A Resilience-Based Site Assessment Tool for Ecological Restoration Planning in Washington County

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Resilient Communities Project
University of Minnesota
Building Community-University Partnerships for Resilience

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Abstract

With continued ecological degradation and human development, ecological restoration is a tactic widely used by land managers. When public land managers, such as county parks systems, are managing natural resources and prioritizing restoration projects, they face great challenges with effectively planning for and anticipating how many resources—namely, time and money—are needed to carry out restoration projects. The natural resources team at Washington County Parks and Trails in eastern Minnesota is interested in a site assessment tool to evaluate incoming land acquisitions to better predict the degree of resources needed to restore the sites within.

One can speculate how a site may recover with supportive restoration efforts by considering the inherent ecosystem resilience remaining within these sites. The amount of resilience determines how much human intervention is necessary to move the site from its current state to a desired state. This project focuses on building a resilience-based site assessment tool for common ecosystem types found in Washington County: upland prairie, oak savanna, deciduous forest, and palustrine wetland.

Creating this tool involved reviewing literature and precedent examples, exploring the passive to active restoration continuum, facilitating discussions with Washington County natural resources staff, and conducting site visits. When building the tool, unique ecosystem characteristics that influence resilience, termed resilience indicators, were selected for each ecosystem type. These resilience indicators were assigned observable metrics to determine the level of resilience remaining in the system. The level of resilience corresponds with the degree of restoration intervention needed—natural, assisted, and reconstructive. Associated protocols were developed to guide restoration practitioners in collecting the data needed to determine the level of resilience left in a site, and therefore the degree of intervention and resources needed to restore it.

The tool enables restoration professionals to have a consistent process across people, time, and ecosystems. The universal user and systematic approach gives the team an objective way to understand potential restoration sites and predict the resources needed to restore them. Future work with this assessment tool includes testing and evaluating the tool's validity and digitizing the process.

Key words: Ecological Restoration, Site Assessment, Restoration Planning, Ecosystem Resilience, Land Acquisition

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Introduction

Ecological restoration is a process in which humans support the recovery or re-construction of ecosystems that are degraded or damaged (Standards Reference Group SERA 2021). Restoration is necessary, because humans have significantly altered and continue to alter natural ecosystems around the world, through direct land conversion for agriculture, urban development, and resource extraction and through disturbances such as pollution, altered nutrient cycles, and climate change. Land management agencies, such as county park systems, care for broad swaths of land in varying levels of ecosystem health. Many agencies engage in ecosystem restoration as part of their land management strategies, especially on new land acquisitions. Land managers must often work with limited resources, such as time and money. Therefore, focusing on restoration strategies that would provide for the most efficient use of these resources is a priority.

Washington County Parks and Trails in eastern Minnesota applied for Resilient Communities Project support from the University of Minnesota, which is a program that brings together local government agencies and students and faculty from the University of Minnesota to partner on projects to bolster resilience in communities (Regents of the Univ. of Minn. 2023). The county's proposal was focused on planning for the future of natural resource land management in Washington County and revolved around exploring active and passive restoration, developing a framework to guide restoration planning, and preparing for future land acquisitions.

As of 2020, Washington County owned approximately 7,300 acres of parks, reserves, and trails and had a possible 3,895 acres to acquire to expand the parks to their master boundaries, as described in the parks comprehensive plan (Washington County 2020). As the natural resources team plans for adding these land acquisitions into their management portfolio, some questions Washington County had were 1) What is a step-by-step process or framework that could help guide land managers in developing the most responsible restoration approach? And 2) What criteria make land best for a more active restoration approach and what types of land are best for a passive restoration approach?

The efforts within this capstone project attempt to respond to those two questions through these goals: 1) create site assessment tool that can be used to evaluate site conditions of prospective or newly added lands to the park system; and 2) build a process to predict the level of resources needed to apply active or passive restoration methods to achieve desirable site conditions. This paper describes the approach and process for achieving these two goals through this narrative and includes the deliverables of the site assessment protocols and tool as appendices.

Resilience Framework: A tool for restoration planning

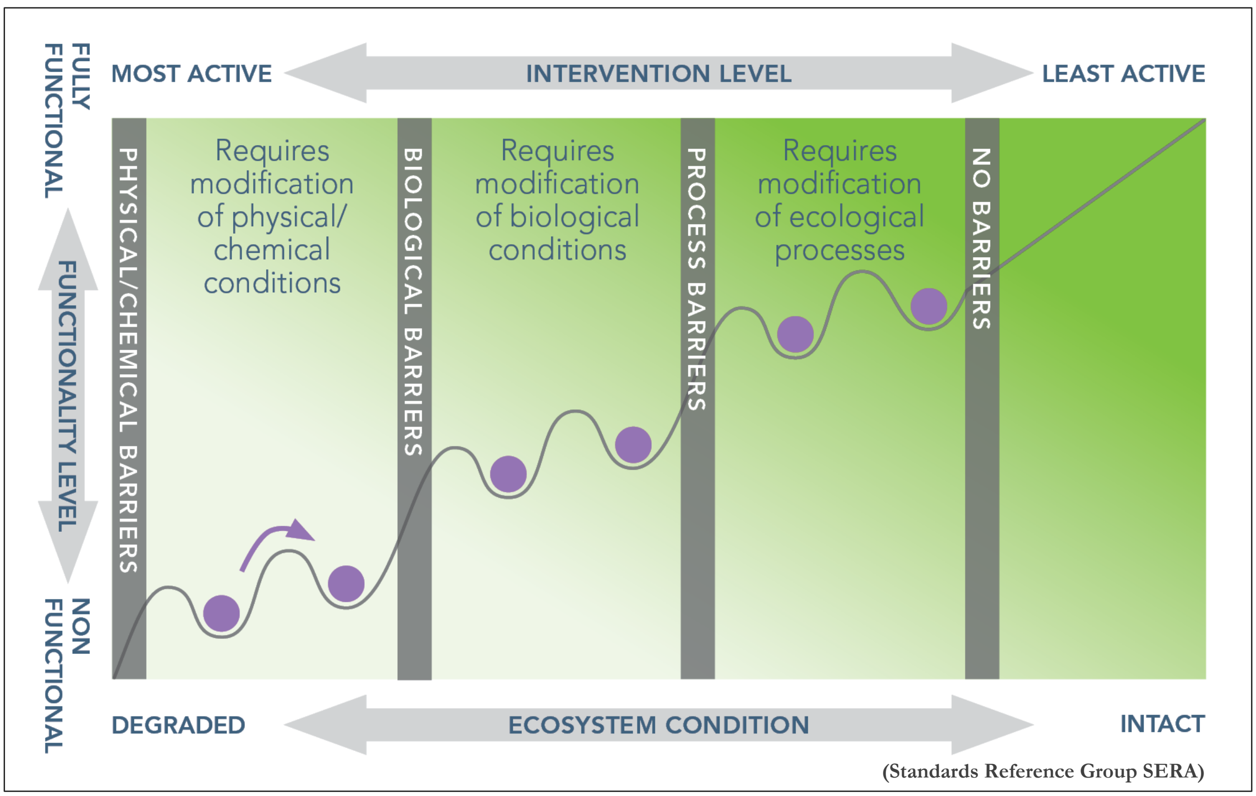
A resilience-based framework offers a path forward—providing a sound ecological approach to understanding sites while improving the ability to plan for and predict how many resources will be needed in restoration. Ecosystem resilience is "the capacity of an ecosystem to withstand change or to recover after a disturbance" (Galatowitsch 2012).

Resilience is important because it helps an ecosystem maintain its functional, natural state despite stressors or disturbances that happen. For example, a floodplain forest community experiences annual flooding disturbances. The native plant community has adapted to these disturbances, and even though the flooding may drown out the herbaceous plants, their adaptations like seed dispersal or growth habit enable them to return. The ecosystem resists being drastically affected by flooding; it is in equilibrium in a stable, natural state.

An ecosystem can exist not only in its natural state, but also in multiple stable equilibrium states depending on the level and types of alteration (Chein 2020). For example, the floodplain forest may have an herbaceous layer dominated by non-native species. After the site experiences flooding, the non-native species return. This ecosystem exists in an alternate stable state—it is resilient to remaining in that state. In this alternate state, that site does not support the diversity of plants and animals or the full ecosystem functions typical to that ecosystem.

