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Regional Guidebook for the Functional Assessment of Organic Flats, Slopes, and Depressional Wetlands in the Northcentral and Northeast Region

U.S. Army Corps of Engineers

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Regional Guidebook for the Functional Assessment of Organic Flats, Slopes, and Depressional Wetlands in the Northcentral and Northeast Region

U.S. Army Corps of Engineers

U.S. Army Engineer Research and Development Center
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Final report

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Abstract

The Hydrogeomorphic (HGM) Approach is a method for developing functional indices and the protocols used to apply these indices to the assessment of ecosystem functions at a site-specific scale. The HGM Approach was initially designed to be used in the context of the Clean Water Act Section 404 Regulatory Program permit review to analyze project alternatives, minimize impacts, assess unavoidable impacts, determine mitigation requirements, and monitor the success of compensatory mitigation. However, a variety of other potential uses have been identified, including the determination of minimal effects under the Food Security Act, design of restoration projects, and management of wetlands.

This report uses the HGM Approach to develop a regional guidebook to

- characterize organic flats, slopes, and depressional wetlands with organic soils, known collectively as *peatlands* throughout the Northcentral and Northeast as defined by the Regional Supplements to the Corps of Engineers Wetland Delineation Manual
- provide the rationale used to select functions for the peatland subclass
- provide the rationale used to select assessment variables and metrics
- provide the rationale used to develop assessment indexes
- provide data from reference wetlands and document their use in calibrating assessment variables and functional indices
- outline the necessary protocols for applying the functional indices to the assessment of wetland functions.

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Preface

This work was performed by the U.S. Army Engineer Research and Development Center (ERDC) in cooperation with the U.S. Army Corps of Engineers (USACE) District Office in St. Paul, MN. Funding was provided through the Wetlands Regulatory Assistance Program (WRAP).

This report was prepared by Dr. Brad Cook and Kevin Clement, Minnesota State University, Mankato, MN; Chris V. Noble, Environmental Laboratory, ERDC; Steve Eggers and Tim Smith, St. Paul District, USACE. This guidebook was developed in cooperation with an Assessment Team (A-Team) of experts familiar with peatlands in the Northcentral and Northeast regions of the United States. Much of the discussion in Chapter 4 is taken or modified from *A Regional Guidebook for applying the Hydrogeomorphic Approach to Assessing the Functions of Headwater Slope Wetlands in Mississippi and Alabama Coastal Plains* (Noble et al. 2007) and *Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Northcentral and Northeast Region* (Version 2.0) (USACE 2011).

In addition, the authors are grateful to the following individuals who contributed their time and expertise at one or more team meetings and/or participated in field sampling of reference wetlands: Elizabeth Summers and Jason Pietroski, ERDC; Greg Larson, and Barbara Walther, St. Paul District, USACE; Fei Yuan, Minnesota State University, Mankato, MN.

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At the time this final draft was prepared, Patricia Tuminello was Chief of the Wetlands and Coastal Ecology Branch, EL; Mark Farr was Chief of the Ecosystem Evaluation and Engineering Division, EL; Sally Yost was Program Manager, WRAP; and the Director of the EL was Dr. Elizabeth C. Fleming.

COL Bryan S. Green was the Commander of ERDC. Dr. Jeffery P. Holland was Director.

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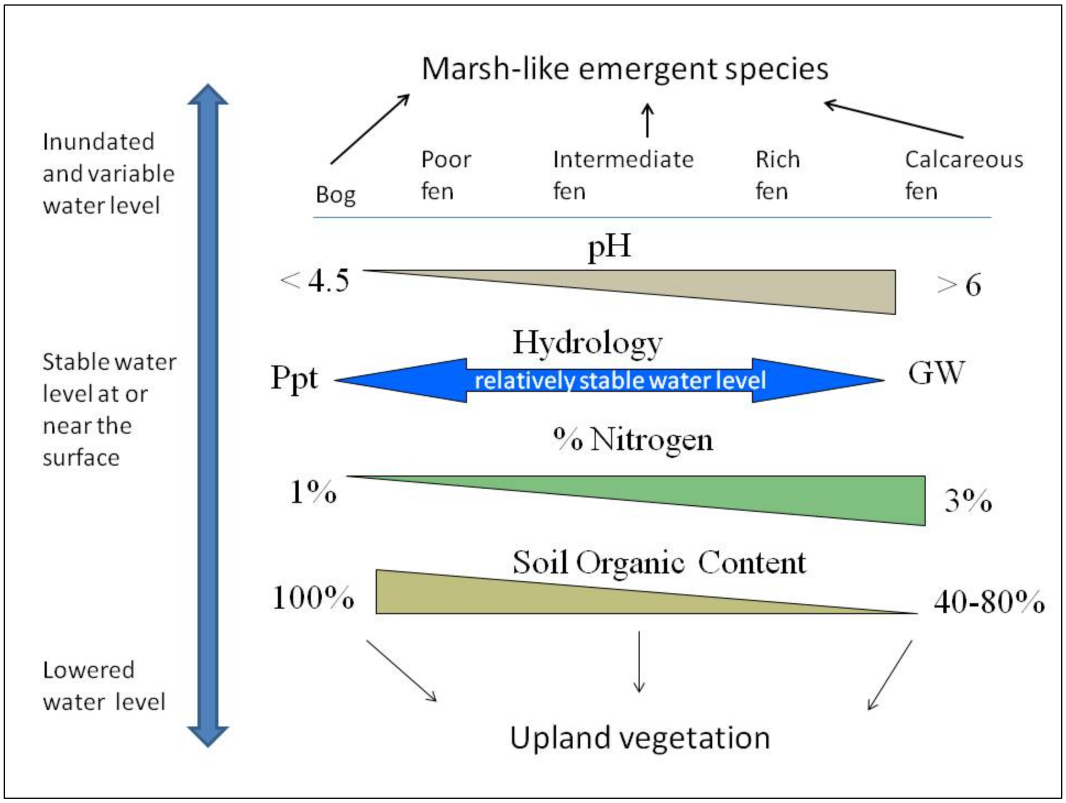
1 Characterization of Organic Slope, Flats, and Depressional Wetlands of the Northcentral and Northeast Region

Introduction

This guidebook was developed for the purpose of assessing the functions of flats, slopes and depressional wetlands dominated by organic soils within the Reference domain described below. These are collectively referred to as *peatlands* throughout this guidebook. This guidebook is intended to assess wetlands that have an organic surface layer 20 centimeters (cm) (8 inches (in.)) or more thick or an organic soil layer(s) that occupies at least one-half of the upper 80 cm (32 in.). Areas near the boundary between the peatland and adjacent uplands may have organic soil thicknesses less than 20 cm (8 in.) or an organic layer may be absent. These areas are intended be assessed using the guidance provided in this guidebook as part of the peatland complex. It is possible to assess the functions of peatlands in the Northcentral and Northeast Region using only the information contained in Chapter 3. Users should familiarize themselves with the information in Chapters 1 and 2 prior to conducting an assessment.

Peatlands refer to a continuum of wetlands that encompass three wetland classes as described by Brinson (1993). Fens are an example of slope wetlands, which are dominated by groundwater inputs. At the other extreme are flats and depressions which have precipitation as the dominant source of water inputs. Bogs are an example of a flat or depressional wetland. There is a continuum along a gradient between the extremes of fens and bogs (Figure 1). The classification and identification of these subclasses becomes problematic and less well defined in the literature. Classification is complicated by natural and anthropogenic changes in water source over time within the wetland (Bridgham et al. 2001). It is possible and practical to combine these separate wetland classes for the purpose of a rapid functional assessment because they share common characteristics including (a) a water table at or near the soil surface nearly all year, (b) the accumulation of organic matter, and (c) the development of organic soil layers. The unique hydrologic regime and organic matter accumulation in peatlands dominates the way in which this group of wetlands functions.

Figure 1. An Illustration of the general continuum between bogs and fens.



