adianthoides

***ecotope* 2349A:** Janssens, 9/25/2002, 47434A1, 47439A2, 47442A3, 47444A3, 47445A1, 47449A1, 47450A1, 47451A1, 47455A4, 47456A1, 47458A1, 47459A1, 47461A1, 47464A1, 47466A2, 47468A1, 47471A1, **ecotope 6643X:** Dejoode, 6/17/2005, 396A1, **ecotope 6644X:** Dejoode, 6/16/2005, 414A2, 6/17/2005, 33A1, 6/27/2005, 53A1, 57A1, 58A1, 59A1, 111A3, 116A1, 119A2, 403A1

Hypnum lindbergii

***ecotope* 2349A:** Janssens, 9/25/2002, 47436A1, 47437A1, 47439A1, 47449A2, 47451A2, 47460A1, 47470A1, **ecotope 6644X:** Dejoode, 6/27/2005, 112A1

Hypnum pratense

***ecotope* 6644X:** Dejoode, 6/16/2005, 176A3, 177A1, 418A1, **ecotope 6646X:** Dejoode, 6/28/2005, 304A2

Plagiomnium ellipticum

***ecotope* 2349A:** Janssens, 9/25/2002, 47447A4, 47455A1, **ecotope 6643X:** Dejoode, 6/17/2005, 371A2, 387A2, 388A3, **ecotope 6644X:** Dejoode, 6/16/2005, 171A1, 172A2, 173A2, 175A1, 176A2, 177A3, 178A1, 180A2, 415A2, 416A1, 417A2, 418A2, 419A1, 420A2, 6/17/2005, 1A3, 2A1, 3A1, 6A2, 7A1, 8A1, 215A2, **ecotope 6645X:** Dejoode, 6/28/2005, 351A2, 353A1, 354A2, 356A1, 357A2

Thuidium recognitum

***ecotope* 2349A:** Janssens, 9/25/2002, 47438A1, 47452A1, 47453A1, 47454A1