This concept is illustrated in Figure 1. The dots represent the site's condition, from intact to degraded, while the troughs represent alternate stable states with various levels of functional quality, from non-functional to fully functional. An ecosystem's ability to recover is influenced by how degraded it is—the conditions of ecological processes and the biotic and abiotic components. The ecosystem condition then directly relates to the level of intervention needed to restore the site (Standards Reference Group SERA 2021).

FIGURE 1. CONCEPTUAL MODEL OF ECOSYSTEM DEGRADATION AND RESTORATION



"The troughs in the diagram represent basins of stability in which an ecosystem property (ball) can remain in a steady state prior to being shifted by a restoration activity past a barrier (peaks) towards a higher functioning state" (Reprinted from Standards Reference Group SERA 2021, page 7).

The remaining ecosystem resilience in a site considerably affects how possible it would be to restore it to a natural state (Chein 2020). Therefore, knowing the level of resilience of a site is an important planning tool for restoration professionals to understand the magnitude of intervention and resources needed to achieve desired restoration outcomes. To make these predictions, it is possible to examine certain resilience indicators, or cues, that point to the remaining resilience an ecosystem has to bounce back to a desired, functional state. These indicators vary by ecosystem type but are generally encompassed by the existing plant community and soil as well as the site's history and surroundings.

Restoration Strategy: Passive and Active Approaches

Restoration methods have often been described as taking either a passive approach or an active approach. Passive restoration involves removing degradation pressures and relying on natural ecosystem processes to recover, while active restoration involves direct and continued human intervention to alter the ecosystem back to a more naturally functional state (Krishnan and Osuri 2023). While these definitions may seem straightforward, it is hard to classify restoration efforts in this dichotomy due to great variability among ecosystems, site degradation, intervention methods, and many other factors. Restoration professionals in academic circles and within Washington County are starting to think of restoration along a continuum of passive to active.

Exploration of this continuum involved mapping where site qualities and intervention methods would fall along this gradient. Rather than a dichotomy, this exercise included three levels of restoration intervention—natural restoration, assisted restoration, and reconstructive restoration (Atkinson and Bonser 2020). This framework recognizes that these strategies are not mutually exclusive and that not all scenarios can fit within the three categories. It does, however, offer nuance and clarity beyond the traditional passive-active dichotomy. Table 1 describes these three restoration approaches and their associated ecosystem resilience, management activities, benefits, and tradeoffs.

TABLE 1. PASSIVE–ACTIVE CONTINUUM

<table>
<tr><th rowspan="2"></th><th colspan="3">Passive → → → Active</th></tr>
<tr><th>Natural restoration</th><th>Assisted restoration</th><th>Reconstructive restoration</th></tr>
<tr><td>Site-Based Restoration Goals</td><td>Allow a resilient ecosystem to undergo natural processes by removing degradation pressures and re-establishing disturbance patterns.</td><td>Assist a moderately resilient ecosystem by removing degradation pressures, re-establishing disturbance patterns, and addressing biotic conditions.</td><td>Support complete ecosystem transformation of a site with low or no ecosystem resilience and extensive degradation by addressing abiotic and biotic conditions.</td></tr>
<tr><td>Site Ecosystem Resilience</td><td>High level of ecosystem resilience with low levels of degradation</td><td>Moderate level of ecosystem resilience with moderate levels of degradation</td><td>Very low to no ecosystem resilience—shift in equilibrium state is required</td></tr>
<tr><td rowspan="4">Types of management activities</td><td colspan="3">End or limit continued degradation: Eliminate or adjust grazing, remove contamination sources, stop timber harvest, retire agricultural land, restrict water flow, etc.</td></tr>
<tr><td colspan="3">Re-establish natural disturbance patterns: Re-introduce fire, control flooding/drawdown levels, mimic gap dynamics, introduce conservation grazing</td></tr>
<tr><td rowspan="2"></td><td>Biotic modification: Modify plant community composition through invasive species control and/or seeding or planting</td><td>Biotic modification: Re-establish native plant community over a major portion of the site.</td></tr>
<tr><td></td><td>Abiotic modification: Remediate physical or chemical site conditions, such as reshaping water courses, erosion control, nutrient reduction, etc.</td></tr>
<tr><td>Benefits</td><td>Fewer resources needed. Allows natural processes to take place and determine ecological trajectory (rather than human choices).</td><td>Speeds up succession process while still working with the remaining resilience in the system. Reduced risk of investment as it is not a full transformation.</td><td>Addresses problematic natural areas, so there is a lasting shift to a desirable condition.</td></tr>
<tr><td>Tradeoffs</td><td>Potentially slow, years- or decades-long process (depending on time to maturity of dominant vegetation).</td><td>Can potentially be resource-intensive, depending on ongoing management needs.</td><td>Resource intensive. Extensive site transformation can be challenging for the public to understand while in progress. Can potentially be high risk investment if the restoration is not successful.</td></tr>
</table>

Resilience-based site assessments offer an approach to predict how certain restoration interventions could support ecosystem recovery. Ecosystems with high resilience can recover adequately with minimal interventions (natural restoration) while ecosystems with moderate resilience may need more and greater interventions (assisted restoration). Additionally, some ecosystems have entered an alternate stable state—those sites resisting restoration interventions in favor of this altered state. The alternate stable state sites require extensive interventions to overcome certain thresholds to move towards the desired state and re-build that ecosystem resilience (reconstructive restoration).

Site Assessment Tool Development

To understand the factors involved in developing a resilience-based site assessment tool, I examined the literature and precedent examples of site assessments and resilience indicators. The purpose of this exercise was not to start from scratch, but to incorporate elements of existing tools and tailor tool development to the needs of Washington County. Many resources served as inspiration and direct sources that influenced the development of this tool (see table 2).

TABLE 2. SOURCES THAT INFLUENCED TOOL DEVELOPMENT

Resource	Citation	Influence
A Resilience-Based Site Assessment Tool for Oak Savanna Restoration Practice	(Chein 2020)	Precedent example, tool approach, oak savanna indicators
Wetland Resilience Calculator	(MN Board of Water and Soil Resources, unpublished)	Precedent example, tool approach, wetland indicators
Rapid Floristic Quality Assessment Manual	(Bourdaghs 2014)	Site assessment protocols
Minnesota Wetland Restoration Guide	(Wenzel and Shaw 2012)	Wetland indicators
Ecological Landscape Planning & Management	(Shaw and Stolpestad, unpublished)	Site assessment protocols
Community Description Worksheet	(Montgomery RA, unpublished)	Site visit worksheets
Cost-Estimation for Landscape-Scale Restoration Planning in the Upper Midwest, U.S.	(Phillips-Mao et al. 2015)	Cost estimation approach

These sources and the cited literature aided the development of Table 1—the passive to active continuum—in an effort to explore the different levels of passive and active restoration and their associated management activities, benefits, and tradeoffs. This foundation allowed us to facilitate discussions with the restoration management professionals at Washington County to understand their approach to restoration and how different levels of restoration effort are related to restoration planning on incoming land acquisitions.

To explore the site assessment process, I conducted site visits to experience first-hand how this tool would be used. In summer of 2023, I visited twelve sites at three parks: Lake Elmo Park Reserve, Pine Point Regional Park, and Big Marine Park Reserve. The sites represented different ecosystem types, including upland prairie, oak savanna, deciduous forest, and palustrine wetlands, and had varying levels of ecosystem resilience. The site visits enabled me to understand how on-site observations can inform predictions about ecosystem resilience and the degree of restoration effort needed. Throughout protocol development, the site visits continued to reinforce how resilience indicators need to be observable, easily quantifiable, and quickly assessed to optimize time on site.

Throughout the development of the protocols and associated worksheets, there were regular check-ins to gather valuable feedback from restoration professionals about the resilience indicators, their metrics, and the process for which to observe and record them. A site visit in early November offered a chance to pilot test the entire process on a recent 80-acre land acquisition at Big Marine Park Reserve. This pilot test was encouraging for many parts of the protocols and led to some crucial adjustments to the site visit and summary worksheets.