This guidebook was developed with the input of a multiagency, interdisciplinary team. Information about wetland classification and how guidebooks are developed can be found in the following documents:

A Hydrogeomorphic Classification for Wetlands (Brinson 1993). http://el.erdc.usace.army.mil/elpubs/pdf/wrpde4.pdf

Hydrogeomorphic (HGM) Approach to Assessing Wetland Functions: Guidelines for Developing Guidebooks (Version 2) (Smith et al. 2013). http://el.erdc.usace.army.mil/elpubs/pdf/trel13-11.pdf

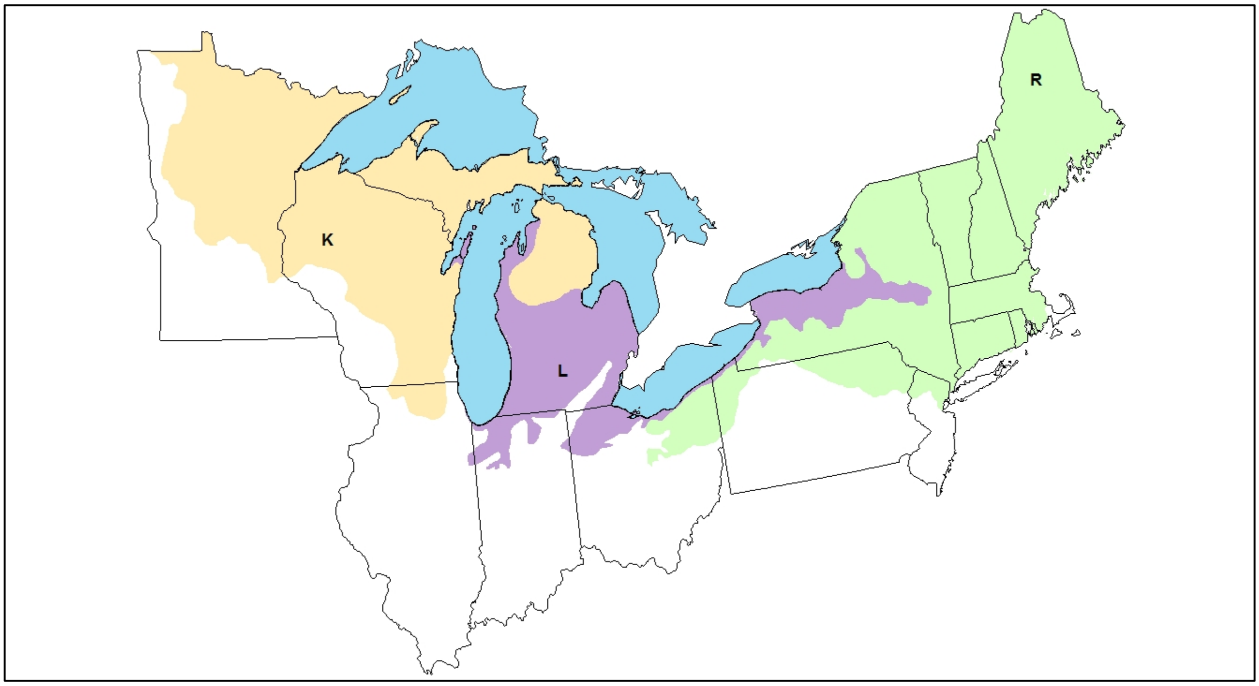
Regulatory agencies are responsible for determining permit requirements. For example, in recently disturbed locations or atypical circumstances, a regulatory body may require data from an adjacent undisturbed area to be evaluated and applied to the assessment report. In other cases, regulatory agencies may determine that recently or intentionally disturbed areas did not meet reference standard conditions prior to disturbance.

Regional subclass and Reference domain

This regional assessment method was developed to assess the functions of organic slopes, flats, and depressional wetlands within the Reference domain that include the following Land Resource Regions (LRR): Northcentral Forest (LRR K), Central Great Lakes Forests (LRR L), and Northeastern Forests (LRR R) as designated by the USDA, NRCS (2006) (Figure 2). These LRRs include the major land resource areas (MLRA) listed in Table 1. This area is referred to as the Peatland reference domain herein and generally conforms to the area described in the Northcentral and Northeast Regional Supplement for wetland identification and delineation (U.S. Army Corps of Engineers (USACE) 2010, 2011). Descriptions of the LRR and MLRA can be found in U.S. Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS) (2006).

Organic slopes, flats and depressional wetlands, are commonly known as bogs or fens. The term *peatlands* is generally used to refer to all wetland communities characterized by an organic soil layer regardless of the degree of decomposition of the organic soils that have water tables at or near the soil surface throughout the year (Moore and Bellamy 1974; Mitch and Gosselink 2007). Peatlands primarily develop in areas associated with positive water balances (i.e., precipitation exceeds evapotranspiration) and where soil saturation and anaerobic conditions restrict microbial decomposition to rates far less than primary production (Vitt 1994). These conditions can result in the accumulation of organic matter to depths >20 cm (8 in.) (Soil Survey Staff 2014;), with depths >2 meters (m) (6.5 feet (ft)) commonly observed (Gorham 1991). In most other wetland communities, the frequency and magnitude of hydrologic fluctuations, which strongly influence the depth to and duration of aerobic conditions, create environments for greater microbial decomposition (Collins and Kuehl 2001) and limit accumulations to smaller quantities of highly decomposed organic matter (Zoltai and Vitt 1995). Low soil temperatures also decrease the rate of microbial decomposition (Boelter and Verry 1977; Collins and Kuehl 2000; Jenny 1950), which has limited the global distribution of peatland communities primarily to boreal latitudes and high elevation areas (Aselmann and Crutzen 1989.

Figure 2. Map of the Reference domain for peatlands. The area includes LRR K, L, and R.



In the continental interior of North America, the development of peatlands initiated following the retreat of the continental ice sheet, approximately 12,000 years (yr) ago (Almendinger and Leete 1998; Gorham et al. 2007). During this period, cool temperatures and slow-moving glacial melt waters, which stagnated where substrate composition and landscape topography limited water movement, provided the climactic conditions, physical templates, and stable hydrology necessary for organic matter accumulation (Boelter and Verry 1977). Peatlands also occur in the temperate regions of North America (Carpenter 1995; Eggers and Reed 2014; MNDNR 2005 b). In these regions, peatland communities are small, usually only a few hectares (ha) in size (Bedford and Goodwin 2003) and occur in isolation where continuous hydrologic inputs, discharged as groundwater, maintain conditions necessary for organic matter accumulation (Almendinger and Leete 1998; Amon et al. 2002). Glaser (1987) describes extensive peatland complexes as large as 10,000 ha (24,700 acres). Distinctions between all peatland communities are based primarily on complex interactions between a) landscape position, b) organic matter accumulation, and c) the source and chemical composition of hydrologic inputs, which are reflected in the various methods by which peatlands are classified.

Table 1. Major Land Resource Areas within the Peatland Reference Domain.

MLRA	MLRA Symbol
Northern Minnesota Gray Drift	57
Northern Minnesota Glacial Lake Basins	88*
Central Wisconsin and Minnesota Thin Loess and Till	90*
Wisconsin and Minnesota Sandy Outwash	91*
Superior Lake Plain	92
Superior Stony and Rocky Loamy Plains and Hills	93
Northern Michigan and Wisconsin Sandy Drift	94A
Michigan Eastern Upper Peninsula Sandy Drift	94B
Northern Wisconsin Drift Plain	95A
Southern Wisconsin and Northern Illinois Drift Plain	95B
Western Michigan and Northeastern Wisconsin Fruit Belt	96
Southwestern Michigan Fruit and Truck Belt	97
Southern Michigan and Northern Indiana Drift Plain	98
Erie-Huron Lake Plain	99
Erie Fruit and Truck Area	100
Ontario Plain and Finger Lakes Region	101
Central Iowa and Minnesota Till Prairies	103
Eastern Iowa and Minnesota Till Prairies	104
Northern Mississippi Valley Loess Hills	105
Eastern Ohio Till Plain	139
Glaciated Allegheny Plateau and Catskill Mountains	140
Tughill Plateau	141
St. Lawrence-Champlain Plain	142
Northeastern Mountains	143
New England and Eastern New York Upland; Northern Part	144B
Aroostook Area	146

*Identifies MLRS where data was collected.

The functional capacity indexes in this guidebook were calibrated using data from reference peatlands in eastern Minnesota and western Wisconsin. Persons wishing to apply the assessment in other areas should verify that existing reference data adequately describe local conditions (Smith et al. 2013). In some cases additional reference data should be collected and used to revise plant lists and recalibrate subindex graphs (Berkowitz et al. 2014).

Characterization of the regional subclass

Physiography and geology

The southern Laurentian Ice Sheet played a major role in shaping the landscape within the Reference domain. The landscape is characterized by gently undulating to rolling, loess-mantled till plains, drumlin fields, and end moraines mixed with outwash plains associated with major glacial drainageways, swamps, and bogs where peatlands are typically found. In some areas, lake plains and ice-walled lakes are significant. Steeper areas occur mostly as valley side slopes along flood plains and as escarpments along the margins of lakes. Lakes are common, and streams generally have a dendritic pattern. Elevation ranges from 1,100 to 1,950 ft (335 to 595 m). Local relief is mainly less than 10 to 20 ft (3 to 6 m), but some major valleys and hills are 200 ft (60 meters) above the adjacent lowland (USDA NRCS 2006).

The bedrock is a complex of folded and faulted igneous and metamorphic rocks. The bedrock terrain has been modified by glaciation and is covered in most areas by Pleistocene deposits and windblown silts. The glacial deposits or drift form an almost continuous cover in most areas. The drift is as much as several hundred feet thick in many areas. Loess or wind-blown silts covered the area shortly after the glacial ice melted (USDA 2006).

Climate

The climate within the Reference domain is characterized by cold, snowy winters and warm summers (Bailey 1995). Average annual temperatures range from 2 to 12 °C (36 to 54 °F), with summer temperatures averaging in the 20 °C (70 °F) and winter temperatures in the 10 °C (50 °F). Precipitation averages 66–97 cm (26–38 in.) annually. Highest rainfall amounts occur in spring and summer, and the lowest occur in autumn and early winter. Overall, this climate provides a water surplus across the Reference domain, with precipitation exceeding potential evapotranspiration for much of the year. However, water deficits (evapotranspiration exceeds precipitation) usually occur in summer (June–August). Snowfall occurs annually and ranges from 89 cm (35 in.) in the southern part to more than 127 cm (50 in.) at higher elevations in the northern part of the

Reference domain (USDA NRCS 2006). The growing season based on soil temperatures above 5 °C (41 °F) at 50 cm (20 in.) depth (USDA Soil Conservation Service 2006) is generally April through October throughout the Reference domain. With a frost-free period of 6 months or fewer, it is not uncommon for the ground to freeze to a depth of 1 m (3 ft) or more.

Geomorphic setting

Within the Reference domain, peatlands occur primarily as depressions to broad areas in open basins (Figure 3), slopes, and flats, or complexes of these different wetland classes. For the purpose of this guidebook, peatlands are defined as very poorly drained basins, with slopes ≤2%, whose hydrologic inputs are groundwater and/or precipitation. Peatlands can develop wetland/upland mosaics. These areas often have complex microtopography, with repeated small changes in elevation occurring over short distances. Tops of ridges and hummocks are often nonwetland but are interspersed throughout a wetland matrix having clearly hydrophytic vegetation, hydric soils, and wetland hydrology. The *Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Northcentral and Northeast Region*, Chapter 5, provides guidance on delineating wetland/nonwetland mosaics. These ecosystems may or may not have surface water connections to other wetlands or deep water habitats.

Hydrologic regime

Directly or indirectly, a wetland's hydrologic regime, or the magnitude, timing, and duration of flooding, affects all aspects of its structure and function (Mitsch and Gosselink 2000). The hydrologic regime of all wetlands, including peatlands within the reference domain, is determined by numerous interrelated and interacting factors including climate, timing, and amounts of precipitation, the physical characteristics of the wetland and its watershed, soil characteristics, groundwater influences, and evapotranspiration. The common hydrologic feature for peatlands, regardless of the dominant water source or wetland subclass, is that they are inundated with shallow water or have a shallow water table. The soil remains saturated near the soil surface the entire year except during extreme droughts periods or is artificially drained.

Figure 3. Example of a typical peatland.

Soils

Soil microbes use carbon compounds found in organic matter as an energy source. However, the rate at which organic carbon is utilized by soil microbes is considerably lower in a saturated and anaerobic environment than under aerobic conditions (Reddy and DeLaune 2008). Therefore, in saturated soils, partially decomposed organic matter may accumulate. The result in wetlands is often the development of thick organic surfaces, such as peat or muck, or dark organic-rich mineral surface layers. Peatlands are dominated by soils with an organic surface layer with 20 cm (8 in.) or more or the upper 40 cm (16 in.) with an organic soil surface occurring across ≥50% of the assessment area. The remaining wetland should be dominated by soils that have an organic soil surface or mucky modified soil texture. These organic soil layers vary in decomposition from peat (least decomposed) to muck (highly decomposed) (USDA NRC 2006). Narrow wetland areas, typically less than 100 m (328 ft) wide at the wetland upland boundary, may have mineral soils to the surface and can be included in the assessment using methods described in this guidebook. Guidance for determining if a soil is organic or mucky modified and the level of decomposition can be found in Appendix B. The most current soils information for the Reference domain can be found on the Web Soil Survey at http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx.

Flora

The Reference domain is a combination of MLRA that are dominated by deciduous forest and mixed coniferous/deciduous forest. Sugar maple (*Acer saccharum*), basswood (*Tilia americana*), yellow birch (*Betula alleghaniensis)*, white ash (*Fraxinus americana*), red oak (*Quercus rubra*), white oak (*Q. alba*), quaking aspen (*Populus tremuloides*), eastern hemlock (*Tsuga canadensis*), black spruce (*Picea mariana*), tamarack (*Larix laricina*) northern white cedar (*Thuja occidentalis*), red pine (*Pinus resinosa*), and white pine (*P. strobus*) are the dominant trees. Poorly drained soils also support black ash (*Fraxinus nigra*), green ash (*F. pennsylvanica*), silver maple (*A. saccharinum*), red maple (*A. rubrum*), swamp white oak (*Q. bicolor*), balsam fir (*Abies balsamea*), and balsam poplar (*P. balsamifera*) across the Reference domain (MNDNR 2003a,b).

Common shrub species associated with peatlands include but are not limited to leatherleaf (*Chamaedaphne calyculata*), bog-laurel (*Kalmia polifolia*), small cranberry (*Vaccinium oxycoccos*), bog-rosemary (*Andromeda polifolia*), rusty Labrador-tea (*Rhododendron groenlandicum*), bog birch (*Betula pumila*), speckled alder (*Alnus incana*), bog willow (*Salix pedicellaris*), red-osier dogwood (*Cornus sericea*) slender willow (*S. petiolaris*), and pussy willow (*S. discolor*).

Herbaceous species that are commonly found in acidic, nutrient-poor peatlands include but are not limited to buck-bean (*Menyanthes trifoliata*), bog wiregrass sedge (*Carex oligosperma*), tussock cottongrass (*Eriophorum vaginatum*), pitcher plant (*Sarracenia purpurea*), round-leaved sundew (*Drosera rotundifolia*), marsh St. John's wort (*Triadenum fraseri*), tufted loosestrife (*Lysimachia thyrsiflora*), northern marsh fern (*Thelypteris palustris*), and various species of Sphagnum mosses (*Sphagnum spp.*). Herbaceous species of circumneutral-to-alkaline, more nutrient-rich peatlands include but are not limited to tussock sedge (*C. stricta*), Canada blue-joint grass (*Calamagrostis canadensis*), cottongrass bulrush (*Scirpus cyperinus*), cinnamon fern (*Osmundastrum cinnamomeum*), crested shield fern (*Dryopteris cristata*), joe-pye weed (*Eutrochium maculatum*), skunk cabbage (*Symplocarpus foetidus*), and goldthread (*Coptis trifolia*).

Fauna

Peatlands provide habitat for a diverse community of bird, mammal, macroinvertebrate, and amphibian species that require water or moist soils to complete at least a portion of their life cycles. Songbirds, such as Nelson's sparrow (*Ammodramus nelsoni*) and palm warbler (*Setophaga palmarum*) are associated with peatland wetlands within the Reference domain and provide recreational opportunities for birdwatchers and nature enthusiasts. Further, because birds are highly mobile, they serve as a transfer mechanism for nutrients and energy from wetlands to other ecosystems. Several small mammals, including the southern bog lemming (*Synaptomys cooperi*) and water shrew (*Sorex palustris*) also are closely associated with wetlands and similar environments.

Salamanders and frogs often replace fish as the primary vertebrate predators in peatlands within the Reference domain (Jung et al. 2004). Oldfield and Moriarty (1994) found that many species of amphibians and reptiles used peatlands for a least some portion of their life cycle. They identified the following amphibian species as likely to occur in peatlands: the green frog (*Lithobates clamitans*) was restricted to wetlands, while the tiger salamander (*Ambystoma tigrinum*), gray treefrog (*Hyla chrysoscelis*), Cope's gray treefrog (*H. versicolor*), spring peeper (*Pseudacris crucifer*), northern leopard frog (*L. pipiens*), mink frog (*L. septentrionalis*), wood frog (*L. sylvaticus*), American toad (*Bufo americanus*), Canadian toad (*B. hemiophrys*), northern cricket frog (*Acris crepitans*), and plains spadefoot (*Spea bombifrons*) used both wetlands and adjacent upland habitats. Petranka (1998) provides a comprehensive work on salamanders in the United States and Canada.

Anthropogenic alterations

Common land use changes that directly or indirectly impact peatlands in the Reference domain include the construction of county, state, and interstate highways, logging access roads and bridges, urban development, groundwater extraction, drainage, peat mining, turf grass production, and ponding for cranberry and rice agriculture.