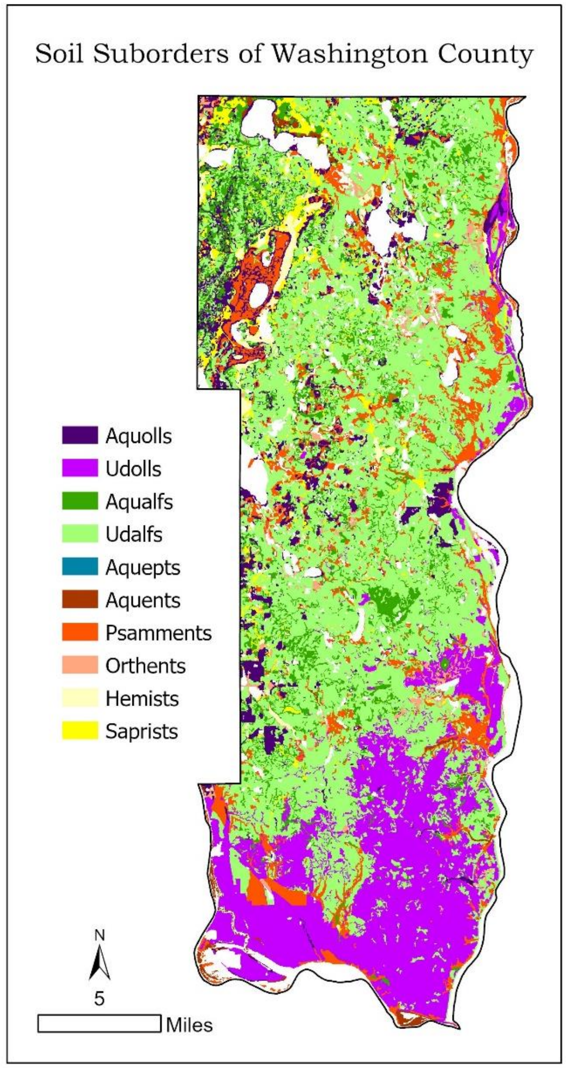
Soils, Plants, and Ecosystem Resilience Indicators

Soils and Native Plant Communities in Washington County

Soil types are related to native plant communities, co-evolving over time to create clearly defined relationships. By examining soil, we can generally understand which types of ecosystems were historically present, and which ones, if restored, could thrive again. Specific characteristics of soil that help determine these relationships are soil order and suborder, fertility, texture, and drainage, which can be found on Web Soil Survey, an online map of soil types and related information administered by the Natural Resources Conservation Service.

Washington County sits in the transition zone between the prairies of the West and the broadleaf forests of the East, making prairie, broadleaf forest, and the transitional oak savanna plant communities most common (Wendt and Coffin 1988). The soil types formed under these plant communities are distinct. Mollisols are formed under prairies and savannas, developing their thick mollic epipedon with the support of deeply and finely rooted prairie perennial forbs and grasses (Weil and Brady 2017). Udolls, a suborder of Mollisols, dominate the southern portion of the county (see Figure 2), indicating that prairies and savannas have long been present in those areas. Alfisols are formed under deciduous forests, their Bt horizons developing illuvial accumulation of clay (Weil and Brady 2017). Udalfs, a suborder of Alfisols, dominate the northern three-quarters of the county, indicating that deciduous forests have long been present in those areas. In areas that have poor drainage, swamps, marshes, and fens have formed, each with their own accompanying plant communities. The soil under these wetlands may be Histosols—organic soil—or they may be poorly drained soils from

Figure 2: Soil suborders in Washington Co., reconstructed from Web Soil Survey data (Soil Survey Staff, NRCS; Minnesota DNR, County boundaries)



other soil orders. Hemists and saprists, suborders of Histosols, as well as other poorly drained soils, suborders starting with "Aq-," are scattered throughout Washington County.

Ecosystem Types and their Resilience Indicators

This section describes each ecosystem and the resilience indicators that help determine the level of resilience that remains in a site. Descriptive tables with all resilience indicators and their associated metrics are included in the protocol worksheets in Appendix B. The protocols for observing and documenting these resilience indicators will be described in the next section and are shared in Appendix A.

Upland Prairie

Upland prairies are graminoid- and forb-dominated ecosystems that have evolved to thrive with frequent fire disturbances at less than 10-year intervals (Minnesota DNR 2005). Prairies typically exist in areas where annual rainfall is less than the annual evapotranspiration—drier climatic conditions. The soil order associated with prairies is Mollisols, and the specific type of upland prairie is closely correlated with soil moisture (Minnesota DNR 2005). Prairie plant diversity spans multiple functional groups, including "nitrogen-fixing legumes, warm- and cool-season grasses, and early- and late-flowering forbs" (Tester et al. 2020). Typical graminoids include big bluestem (*Andropogon gerardii*), prairie dropseed (*Sporobolus heterlepis*), little bluestem (*Schizarchyrium coparium*), Indian grass (*Sorghastrum nutans*), side oats grama (*Bouteloua curtipenduala*), and porcupine grass (*Hesperostipa spartea*). Forb species are extremely diverse and, in some cases, can reach co-dominance with the graminoids. Some woody species persist, and are typically low-growing semi-shrubs, including leadplant (*Amorpha canescens*) and prairie rose (*Rosa arkansana*). Trees and shrubs may be present in low abundances (Minnesota DNR 2005).

Positive resilience indicators for prairie include native vegetative cover, native seed bank, native propagule source from adjacent sites, and fire-adapted species presence. Negative resilience indicators include non-native vegetative cover, non-native seed bank, weedy propagule source from adjacent sites, shrub and canopy cover, weedy pressure from adjacent sites, over-grazing, and soil compaction and erosion. Figure 3 provides image examples of prairie sites with different levels of ecosystem resilience. See the Prairie Worksheet in Appendix B for the resilience indicator metrics and how these indicators are related to differing levels of resilience.

FIGURE 3. IMAGES OF PRAIRIE SITES

These images show prairie sites with different levels of resilience. The high resilience site has a high diversity of forbs grasses. The medium resilience site is an old farm field with annual weeds. The low resilience site is dominated by smooth brome (image courtesy of Chayka K).

Oak Savanna

Oak savannas are categorized within the upland prairie system but demonstrate distinctive qualities from prairies. They are dominated by graminoid and forb species, and they support patches of shrubs and oak canopy (Minnesota DNR 2005). While savannas are also fire-dependent ecosystems, they thrive in areas where fire intensity and frequency are less than is typical of prairies, such as on north-facing slopes, along rivers, or in wetlands (Tester et al. 2020). This reduced level of disturbance allows some fire-tolerant trees and shrubs to persist. Savannas have a similar typical graminoid and forb species to prairies. However, woody plants of savannas are more likely than prairies to feature American hazelnut (*Corylus americana*), smooth sumac (*Rhus glabra*), or quaking aspen (*Populus tremuloides*). The namesake oak trees—often bur oak (*Quercus macrocarpa*) and northern pin oak (*Quercus ellipsoidalis*)—dominate the tree canopy layer (Minnesota DNR 2005).

Positive resilience indicators include oak tree presence and seedling regeneration, native understory cover, native propagule source from adjacent sites, and fire-adapted species presence. Negative resilience indicators include non-oak canopy cover, presence of oak wilt disease, non-native- or shrub-dominated understory, weed pressure from adjacent sites, and soil compaction and erosion. See the Savanna Worksheet in Appendix B for the resilience indicator metrics and how these indicators are related to differing levels of resilience.

Deciduous Forest (Mesic Hardwood)

Mesic hardwood plant communities have steady access to water and nutrients and occur in areas where wildfires are infrequent (Minnesota DNR 2005). Soils belong to the order Alfisols and are relatively fertile, have a medium-dark A-horizon, and are topped with a thin layer of organic matter called duff. Disturbances in this plant community often occur as events that form canopy gaps, such as small-scale windthrows or disease infections like emerald ash borer. The dominant plants are deciduous trees that create a thick canopy in the summer months and lose their leaves in the winter months. Common trees include sugar maple (*Acer saccharum*), basswood (*Tilia americana*), northern red oak (*Quercus rubra*), American elm (*Ulmus americana*), aspen (*Populus tremuloides*), and paper birch (*Betula papyrifera*) (Minnesota DNR 2005). A shade-tolerant shrub and understory layer includes tree saplings and species like ironwood (*Ostrya virginiana*), leatherwood (*Dirca palustris*), box elder (*Acer negundo*), and pagoda dogwood (*Cornus alternifolia*). An herbaceous layer is adapted to low light levels and is abundant in diversity, including ferns and fern allies, spring ephemerals, and sedges (Minnesota DNR 2005).

Positive resilience indicators for deciduous forest include mixed age and diverse native canopy cover, native shade-adapted understory and herbaceous layers, tree seedling regeneration, native propagule source from adjacent sites, gap disturbance dynamics, and a duff layer. Negative resilience indicators include non-native species presence in canopy, understory, and herbaceous layers, weed pressure from adjacent sites, grazing or logging, and soil compaction and erosion. Figure 4 provides image examples of deciduous woodland sites with different levels of ecosystem resilience. See the Forest Worksheet in Appendix B for the resilience indicator metrics and how these indicators are related to differing levels of resilience.

FIGURE 4. IMAGES OF DECIDUOUS WOODLAND SITES

These images show deciduous woodland sites with different levels of resilience. The high resilience site has a high diversity and mixed aged canopy with native ground cover. The medium resilience site has a large canopy gap that is dominated by annual weeds. The low resilience site has a shrub layer overgrown with invasive species.

Palustrine Wetland (Marshes and Meadows)

Palustrine wetlands common in Washington County include deep marshes, shallow marshes, and sedge meadows, occurring mostly as isolated depressions in rolling terrain (Wovcha et al. 1995). Hydrology is the driving force in wetlands—they form in poorly drained soils and experience water saturation that may be permanent, seasonal, or periodic (Tester et al. 2020). Deep marshes typically have a permanent water depth between 6-36 inches (15-90 cm) throughout the whole growing season in most years, while shallow marshes typically have a seasonal water depth up to six inches (15 cm), losing the standing water during the second half of the growing season (Eggers and Reed 2015). Sedge meadows have consistently saturated soils and may experience only brief, periodic inundations (Eggers and Reed 2015).

Vegetation that exists in wetlands is uniquely suited to survive in wet conditions, and the varied hydrological regimes of different wetlands determine which plant communities can grow. Permanently and seasonally inundated wetlands support deep and shallow marshes, which consist of emergent aquatic, floating leaved, and submergent plants (Eggers and Reed 2015), such as cattails (*Typha* spp.), bulrushes, and arrowheads (Minnesota DNR 2005). Briefly inundated wetlands with saturated soils can support sedge meadows, which consist primarily of sedges (*Carex* spp.) (Eggers and Reed 2015).

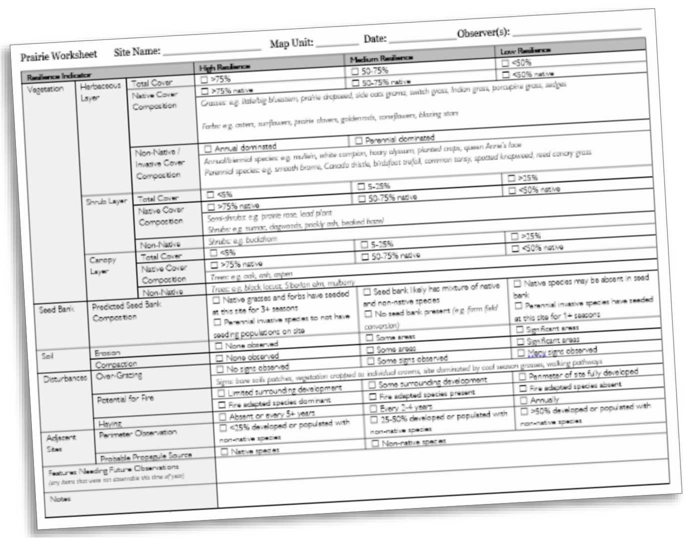
Because wetlands occupy depressional landforms, these different kinds of wetland environments typically form bands, or zones, that correspond to changes in elevation and ponding depth and duration. The uppermost zones are sedge meadows, which surround shallow marsh, if the wetland extends to this depth. Deep marsh occupies the central, low elevation portions of wetlands that are persistently ponded. (Tester et al. 2020). This pattern is observable based on the plant communities present in each zone and the succession of water from saturated soils to shallow depth to deep zones of inundation.

Positive resilience indicators for wetlands include wetland boundaries within the site's boundaries, native seed bank, native vegetative cover, native propagule source from adjacent (namely, upstream) sites, wetland buffers, and Histosol soil order or Aquic soils. Negative resilience indicators include altered water inputs and outputs, weedy seed bank, non-native vegetative cover, weed pressure from adjacent sites, and soil erosion and sedimentation. See the Wetland Worksheet in Appendix B for the resilience indicator metrics and how these indicators are related to differing levels of resilience.

Site Assessment Protocols Description

The site assessment procedure includes a pre-site visit investigation, a site visit, and a post-site visit synthesis. At the end of this process, the goal is to determine the level of ecosystem resilience that remains on the sites within the land acquisition and therefore the degree of restoration intervention needed in restoration.

The pre-site visit investigation is meant to explore maps, aerial imagery, soils, and land use history to determine current and historic vegetation, identify potential opportunities and stressors affecting resilience, and prepare materials for the site visit. The site visit is intended to help document the current vegetation and soil conditions and record metrics of the factors that influence ecosystem resilience. Figure 5 offers an example of the on-site worksheet for assessing prairie ecosystems. Finally, the post-site visit procedure helps to synthesize information gathered and observed in order to establish the level of ecosystem resilience and the degree of restoration intervention needed to restore the site. Refer to Appendix A to read the full protocols and Appendix B to view the associated worksheets.


Prairie Worksheet Site Name: ______ Map Unit: ______ Date: ______ Observer(s): ______

Resilience Indicator			High Resilience	Medium Resilience	Low Resilience
Vegetation	Herbaceous Layer	Total Cover	☐ >75%	☐ 50-75%	☐ <50%
		Native Cover Composition	☐ >75% native	☐ 50-75% native	☐ <50% native
			Grasses: e.g. little/big bluestem, prairie dropseed, side oats grama, switch grass, Indian grass, porcupine grass, sedges		
			Forbs: e.g. asters, sunflowers, prairie clovers, goldenrods, coneflowers, blazing stars		
		Non-Native / Invasive Cover Composition	☐ Annual dominated	☐ Perennial dominated	
			Annual/biennial species: e.g. mullein, white campion, hoary alyssum, planted crops, queen Anne's lace		
			Perennial species: e.g. smooth brome, Canada thistle, birdsfoot trefoil, common tansy, spotted knapweed, reed canary grass		
	Shrub Layer	Total Cover	☐ <5%	☐ 5-25%	☐ >25%
		Native Cover Composition	☐ >75% native	☐ 50-75% native	☐ <50% native
			Semi-shrubs: e.g. prairie rose, lead plant		
			Shrubs: e.g. sumac, dogwoods, prickly ash, beaked hazel		
		Non-Native	Shrubs: e.g. buckthorn		
	Canopy Layer	Total Cover	☐ <5%	☐ 5-25%	☐ >25%
		Native Cover Composition	☐ >75% native	☐ 50-75% native	☐ <50% native
			Trees: e.g. oak, ash, aspen		
		Non-Native	Trees: e.g. black locust, Siberian elm, mulberry		
Seed Bank	Predicted Seed Bank Composition		☐ Native grasses and forbs have seeded at this site for 3+ seasons ☐ Perennial invasive species to not have seeding populations on site	☐ Seed bank likely has mixture of native and non-native species ☐ No seed bank present (e.g. farm field conversion)	☐ Native species may be absent in seed bank ☐ Perennial invasive species have seeded at this site for 1+ seasons
Soil	Erosion		☐ None observed	☐ Some areas	☐ Significant areas
	Compaction		☐ None observed	☐ Some areas	☐ Significant areas
Disturbances	Over-Grazing		☐ No signs observed	☐ Some signs observed	☐ Many signs observed
			Signs: bare soils patches, vegetation cropped to individual crowns, site dominated by cool season grasses, walking pathways		
	Potential for Fire		☐ Limited surrounding development ☐ Fire adapted species dominant	☐ Some surrounding development ☐ Fire adapted species present	☐ Perimeter of site fully developed ☐ Fire adapted species absent
	Haying		☐ Absent or every 5+ years	☐ Every 2-4 years	☐ Annually
Adjacent Sites	Perimeter Observation		☐ <25% developed or populated with non-native species	☐ 25-50% developed or populated with non-native species	☐ >50% developed or populated with non-native species
	Probable Propagule Source		☐ Native species	☐ Non-native species	
Features Needing Future Observations (any items that were not observable this time of year)					
Notes					

Figure 5. Site visit worksheet example

Discussion

This capstone project resulted in a resilience-based site assessment tool that incorporates sound ecological principles with concise protocols. This tool organizes a complex assessment into a standardized process—a pre-site visit investigation, site visit, and post-site visit summary. It will be utilized by natural resource managers in Washington County to systematically assess land acquisitions and to predict resource needs for restoration at these sites—the two major goals highlighted at the inception of this project.