2 Variables, Functions, and Assessment Indexes

Variables

Data for this guidebook calibration data were collected on 68 Peatland reference wetlands within the Reference domain. Ten sites were identified as reference standard sites (Smith et al. 2013). The following six variables are used to assess the functions that are performed by peatlands within the Reference domain:

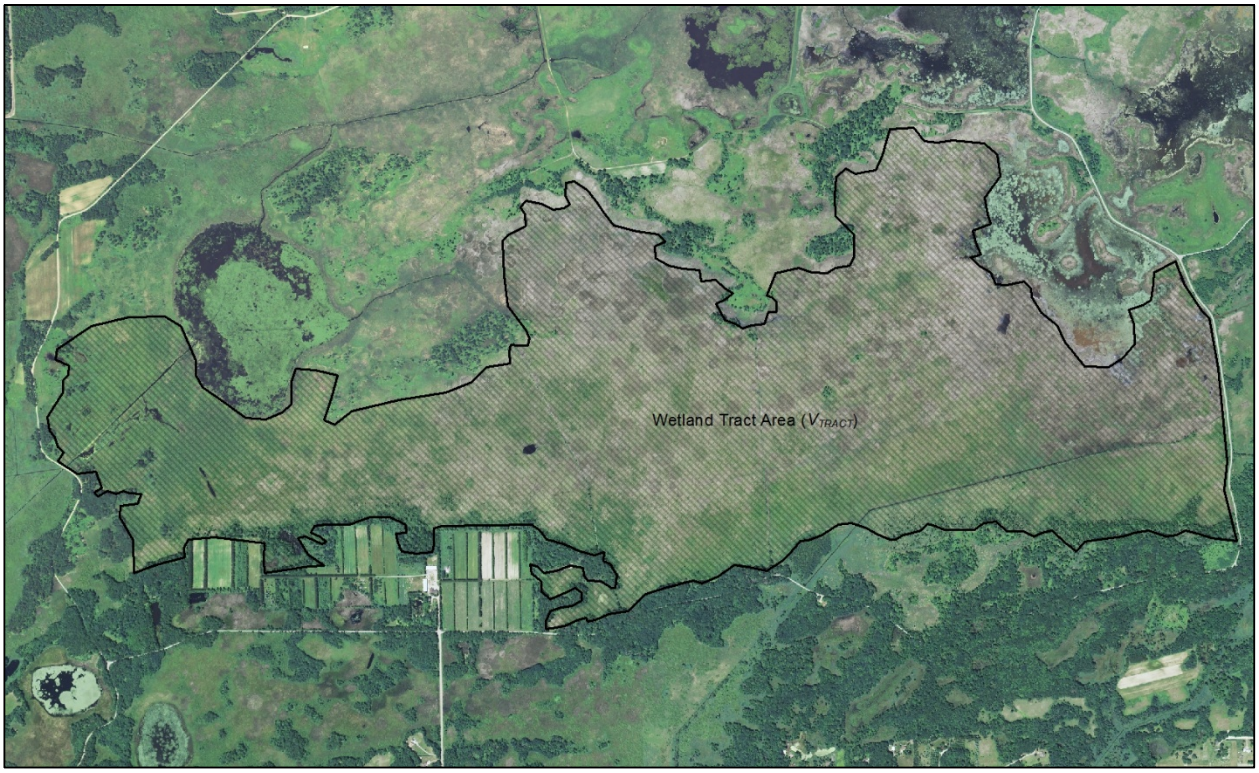
- wetland tract area
- interior core area
- water depth
- vegetation composition
- habitat connections
- surrounding land use.

Each variable is defined, and the rationale for its selection is discussed in the following paragraphs. The relationship of each variable to functional capacity is also given, based on measurements taken in reference wetlands. Procedures for measuring each variable are provided in Chapter 3.

Wetland tract area (V_{TRACT})

This variable is the area of contiguous peatlands, including the wetland assessment area (WAA) that is accessible to wildlife. Reference standard peatlands varied greatly in size, ranging from <5 ha (12 acres) to more than 10,000 ha (24,700 acres). This variable is only used to assess peatlands that are ≥100 ha (247 acres) (Figure 4). The Provide wildlife habitat function for peatlands <100 ha (247 acres) is assessed using a different set of variables. This variable reflects the fact that wildlife movement is not constrained by imaginary lines on a map such as project boundaries. Wildlife movement, although species dependent, is more likely to be constrained by factors such as size of home range, and ecologically meaningful boundaries are more likely to be distinguished by changes in land use, habitat type, or structures such as roads. This variable is only used in the Provide wildlife habitat function.

Figure 4. Illustration of wetland tract area (V_{TRACT}) approximately 450 ha (1,100 acres).



The area of wetland that is not separated by 30 m (98 ft) or more of unsuitable habitat from the area being assessed and the same regional wetland subclass are used to quantify this variable. This range assumes that one-lane, or narrow unpaved roads (e.g., driveways, farm roads), narrow canals, and powerline corridors do not represent significant barriers to most wildlife. Larger roads (e.g., paved county roads) regional canals, and discontinuities were treated as tract boundaries. Based on data from reference standard sites, a variable subindex of 1.0 is assigned when wetland tract size is ≥500 ha (1,236 acres) for peatlands. The score decreases linearly to 0.1 for a tract size of 100 ha (247 acres) (Figure 5).

Interior core area (V_{CORE})

This variable represents the interior portion of a wetland tract with a 300 m (990 ft) buffer. Interior core area is dictated by both the size and shape of the wetland (Figure 6). Large wetland tracts often have large interior core areas, but not always. For example, a large wetland tract that is circular in shape will have a much larger interior core area than a linearly shaped wetland tract of the same total area. In the context of the function, this variable represents the availability of habitat not adversely affected by fragmentation. The percentage of the wetland tract inside a buffer zone

300 m (984 ft) wide is used to quantify this variable. This variable is only used to assess wetlands that are ≥100 ha (247 acres). The Provide wildlife habitat for peatlands <100 ha (247 acres) is assessed using a different set of variables. This variable is only used in the Provide wildlife habitat function.

Figure 5. The relationship between wetland tract area (V_{TRACT}) and functional capacity.