This tool has broad applications for natural resource managers in Washington County and beyond. It focuses on four commonly found ecosystems in the county and in the greater Twin Cities area: upland prairie, oak savanna, deciduous forest, and palustrine wetlands. By utilizing this tool, the natural resources team can gain valuable insights into new land acquisition sites in a coordinated manner by examining land use history, soil, and hydrology and by observing specific site conditions. These observations and their associated ecological resilience metrics help to determine the site's ecological resilience, which is correlated with the degree of resources needed for restoration—natural restoration, assisted restoration, or reconstructive restoration. Knowing the resource needs will help land managers to prioritize restoration efforts across sites and allocate limited resources accordingly.

A major strength of the tool is that it can be used by restoration professionals who have had many years of experience and by interns or professionals newer to the field. Throughout tool development, many choices were made to support this goal, such as ensuring ecological resilience indicators are readily observable, clearly connecting those observations to resilience levels, and outlining succinct protocols with supporting resources, if needed. The universal user approach is beneficial, so interns and seasonal staff can support assessment efforts, and similar conclusions about ecological resilience can be drawn no matter how much restoration experience the user has.

Another strength of this tool is the standardized approach to organizing and interpreting data and observations. The worksheets enable the user to uniformly document a considerable amount of information, including vegetation, hydrology, soils, disturbances, and other site conditions. The arrangement of this data supports quick interpretation to determine the site's level of ecological resilience. By then translating this data into a color-coded map, the data becomes spatially tied, illustrating ecological resilience across many sites and adding an additional layer of interpretation to guide decision-making.

Two principal opportunities for the future development of this tool include validation and testing as well as digitization. Validation and testing of this site assessment tool would involve deploying the tool with multiple people across many sites. Comparisons could be made within and among sites to see how the tool performs by user and by ecosystem type. Results of these comparisons would inform refinement of the protocols and resilience indicator metrics. Digitization of the tool would involve translating the current, analog version of this tool into a pdf, app, or web-based format. A digital format would support smoother transitions between the office and the field, a more spatially integrated approach, and a simpler long-term data storage solution.

As land acquisitions are added to the parks system in Washington County, natural resource managers now have a systematic tool to assess the resilience of the ecosystems within to predict the degree of resources needed to restore the sites. The valuable insights offered by the tool will aid in natural resource planning to allocate resources accordingly to maximize ecological restoration efforts.

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Site Assessment Protocols

Introduction

This set of procedures and associated worksheets guides a restoration professional, staff member, or intern through the steps needed to fully explore and gather insights about a land acquisition site. The process includes a pre-site visit investigation, a site visit, and a post-site visit summary. At the end of this process, the goal is to determine the level of ecosystem resilience that remains on the site, and therefore the degree of restoration intervention needed to restore the site.

Pre-Site Visit Investigation Protocol

The goal of this investigation is to examine the map, aerial images, and history of the site to determine which ecosystem type(s) should most likely be on this site and which on- and off-site pressures affect the resilience of the ecosystem. It will also prepare materials for the site visit and highlight features of interest that need additional examination in the field.

- *Estimated duration:* 45-75 minutes
- *Materials required:* Computer with internet access and a printer

Step 1: Create maps of the site and surrounding areas

Find the land acquisition site on the County GIS website (link). Select the most recent aerial photography as the base map. Define the boundaries of the land acquisition site by selecting parcels or by using drawing tools. For the following exploration, you may choose to utilize the online GIS platform to annotate the map. Or you may choose to export and print the maps first and annotate them on paper. One map should be zoomed in to the extent of the site and one map zoomed out one mile to obtain a landscape context.

First, examine the site map for vegetation coverage—different zones indicated by trees, shrubs, crops, turf, etc. Sketch and label map units within the site based primarily on these vegetation cover types. The map units correspond to specific site visit protocols. These map units can be refined as more is learned about soils, hydrology, and human development.

Inspect the map for notable features that are or could be an indication of human-caused change (buildings, roads, trails, driveways, etc.) and of hydrology (faint lines indicating drain tiles, ditching, berms, standing water, etc.). These features help determine factors that affect restoration, such as compacted soil and altered hydrological regimes. Mark and label these places on the map, indicating locations that should be explored during the site visit.

Second, examine the site landscape context map for vegetation coverage and other features. On the site's borders, highlight areas that are natural vs. developed. Label potential habitat patches or corridors as well as land uses that may impact the site, such as farming (pesticides, erosion) or roads (salt). These contextual items help determine potential native propagule sources, weed pressures, or other site stressors.

Step 2: Explore soil and hydrology data

Determine basic soil and hydrology characteristics present on site to determine ecosystem types and wetland history by creating a soil report through Web Soil Survey (link). If you need a primer on how to use Web Soil Survey, visit this website (link). Create an area of interest for the site that matches the site's boundaries. Save the area of interest for future use. Under Soil Data Explorer, find each of the following items. Click "View Rating" within the toolbar, then "Add to Shopping Cart" in the upper right corner.

- Soil order: Find under Suitability and Limitations for Use > Land Classifications > Soil Taxonomy Order. The soil orders are closely related to which plant communities historically were on the site and could thrive on the site now.
- Texture: Find under Soil Properties and Qualities > Soil Physical Properties > Surface Texture. The surface texture dictates many soil properties, including water infiltration and holding capacity, fertility, erosion potential, etc.
- Hydrologic conditions: Multiple characteristics define hydrologic conditions. The following characteristics can help distinguish upland from wetland areas.
    - Soil moisture: Find under Suitabilities and Limitations for Use > Land Classifications > Soil Moisture Class.
    - Hydric rating: Find under Suitabilities and Limitations for Use> Land Classifications > Hydric Rating for Map Unit.
    - Drainage class: Find under Soil Properties and Qualities > Soil Qualities and Features > Drainage class.
    - Depth to water table: Find under Soil Properties and Qualities > Water Features > Depth to Water Table.

After these items are added to the shopping cart, go to the "shopping cart" tab and "check out" (it is free). It will allow you to either download the report immediately, or it may email it to you. Save the soil report in the project folder.

Open the soil report to summarize the information by using the associated pre-site visit worksheet to document the findings for each map unit. Based on this additional information, adjust the map units accordingly (e.g., if soils indicate a wetland should be present, but it was not discernable based on land cover). Use Figure A-1 to aid in choosing which ecosystem type is appropriate for each map unit.

Step 3: Investigate site history

The site's history influences its current ecological resilience. This segment of the investigation can help to clarify less obvious features that influence resilience, such as hydrological alterations, seed bank, and disturbance history. Compare the site map and landscape context map with historical aerial photos. Visit the DNR's Landview website (link), the Borchert map library (link), or MnGeo's web map service (link) and find the site location and surrounding area. Inspect two to four background layers imagery or historic air photos from different time periods for evidence of human disturbance and changes in natural features. Pay special attention to any significant changes and their timeline. Notable features might include the following:

- Vegetation coverage: What was the historical vegetation? What changes took place and when? Changes might include logging, farming, grazing, or natural disturbances like wind throw, flooding, or fire.
    - If site was farmed: How many years in production? What crops were produced? Did the field ever sit fallow for any seasons? If so, when? What was the pesticide use? How recently?
- Development: What have humans built over time? Features such as road construction, residential development, added impervious surfaces, etc.
- Hydrological changes: Faint lines that may indicate drain tiles or ditching, berms were installed, standing water changes shape, etc.

While aerial photography can offer a lot of information about a site's history, additional sources can be reviewed as time allows and as specific questions need to be answered. Additional sources that can help illustrate site history include:

- Ownership history: Knowing the ownership history can help clarify some human development questions or other relevant details.
- Landowner or neighbor conversations: If possible, it may be helpful to have a conversation with a previous landowner or neighbors to help fill in the gaps regarding human development, farming and grazing practices, problematic invasive species, or other relevant details.
- County Biological Survey maps: This map delineates natural communities and rare species that may be present on the site or nearby.

Document the site history findings on the pre-site visit worksheet.

Step 4: Prepare for site visit

After exploring the site maps, soils data, aerial photos, and site history, determine map units, highlight features to visit in the field, and prepare for the site visit.

- Finalize map units: Adjust map units based on information gathered, ensuring homogenous units are based on soils, site history, hydrology, and vegetative cover. Determine which ecosystem type is most likely appropriate for restoration for each map unit by using Figure A-1 as an aid.
- Indicate features to visit: On the map, mark and label features that need further examination in the field. On the worksheet, label and describe those features and what needs to be determined on site.
- Prepare worksheets: Print the appropriate ecosystem type site visit worksheets and pre-fill the header fields. Be sure to have extra worksheets of each ecosystem type to use if the site visit observations add or alter map units.
- Plan site visit route: Sketch a site visit route on the map based on the map units, site boundaries, and significant features.

Site Visit Protocol

The goal of the site visit is to document native and non-native vegetation composition and coverage, confirm soil and hydrology information, visit site features elucidated during the pre-site visit investigation, and record significant factors that may influence ecosystem resilience.

- *Estimated duration:* Time on site depends on site size. A two-hour site visit is estimated to cover a site with approximately five map units and up to 20 acres.
- *Timing:* The time of year affects what is observable on site. Consider conducting site visits from late spring to fall and in weather that enables an appropriately paced visit and note-taking.
- *Materials required:* Printed site maps, printed site visit worksheets (with extras of each type), clipboard and pencil/pen, phone or tablet with GIS app for notes (i.e., Avenza), plant identification resources, and hand soil core sampling tool

Meander and document observations

Follow the site visit route plan and adjust as needed based on site conditions. Visit each map unit and feature to make observations and, if possible, take soil cores to verify what was downloaded from Web Soil Survey. Document findings on the worksheets, on the maps, with pictures, and potentially in a GIS application (like Avenza).

When completing the site visit worksheets for each map unit, follow the prompts and check the boxes based on your observations. For plant species, circle and write in the plant species that are present. Note that some resilience indicators may not be observable at the time of the site visit, so feel free to leave that item blank and make a note that it needs to be observed at a different time of year.

At the end of the site visit, be sure to have the following items:

- Site map with additional notes and adjustments to map units, as needed
- Completed ecosystem type worksheets
- Location-based notes about significant observations related to vegetation, soil, hydrology, or other features that were not captured by the map or worksheets
- Pictures from within each map unit

Post-Site Visit Summary Protocol

The goal of this protocol is to synthesize information gathered and observed in order to establish the level of ecosystem resilience and therefore the degree of restoration intervention needed to restore the site. Additionally, this summary will be documented to ensure the assessment remains available and can be revisited in the future.

- *Estimated time:* 15-30 minutes
- *Materials required:* All notes and completed worksheets, computer

Use the post-site visit worksheet to create a summary. For each map unit, assign a resilience level and restoration approach (high resilience = natural restoration; medium resilience = assisted restoration; low resilience = reconstructive restoration). These assignments will be based on the documented resilience indicator metrics and may incorporate the restoration professional's working knowledge and experience. In general, a site's resilience will likely correlate with the resilience category with the greatest number of indicator metrics observed. However, some sites may display metrics from all three resilience categories. The restoration professional should use their best judgement when assigning resilience categories and restoration approaches to map units. After these are assigned, document the likely restoration interventions needed, any remaining questions, and final notes about each map unit.

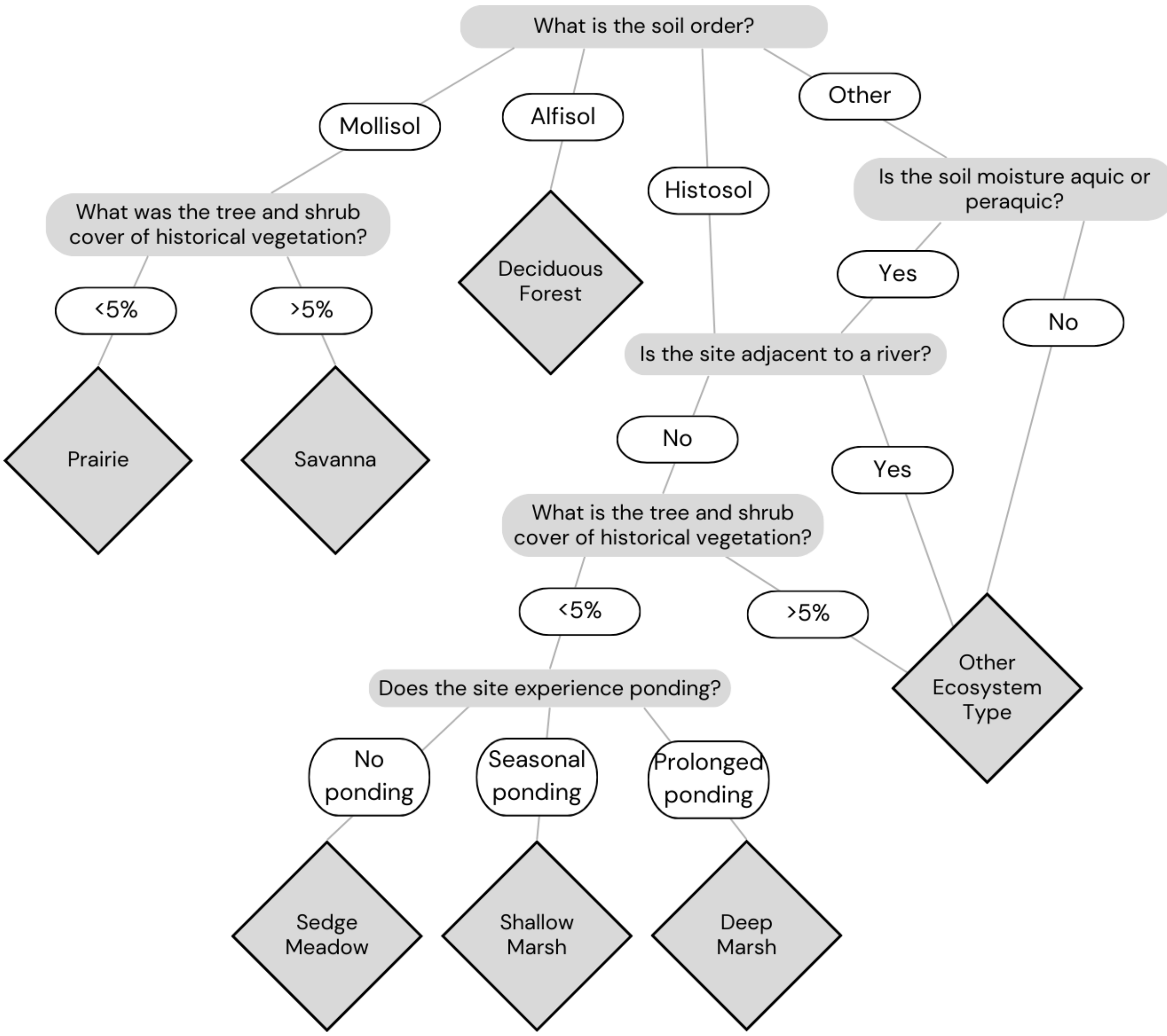
On the site map, highlight each map unit according to the resilience level (high = green; medium = yellow; low = red). This visual representation of ecological resilience can help reveal patterns across the sites and perhaps help prioritize high value areas for restoration.

Upload and save all notes, maps, and completed worksheets.