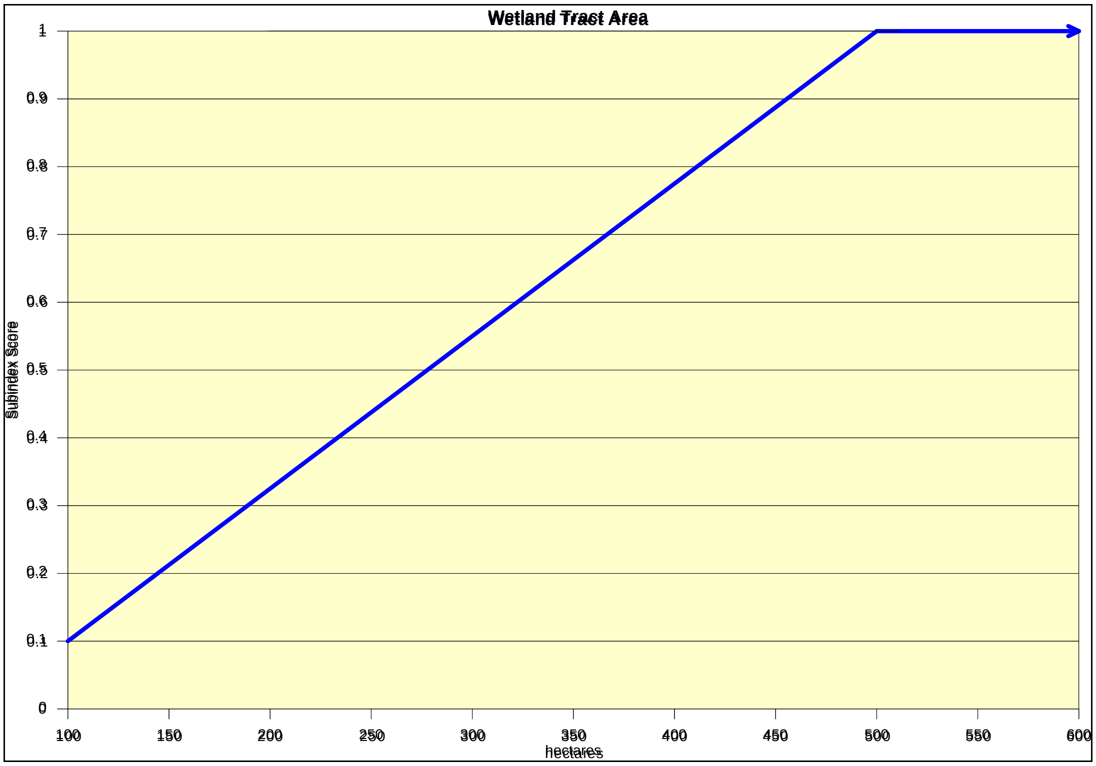
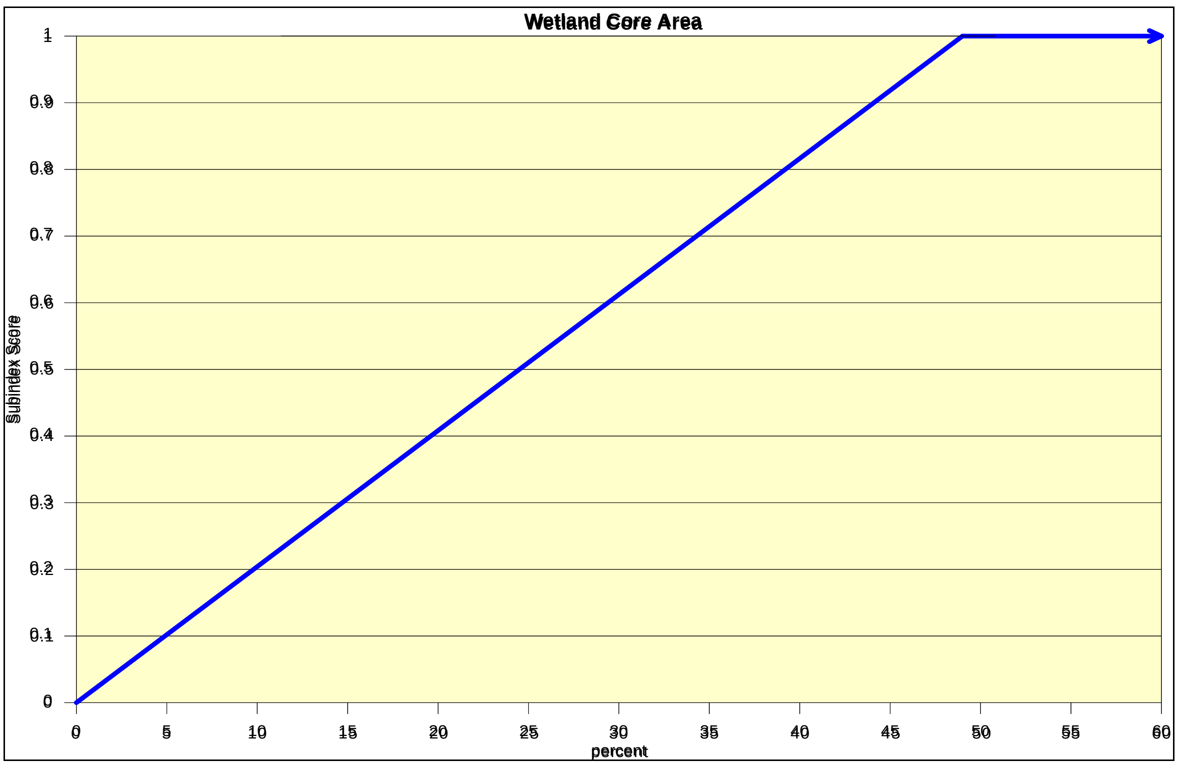


Figure 6. Illustration of interior core area (V_{CORE}) with a 300 m (984 ft) buffer within the wetland tract area (V_{TRACT}).

In reference peatlands, interior core areas ranged from 0% to 95%. Based on the range of values from reference standard wetlands, a variable subindex of 1.0 is assigned when 49% or more of the wetland tract is inside a buffer of at least 300 m (984 ft) (Figure 7). As the percentage of the wetland tract within a 300 m (984 ft) buffer decreases, a linear decrease in subindex is applied. This is based on the assumption that, as the interior core area decreases, the suitability of the wetland for species requiring isolation from predators that frequent edges also decreases.

Figure 7. The relationship between wetland core area (V_{CORE}) and functional capacity.



Habitat connections ($V_{CONNECT}$)

This variable is defined as the percentage of the wetland perimeter and width of suitable wetland or upland wildlife habitat that is connected to the WAA. This variable is only used to assess peatlands that are <100 ha (247 acres) in size. To be considered in this calculation, a zone or buffer of suitable habitat must extend at least 10 m (32.8 ft) beyond the wetland boundary. It is assumed that nearly all upland forested areas with normal stocking will provide at least minimally suitable habitat for amphibians and most other wildlife species that may depend on wetlands and adjacent habitats for food, cover, and breeding sites. Managed pine forests and plantations are considered suitable only if soils, litter, and ground-layer vegetation have not been disturbed extensively (e.g., bedded) such that cover has been eliminated and animal movement is impeded. Areas devoted to row crops, closely mowed areas, grazed pastures, and urban areas are not suitable habitat. $V_{CONNECT}$ applies only to the Provide wildlife habitat function.

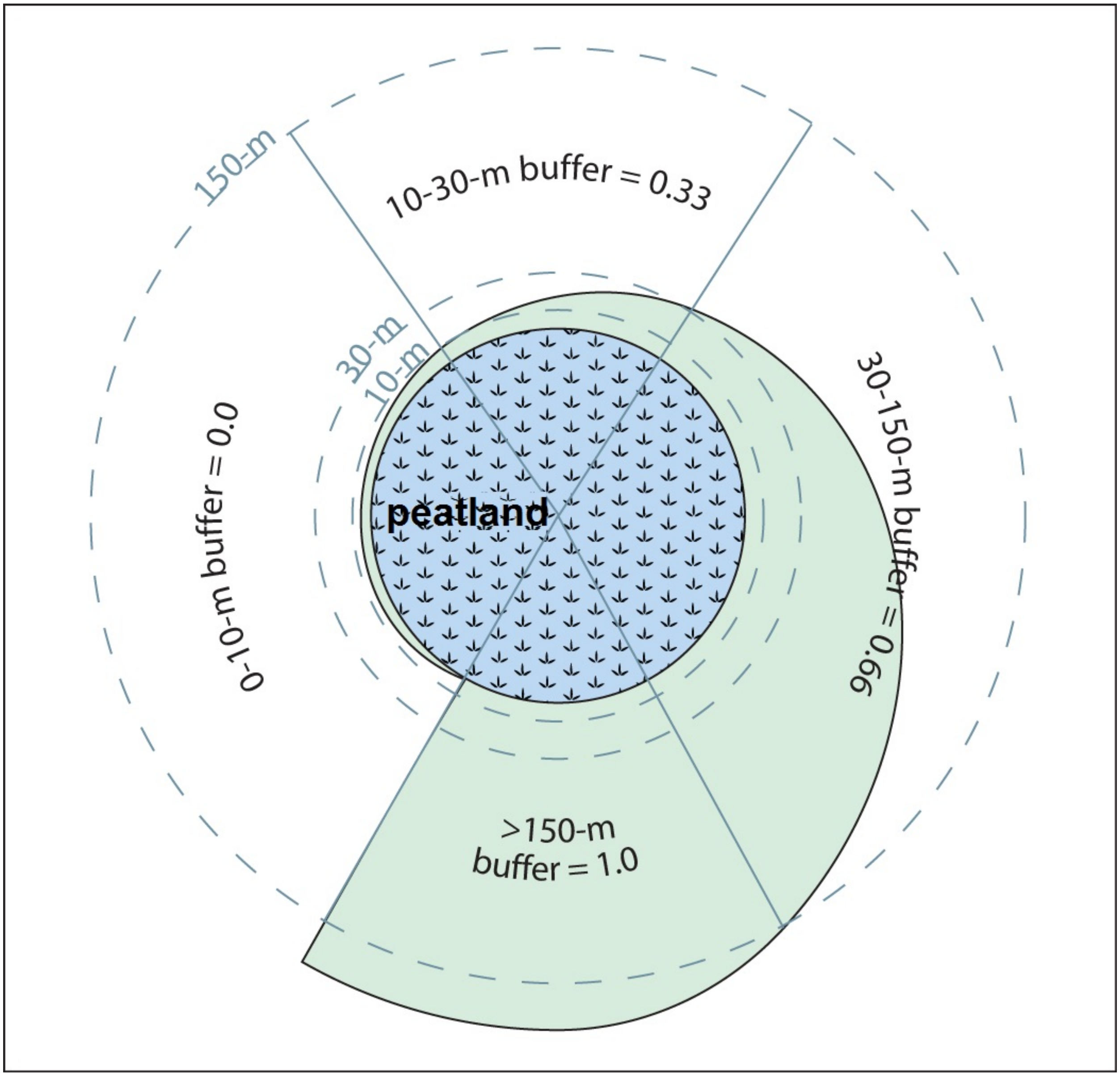
The width of the habitat that is connected to the wetland also is considered in this variable. Ideally a zone or buffer of suitable habitat should extend 150 m (492 ft) or more beyond the wetland boundary and that condition existed at all reference standard wetlands sampled. A narrower zone or buffer can provide habitat for many amphibian, reptile, and avian species that utilize peatlands. This is done by multiplying the length of suitable habitat by one of the following constants based on the width of suitable habitat. If the width is >150 m (492 ft), multiply by 1.0; if the width is >30 m and <150 m (98.4–492 ft), multiply by 0.66; if the width is > 10 m and <30 m (32.8–98.4 ft), multiply by 0.33; if the width is <10 m (32.8 ft), multiply by 0.0 (Figure 8). The sum of the five categories divided by the total length of the wetland perimeter is used determine the subindex for $V_{CONNECT}$ (Figure 9).

A subindex value of 0.0 is assigned to sites where none of the wetland perimeter is buffered by a zone of suitable habitat. Reference standard wetlands displayed 95% to 100% of their perimeters suitably buffered by a zone at least 150 m (492 ft) wide. At sites where the percentage of the wetland perimeter with a suitable buffer is between 0% and 85%, or the width is less than 10 m (32.8 ft), the relationship between the percentage of suitable buffer and functional capacity is reduced (Figure 9).

Surrounding land use (V_{SLUSE})

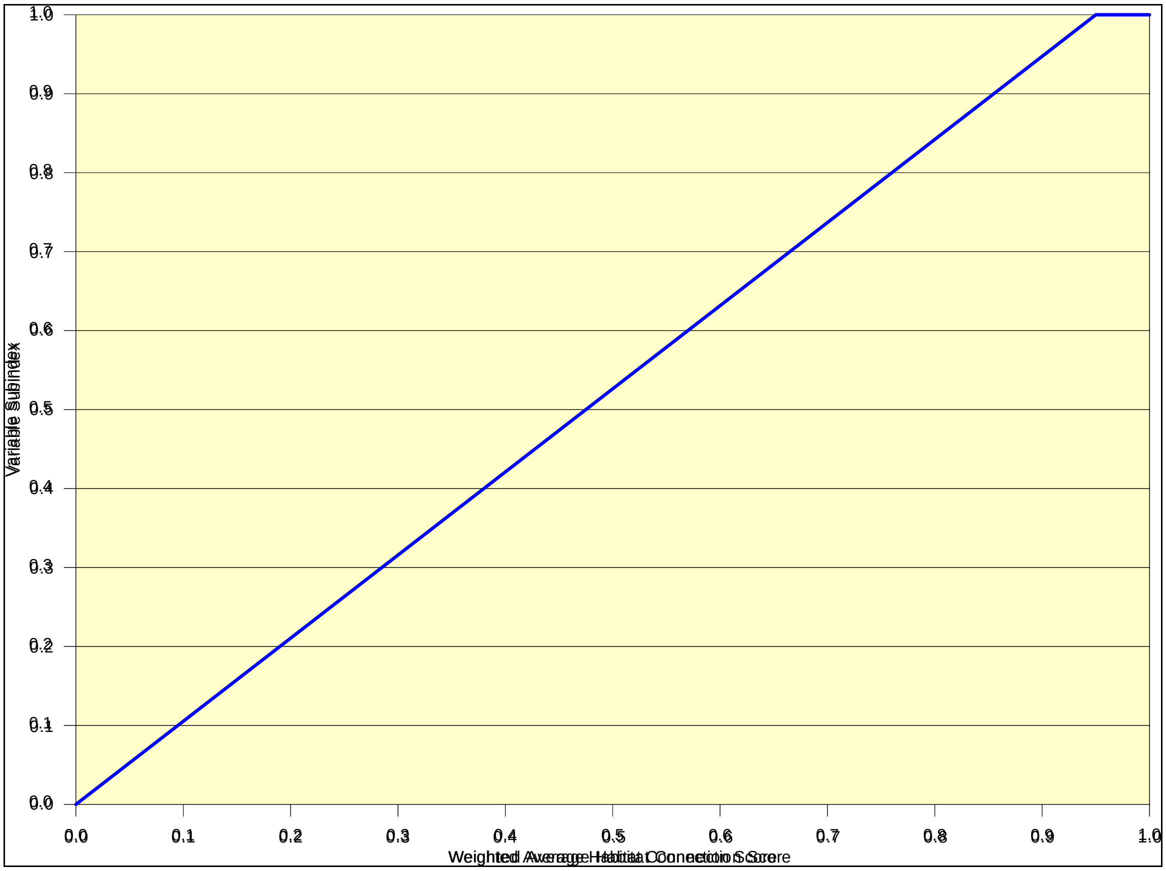
This variable is defined as the surrounding land use within a 500 m (1,025 ft) wide zone immediately outside the 150 m (492 ft) $V_{CONNECT}$ buffer zone utilized in the determination of $V_{CONNECT}$. This variable is only used to assess peatlands that are ≤100 ha (247 acres) in size. Variable scores are based upon the weighted average of the combination of percent land cover and land-use classifications. To calculate this variable subindex score, the percentage of the area surrounding the WAA and outside the 150 m (492 ft) $V_{CONNECT}$ buffer zone in each of the land use categories (forested, residential, industrial, etc.) must be calculated or estimated. This requires the use of internet resources, landscape images, and/or GIS, along with field reconnaissance and verification. V_{SLUSE} applies to the Provide wildlife habitat function only.

Figure 8. Illustration of $V_{CONNECT}$. In this example, the length of the wetland perimeter is 20 m long that has a buffer ≥150 m wide; the length of the wetland perimeter is 30 m long that has a buffer ≥30 to <150 m wide; the length of the wetland perimeter is 20 m long that has a buffer ≥10 m and <30 m wide; and the length of the wetland perimeter is 30 m long and a buffer width <10 wide.



Width Categories (m)	Length (m)	Buffer Score	Length * Buffer Score
≥150	20	1.0	20
≥30 and <150	30	0.66	19.8
≥10 and <30	20	0.33	6.6
<10	30	0.0	0
Total	100		46.4
Total length * buffer score/total length = weighted average		46.4/100 = 0.46	

Figure 9. Relationship between habitat connections ($V_{CONNECT}$) and functional capacity.



Landscape-based metrics of land use and land cover affect runoff quantity and water quality within watersheds (Jones et al. 2001; Rheinhardt et al. 2009). Surrounding land use conditions determine the structure and function of downstream environments (Bolstad et al. 2003). With increased disturbance and decreased infiltration capacity in the surrounding watershed, more surface water enters downstream waters than under the unaltered condition (Simmons et al. 2008; Townsend et al. 2009; DeFries and Eshleman 2004). Increased runoff increases sediment and nutrient loading and impacts water quality during base and peak flow events (Poor and McDonnell 2007; Herlihy et al. 1998; Bolstad and Swank 1997).

The subindex score is based on the weighted average of the habitat scores associated with the various land uses identified in the watershed catchment outside the buffer zone (see Appendix B for an example calculation). Areas affected by naturally occurring wildfires (lightning strikes), controlled burns designed for forest management, and other burned natural areas should not receive a decreased land use score. Land use can be classified using aerial or orthographic photographs, and topographic resources, which are available from a number of internet sources including TerraServer (http://terraserver-usa.com), Google Maps (http://maps.google.com/), and the USDA Geospatial Data Gateway (http://datagateway.nrcs.usda.gov).

Areas surrounding reference standard sites had >75% native forest and native range coverage (Table 2). Reference standard reaches contained a maximum of 7% impervious surfaces as roads and gravel areas, and no industrial, agricultural, or residential areas. Some reference standard wetlands were previously impacted by land clearing for agricultural, pastureland, limited road building, and forestry activities, but mature floral communities have been re-established, and soil conditions remain stable and displayed limited erosion.