Link URLs

- County GIS website: https://www.arcgis.com/apps/webappviewer/index.html?id=c07b8931249b47be81278a79103bd698
- Web Soil Survey: https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx
- Web Soil Survey tutorial: https://www.nrcs.usda.gov/conservation-basics/natural-resource-concerns/soils/getting-started-with-web-soil-survey
- DNR Landview: https://www.dnr.state.mn.us/maps/landview/index.html
- Historical aerials from Borchert Map Library: https://apps.lib.umn.edu/mhapo/
- MnGeo's web map service: https://www.mngeo.state.mn.us/chouse/wms/geo_image_server_agol.html

FIGURE A-1. DECISION TREE TO DETERMINE POTENTIAL ECOSYSTEM FOR DEGRADED OR CONVERTED SITES



Appendix B

Pre-Site Visit Worksheet Site Name: ________________ Date: ________________ Investigator(s): ________________________

Map unit	Current vegetation	Soil order	Hydrology	Site history & human-caused changes	Current or potential ecosystem type	Features to visit in map unit *(e.g., 1: possible drain tile; 2: check soil compaction)*
	☐ Trees ☐ Shrubs ☐ Herbaceous ☐ Crops ☐ Turf ☐ Impervious ☐ Other: __________	☐ Mollisol ☐ Alfisol ☐ Histosol ☐ Other: ________	*Soil moisture:* ☐ Aquic or peraquic *Hydric rating:* ☐ 100% or 66-99% *Drainage class:* ☐ sub-aqueous ☐ very/poorly drained *Depth to water table:* ☐ 0-25cm/25-50cm	☐ Compaction ☐ Erosion ☐ Altered hydrology ☐ Wetland drained *when?:* __________ ☐ Farmed *when?:* __________ ☐ Native seed bank	☐ Prairie ☐ Savanna ☐ Deciduous forest ☐ Deep marsh ☐ Shallow marsh ☐ Sedge meadow ☐ Other	
	☐ Trees ☐ Shrubs ☐ Herbaceous ☐ Crops ☐ Turf ☐ Impervious ☐ Other: __________	☐ Mollisol ☐ Alfisol ☐ Histosol ☐ Other: ________	*Soil moisture:* ☐ Aquic or peraquic *Hydric rating:* ☐ 100% or 66-99% *Drainage class:* ☐ sub-aqueous ☐ very/poorly drained *Depth to water table:* ☐ 0-25cm/25-50cm	☐ Compaction ☐ Erosion ☐ Altered hydrology ☐ Wetland drained *when?:* __________ ☐ Farmed *when?:* __________ ☐ Native seed bank	☐ Prairie ☐ Savanna ☐ Deciduous forest ☐ Deep marsh ☐ Shallow marsh ☐ Sedge meadow ☐ Other	
	☐ Trees ☐ Shrubs ☐ Herbaceous ☐ Crops ☐ Turf ☐ Impervious ☐ Other: __________	☐ Mollisol ☐ Alfisol ☐ Histosol ☐ Other: ________	*Soil moisture:* ☐ Aquic or peraquic *Hydric rating:* ☐ 100% or 66-99% *Drainage class:* ☐ sub-aqueous ☐ very/poorly drained *Depth to water table:* ☐ 0-25cm/25-50cm	☐ Compaction ☐ Erosion ☐ Altered hydrology ☐ Wetland drained *when?:* __________ ☐ Farmed *when?:* __________ ☐ Native seed bank	☐ Prairie ☐ Savanna ☐ Deciduous forest ☐ Deep marsh ☐ Shallow marsh ☐ Sedge meadow ☐ Other	
	☐ Trees ☐ Shrubs ☐ Herbaceous ☐ Crops ☐ Turf ☐ Impervious ☐ Other: __________	☐ Mollisol ☐ Alfisol ☐ Histosol ☐ Other: ________	*Soil moisture:* ☐ Aquic or peraquic *Hydric rating:* ☐ 100% or 66-99% *Drainage class:* ☐ sub-aqueous ☐ very/poorly drained *Depth to water table:* ☐ 0-25cm/25-50cm	☐ Compaction ☐ Erosion ☐ Altered hydrology ☐ Wetland drained *when?:* __________ ☐ Farmed *when?:* __________ ☐ Native seed bank	☐ Prairie ☐ Savanna ☐ Deciduous forest ☐ Deep marsh ☐ Shallow marsh ☐ Sedge meadow ☐ Other	

Appendix B

Prairie Worksheet Site Name: ___________________ Map Unit: ________ Date: _____________ Observer(s): ___________________________

Resilience Indicator			High Resilience	Medium Resilience	Low Resilience
Vegetation	Herbaceous Layer	Total Cover	☐ >75%	☐ 50-75%	☐ <50%
		Native Cover Composition	☐ >75% native	☐ 50-75% native	☐ <50% native
			Grasses: e.g., little/big bluestem, prairie dropseed, side oats grama, June grass, switch grass, Indian grass, porcupine grass, sedges *Forbs: e.g., asters, sunflowers, prairie clovers, goldenrods, coneflowers, blazing stars*		
		Non-Native / Invasive Cover Composition	☐ Annual dominated	☐ Perennial dominated	
			Annual/biennial species: e.g., mullein, white campion, hoary alyssum, planted crops, queen Anne's lace *Perennial species: e.g., smooth brome, Canada thistle, birdsfoot trefoil, common tansy, spotted knapweed, reed canary grass*		
	Shrub Layer	Total Cover	☐ <5%	☐ 5-25%	☐ >25%
		Native Cover Composition	☐ >75% native	☐ 50-75% native	☐ <50% native
			Semi-shrubs: e.g., prairie rose, lead plant *Shrubs: e.g., sumac, dogwoods, prickly ash, beaked hazel*		
		Non-Native	*Shrubs: e.g., buckthorn*		
	Canopy Layer	Total Cover	☐ <5%	☐ 5-25%	☐ >25%
		Native Cover Composition	☐ >75% native	☐ 50-75% native	☐ <50% native
			Trees: e.g., oak, ash, aspen		
		Non-Native	*Trees: e.g., black locust, Siberian elm, mulberry*		
Seed Bank	Predicted Seed Bank Composition		☐ Native grasses and forbs have seeded at this site for 3+ seasons ☐ Perennial invasive species to not have seeding populations on site	☐ Seed bank likely has mixture of native and non-native species ☐ No seed bank present *(e.g., farm field conversion)*	☐ Native species may be absent in seed bank ☐ Perennial invasive species have seeded at this site for 1+ seasons
Soil	Erosion		☐ None observed	☐ Some areas	☐ Significant areas
	Compaction		☐ None observed	☐ Some areas	☐ Significant areas
Disturbances	Over-Grazing		☐ No signs observed	☐ Some signs observed	☐ Many signs observed
			Signs: bare soils patches, vegetation cropped to individual crowns, site dominated by cool season grasses, walking pathways		
	Potential for Fire		☐ Limited surrounding development	☐ Some surrounding development	☐ Perimeter of site fully developed
			☐ Fire adapted species dominant	☐ Fire adapted species present	☐ Fire adapted species absent
	Haying		☐ Absent or every 5+ years	☐ Every 2-4 years	☐ Annually
Adjacent Sites	Perimeter Observation		☐ <25% developed or populated with non-native species	☐ 25-50% developed or populated with non-native species	☐ >50% developed or populated with non-native species
	Probable Propagule Source		☐ Native species	☐ Non-native species	
Features Needing Future Observations *(any items that were not observable this time of year)*					
Notes					

Savanna Worksheet Site Name: ________________ Map Unit: ________ Date: ____________ Observer(s): ________________________

Resilience Indicator			High Resilience	Medium Resilience	Low Resilience
Vegetation	Herbaceous Layer	Total Cover	☐ >75%	☐ 50-75%	☐ <50%
		Native Cover Composition	☐ >75% native	☐ 50-75% native	☐ <50% native
			Grasses: e.g., little/big bluestem, prairie dropseed, side oats grama, June grass, Indian grass, porcupine grass, sedges *Forbs: e.g., asters, sunflowers, prairie clovers, goldenrods, coneflowers, blazing stars*		
		Non-Native / Invasive Cover Composition	☐ Annual dominated	☐ Perennial dominated	
			Annual/biennial species: e.g., mullein, white campion, hoary alyssum, planted crops, queen Anne's lace *Perennial species: smooth brome, Canada thistle, birdsfoot trefoil, common tansy, spotted knapweed, common toadflax*		
	Shrub Layer	Total Cover	☐ <25%	☐ 25-50%	☐ >50%
		Native Cover Composition	☐ >75% native	☐ 50-75% native	☐ <50% native
			Semi-shrubs: e.g., prairie rose, lead plant *Shrubs: e.g., sumac, dogwoods, prickly ash, beaked hazel*		
		Non-Native	*Shrubs: e.g., buckthorn*		
	Canopy Layer	Total Cover	☐ 5-60%	☐ <5% or >60%	☐ Nearly 0% or nearly 100%
		Native Cover Composition	☐ >50% oak trees	☐ <50% oak trees	☐ Oak trees absent
			Trees: e.g., oak, ash, aspen		
		Non-Native	*Trees: e.g., black locust, Siberian elm, mulberry*		
Oak Regeneration	Oak Seedlings/Saplings		☐ Present	☐ Absent	
	Oak Wilt Disease		☐ Absent on site and adjacent sites	☐ Present on adjacent sites	☐ Present on site
Soil	Erosion		☐ None observed	☐ Some areas	☐ Significant areas
	Compaction		☐ None observed	☐ Some areas	☐ Significant areas
Disturbances	Signs of Over-Grazing		☐ No signs observed	☐ Some signs observed	☐ Many signs observed
			Signs: bare soils patches, vegetation cropped to individual crowns, site dominated by cool season grasses, walking pathways		
	Potential for Fire		☐ Limited surrounding development	☐ Some surrounding development	☐ Perimeter of site fully developed
			☐ Fire adapted species dominant	☐ Fire adapted species present	☐ Fire adapted species absent
	Haying		☐ Absent or every 5+ years	☐ Every 2-4 years	☐ Annually
Adjacent Sites	Perimeter Observation		☐ <25% developed or populated with non-native species	☐ 25-50% developed or populated with non-native species	☐ >50% developed or populated with non-native species
	Probable Propagule Source		☐ Native species	☐ Non-native species	
Features Needing Future Observations *(any items that were not observable this time of year)*					
Notes					