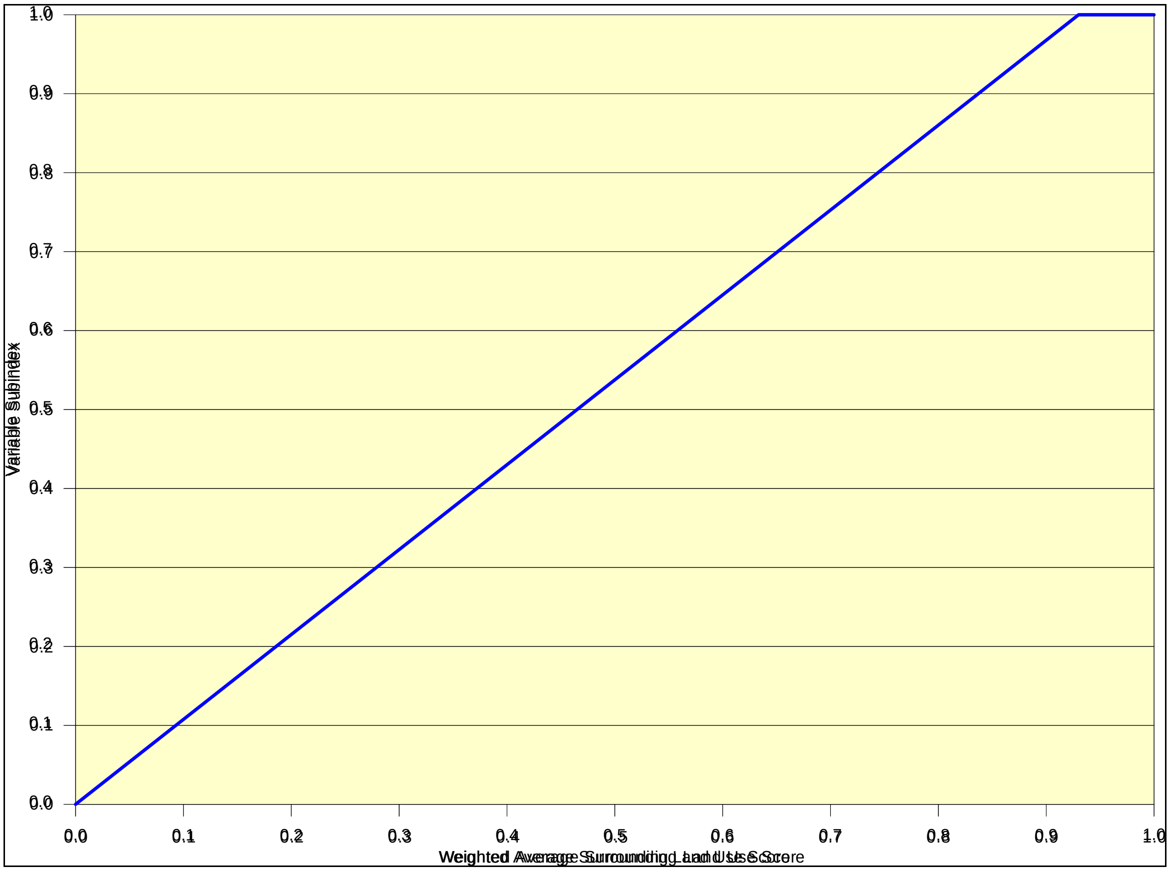
Table 2. Surrounding land use and associated habitat scores.*

Land Use	Habitat Score
Forest (ungrazed)	1.0
Wetland dominated by native species	1.0
Forest (grazed)	0.7
Orchards and tree farms	0.5
Green space (lawns, parks, golf courses, etc.)	0.4
Pasture and hayland	0.4
Low-density residential (≥1 acre lots)	0.3
Gravel roads	0.1
Wetland dominated by invasive plant species	0.1
High-density residential (<1 acre lots)	0.1
Cropland (row crops)	0.1
Water (ponds, lakes, etc.)	0
Wetland with altered hydrology (ponded, drained, etc.)	0
Paved (roads, parking lots, roofs, etc.)	0
Compacted soil (dirt roads, construction areas, etc.)	0
Commercial and business	0
Industrial	0

*Modified from USDA Natural Resources Conservation Service (1986).

Other reference sites contained additional land uses, including large areas of grass cover, industrial coverage >70%, agricultural land uses, roads and gravel pads, and residential coverage, resulting in decreased subindex scores. Surrounding land use scores between 0.93 and 1.0 receive a subindex score of 1.0, and subindex scores decline linearly to 0.0 as the surrounding land use score drops below 0.93 (Figure 10).

Figure 10. Relationship between weighted average for land use surrounding the WAA and functional capacity.



Water depth (*V_{WD}*)

This variable is the weighted average depth of surface water or depth to the water table within the vegetation communities identified in the WAA. Figure 11 shows a wetland with altered hydrology. V_{WD} applies to the Hydrology function only.

This variable reflects the range of water depth observed in reference standard peatlands with no direct (onsite) anthropogenic alterations (i.e., no obstructions to natural water storage or flow, no dams, no impoundments, no roads within the wetland, and no incoming or outgoing ditches and tiles). Other peatlands within the Reference domain exhibited direct alterations from drainage, ponding, or other hydrologic modifications or management to peatland hydrology. Peatland hydrology can also be impacted by indirect (offsite) anthropogenic alterations (e.g., municipal or agricultural wells) that can lower the regional water table. The intent of this variable is to characterize the water depth of peatlands under both natural and altered hydrologic conditions.

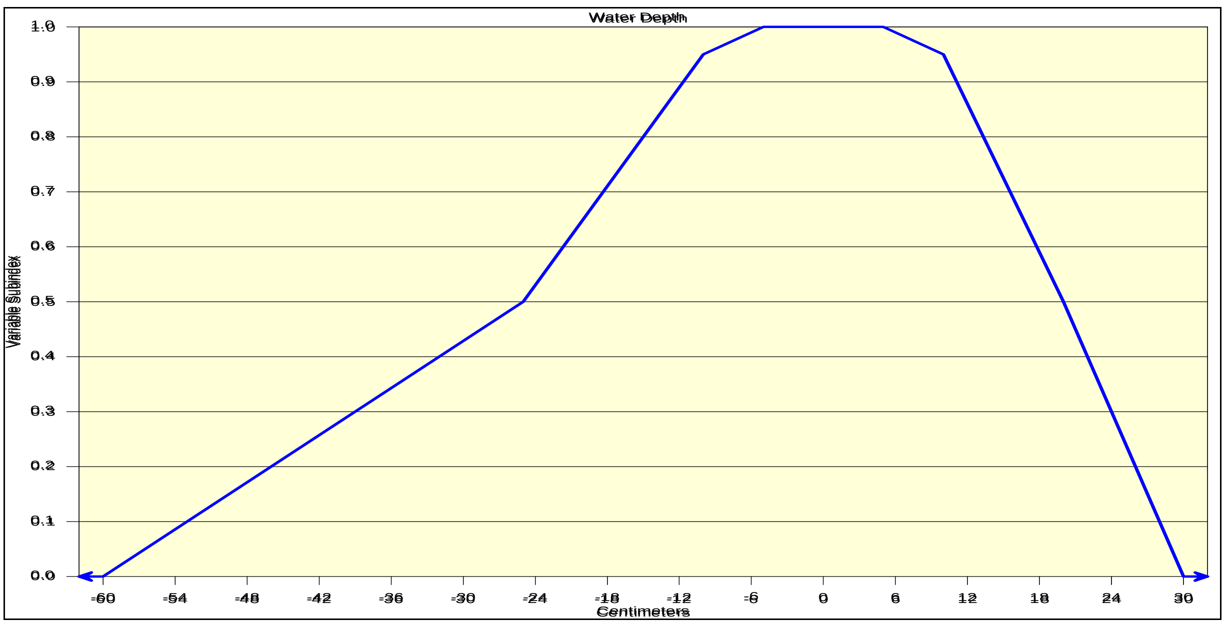
Figure 11. Peatland with altered hydrology.

Under reference standard conditions with no direct or indirect alterations to peatland hydrology, water depth was between –5 cm (–2 in.) and +5 cm (+2 in.) of the peat surface and received a subindex score of 1.0. Peatlands with minor hydrologic alterations had water depths between –10 cm (–4 in.) and +10 cm (+4 in.) of the peat surface and were given a subindex score of 0.95 (Figure 5).

Average water depth for peatlands affected by direct impacts (e.g., dams, road crossings, beaver activity) resulted in water depth that was 20 cm (8 in.) above the peat surface. These sites were given a subindex score of 0.5. Most water depths for reference peatlands with increased water storage ranged between 10 and 30 cm. (4 and 12 in.). Given the vagaries of the complex effects of indirect alterations on peatland hydrology, the impacts to the natural hydrology of peatlands were assumed to be linear for water depths between 10 and 30 cm (4 and 12 in.). Peatlands with water depths ≥30 cm (12 in.) receive a subindex score of 0.0 (Figure 5).

Average water depth for peatlands with apparent ditching, tiling, or groundwater extraction was –25 cm (–10 in.) below the organic soil surface received a subindex score of 0.5. Most water depths for reference wetlands with reduced water storage ranged between –10 and –40 cm (–4 and -16 in.). Given the vagaries of the complex effects of indirect alterations on peatland hydrology, the impacts to the natural hydrology were assumed to be linear for water depths between –10 and –40 cm (–4 and –16 in.). Also, given the naturally high water storage capacity of organic soils, it is assumed that as long as there was at least 30 cm (12 in.) of organic soils within the wetland, that some functional capacity for water storage existed. Consequently, peatlands with a water table depth ≥–60 cm (–24 in.) below the organic soil surface were given subindex score of 0.0 (Figure 12).

Figure 12. The relationship between the weighted average water depth, below or above the organic soil surface, for all plant communities within the WAA and functional capacity for water depth (V_{WD}).