Appendix B

Forest Worksheet Site Name: ____________________ Map Unit: _________ Date: ______________ Observer(s): _____________________________

Resilience Indicator			High Resilience	Medium Resilience	Low Resilience
Vegetation	Herbaceous Layer	Total Cover	☐ >50%	☐ 25-50%	☐ <25%
		Native Cover Composition	☐ >75% native	☐ 50-75% native	☐ <50% native
			☐ Tree seedlings/saplings present	☐ Tree seedlings/saplings absent	
			Herbs: ferns, sedges, spring ephemerals, mosses		
		Non-Native	*Herbs: garlic mustard, motherwort, buckthorn*		
	Shrub / Understory Layer	Total Cover	☐ <25%	☐ 25-50%	☐ >50%
		Native Cover Composition	☐ >75% native	☐ 50-75% native	☐ <50% native
			Shrubs/understory: e.g., gooseberry, chokecherry, bladdernut, elder, ironwood, pagoda dogwood		
		Non-Native	*Shrubs: e.g., buckthorn, Tatarian honeysuckle, winged burning bush, Japanese barberry, amur maple*		
	Canopy Layer	Total Cover	☐ >75%	☐ 50-75%	☐ <50%
		Native Cover Composition	☐ >75% native	☐ 50-75% native	☐ <50% native
			Trees: e.g., maple, basswood, oak, elm, aspen, birch		
		Non-Native	*Trees: e.g., black locust, amur maple, Siberian elm, mulberry*		
Soil	Duff Layer		☐ Thick	☐ Thin	☐ Absent
	Erosion		☐ None observed	☐ Some areas	☐ Significant areas
	Compaction		☐ None observed	☐ Some areas	☐ Significant areas
Disturbances	Signs of Over-Grazing		☐ No signs observed	☐ Some signs observed	☐ Many signs observed
			Signs: bare soils patches, vegetation cropped to individual crowns, site dominated by cool season grasses, walking pathways		
	Gap Dynamics		☐ Canopy gaps present	☐ Canopy gaps absent	
	Logging		☐ Logging mimics gap dynamics	☐ Logging does not mimic gap dynamics	
			Signs: cut stumps visible, clearcut area		
Adjacent Sites	Perimeter Observation		☐ <25% developed or populated with non-native species	☐ 25-50% developed or populated with non-native species	☐ >50% developed or populated with non-native species
	Probable Propagule Source		☐ Native species	☐ Non-native species	
Features Needing Future Observations *(any items that were not observable this time of year)*					
Notes					

Appendix B

Wetland Worksheet Site Name: ___________________ Map Unit: ________ Date: _____________ Observer(s): __________________________

Resilience Indicator			High Resilience	Medium Resilience	Low Resilience
Wetland Type	Deep Marsh	Herbaceous Layer	☐ >75% native	☐ 50-75% native	☐ <50% native
			Native species: e.g., broad-leaved cattail, bulrushes, giant bur-reeds, pickerelweed, pondweeds *Non-native/invasive species: e.g., narrow-leaved or hybrid cattail, purple loosestrife, Phragmites australis (European var.)*		
		Shrub/Canopy	☐ <5% cover	☐ >5% cover	
	Shallow Marsh	Herbaceous Layer	☐ >75% native	☐ 50-75% native	☐ <50% native
			Native species: e.g., broad-leaved cattail, bulrushes, arrowhead, lake sedge, sweet flag *Non-native/invasive species: e.g., narrow-leaved or hybrid cattail, reed canary grass, purple loosestrife, Phragmites australis (European var.)*		
		Shrub/Canopy Layer	☐ <5% cover	☐ 5-25% cover	☐ >25% cover
			Native species: e.g., red osier dogwood, speckled alder, willow (can be aggressive) *Non-native species: e.g., glossy buckthorn*		
	Sedge Meadow	Herbaceous Layer	☐ >75% native	☐ 50-75% native	☐ <50% native
			Native species: e.g., sedges, spike-rushes, bulrushes, nutgrasses, Canada blue-joint grass *Non-native species: e.g., smooth brome, reed canary grass, Phragmites australis (European var.)*		
		Shrub/Canopy Layer	☐ <5% cover	☐ 5-25% cover	☐ >25% cover
			Native species: e.g., dogwoods, willows (can be aggressive) *Non-native species: e.g., glossy buckthorn*		
Hydrology	Alterations		☐ Water inputs not significantly altered	☐ Water inputs altered, but adjustable	☐ Water inputs cannot be adjusted
			☐ Water outputs altered, but can be adjusted on site		☐ Water outputs cannot be adjusted
			Signs of alterations: water inlet or outlet infrastructure, ditching, drain tiling, earthen berms		
	Wetland Boundaries		☐ Exist within site boundaries	☐ Exist outside of site boundaries	
Seed Bank	Time of Drainage/Cultivation		☐ <20 years ago	☐ >20 years ago	
	Perennial Invasive Species		☐ Seeding populations absent	☐ Seeding populations present on site for 1+ years	
Soil	Erosion/Sedimentation		☐ None observed	☐ Some areas	☐ Significant areas
			Signs: look for evidence from adjacent fields and toe slope soil cores		
Disturbances	Flood/Drought Cycle (Water Level Changes)		☐ Appears typical for wetland type	☐ Appears atypical for wetland type	
			Signs: ponding depth (dependent on rain and time of year), appropriate emergent vegetation, mud flats/bare areas		
	Farming Duration on Site		☐ <5 years	☐ 5-20 years	☐ >20 years ago
Adjacent Sites	Perimeter Observation		☐ <25% developed, in farming, or populated with non-native species	☐ 25-50% developed, in farming, or populated with non-native species	☐ >50% developed, in farming, or populated with non-native species
	Upstream Propagule Source		☐ Native species	☐ Non-native species	
Wetland Buffers	150 Foot Buffer Area Around Wetland		☐ >75% native vegetation	☐ 50-75% perennial vegetation (some impervious surfaces or farmland)	☐ <50% perennial vegetation (a lot of impervious surfaces or farmland)
Features Needing Future Observations *(any items that were not observable this time of year)*					
Notes					

Post-Site Visit Worksheet Site Name: ___________________ Date: __________________ Investigator(s): _______________________________

Map Unit	Level of Resilience	Restoration Approach	Restoration Interventions Needed	Notes / Remaining Questions
	☐ High ☐ Medium ☐ Low	☐ Natural restoration ☐ Assisted restoration ☐ Reconstructive restoration		
	☐ High ☐ Medium ☐ Low	☐ Natural restoration ☐ Assisted restoration ☐ Reconstructive restoration		
	☐ High ☐ Medium ☐ Low	☐ Natural restoration ☐ Assisted restoration ☐ Reconstructive restoration		
	☐ High ☐ Medium ☐ Low	☐ Natural restoration ☐ Assisted restoration ☐ Reconstructive restoration		
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	☐ High ☐ Medium ☐ Low	☐ Natural restoration ☐ Assisted restoration ☐ Reconstructive restoration		
	☐ High ☐ Medium ☐ Low	☐ Natural restoration ☐ Assisted restoration ☐ Reconstructive restoration		
	☐ High ☐ Medium ☐ Low	☐ Natural restoration ☐ Assisted restoration ☐ Reconstructive restoration		

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