Vegetation composition (V_{COMP})

The vegetation composition variable is the weighted average of the Peatland Fidelity Index (P-value) of the dominant species for all vegetation communities within the WAA. Bourdaghs et al. (2006) showed that using a weighted-average C-value of the dominant species provided a valid and rapid assessment of wetland vegetative communities. The approach used in this assessment is based on the concept of the floristic quality index (FQI) assessment described by Bourdaghs (MPCA 2012).

One way of judging the degree of disturbance to a peatland is to determine the "fidelity index" of the dominant species in the plant community. This approach essentially integrates many influencing factors such as hydrology and soil properties, successional patterns, and disturbances.

P-value is a numerical ranking from 0 to 10. Species receiving a score of 10 have narrow habitat requirements and/or little tolerance of natural or anthropogenic disturbance. As habitat requirements and tolerance to disturbance increases scores are reduced to zero. P-values are assigned by a group of regional experts based on data from reference sites and best professional judgment (BPJ). P-value scores were assigned for this assessment by the development team to reflect the specific habitat of reference standard peatlands. For example, fifty-two species with a faculative upland (FACU) wetland status (Lichvar et al. 2014) were documented in reference peatlands. Those species were further evaluated and assigned a P-value between 0 and 4 based on the following: 1) frequency of occurrence in reference wetlands; 2) whether that species was native vs. non-native; 3) whether that species was an indicator of disturbance vs. an indicator of higher condition; 4) whether a single occurrence of that species was considered an anomaly; and 5) best professional judgment. All other FACU or upland (UPL) species would automatically be assigned a P-value of 0. Bryophytes comprise an important group of wetland plants but are not included in this assessment. The difficulty of identifying bryophyte species makes them impractical for incorporating into a rapid wetland assessment. The most current wetland plant status can be found on the National Wetland Plant List (NWPL) webpage (http://rsgisias.crrel.usace.army.mil/apex/f?p=703:1:). Lichvar and Minkin (2008) provide definition and discussion of wetland plant status. Table 3 provides an example of selected dominant species and P-value. A complete list of species found during data collection for the peatland assessment can be found in Appendix B or as a drop-down list in the calculator. Those that have a wetland indicator status of FAC, Facultative Wetland (FACW), or Obligate Wetland (OBL) and were assigned a score of 0.0 should be changed to 1.0. All other species should receive the score assigned in Floristic Quality Assessment for Minnesota Wetlands (Milburn et al. 2007). Other published region-specific C-values can be used if available.

Table 3. Example of dominant plant species found in peatlands and the corresponding indicator status and P-value.

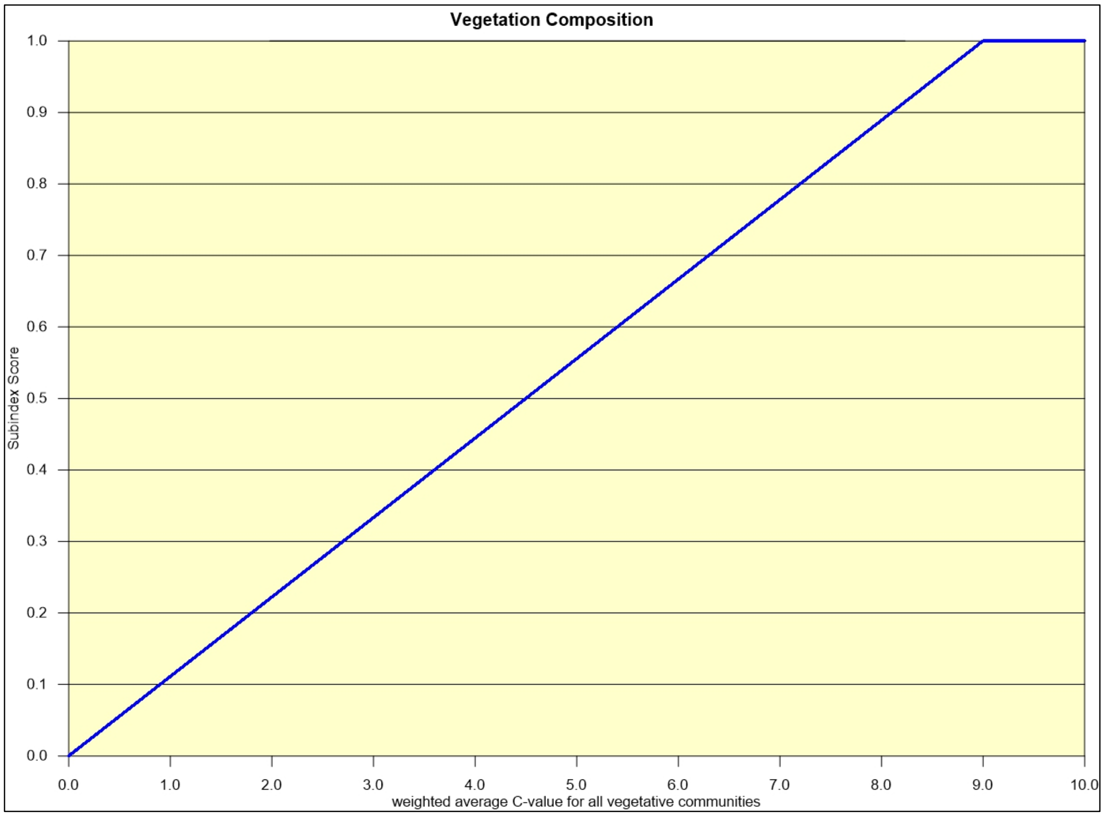
Species	Common Name	P-Value
Acer rubrum var. rubrum	red maple	3
Alnus incana ssp. rugosa	speckled alder	10
Aralia nudicaulis	wild sarsaparilla	4
Calamagrostis canadensis	bluejoint	10
Carex lacustris	lakebank sedge	5
Carex lasiocarpa var. americana	wiregrass sedge	10
Carex oligosperma	bog wiregrass sedge	10
Carex stricta	tussock sedge	10
Typha augustifola	narrow-leaf cat-tail	1

The method requires the identification of species that cover 20% or more of the vegetative community. If more than one vegetative community is being assessed, then the species for each community should be evaluated separately, and a weighted average for all communities within the WAA determined. Users should be familiar with the Native Plant Communities of Minnesota for the Laurentian Mixed Forest Providence and the Eastern Broadleaf Forest Province (MNDNR 2003a,b). A list of plant communities associated with peatlands can be found in Appendix B. While the plant communities identified were developed specifically for Minnesota, they are also applicable throughout the Reference domain for assessment purposes. If more local vegetative communities have been identified and documented, then they should be used and documented on field data sheets. Once the weighted average is calculated for each vegetative community, the weighted average for the combined vegetative communities is based on the percentage of the WAA covered by each community. Applying the combined weighted average for the WAA, Figure 13 is used to determine the subindex for V_{COMP}.

The procedure used to sample and measure dominance and determine V_{COMP} is described in Chapter 3. V_{COMP} is used in the Biogeochemical cycling, Maintence of characteristic plant communities, and Wildlife habitat functions.

These calculations are made within the spreadsheet calculator when percent cover by species for each vegetative community is identified.

Figure 13. Relationship between the weighted average P-value of all plant communities within the WAA and functional capacity for vegetation composition (V_{COMP}).



Functions

The following sequence is used to present and discuss each function:

1. Definition: Defines the function.
2. Rationale for selecting the function: Provides the rationale for why a function was selected and discusses onsite and offsite effects that may occur as a result of lost functional capacity.
3. Characteristics and processes that influence the function: Describes the characteristics and processes of the wetland and the surrounding landscape that influence the function and lay the groundwork for the description of assessment variables.
4. Functional capacity index (FCI): Describes the equation from which the FCI is derived and discusses how assessment variables interact to influence functional capacity.

Function 1: Water storage

Definition

When water inputs exceed water outputs in a wetland, water is stored. All wetlands at least temporarily store water within the soil and/or above the soil surface. In its simplest terms, water storage can be estimated as the product of the wetland surface area and the mean depth of free water within the wetland (although corrections can be made for the space occupied by soil particles and soil textures). Therefore, an independent measure of water storage is a measure of the water volume (e.g., m^3) within the wetland. Volumetric water storage within a wetland changes in time (i.e., daily, seasonally, annually), and consequently water storage could be defined and measured as a rate (e.g., m^3/yr). However, quantifying water storage as a rate for a reference standard set of many wetlands for assessment method development is impractical due to time and budget constraints and is even more impractical to quantify for a rapid assessment procedure. To quantify water storage as a volume is more practical and can be simplified for the purposes of rapid assessment for sub-boreal peatlands in the Reference domain.

For the purpose of this guidebook, water depth above and below the organic soil surface is used as an indicator of water storage. Previous studies support this decision. Hauer et al. (2002) and Cook and Hauer (2007) measured water storage in 20 and 37 depression wetlands, respectively, comparing two methods. One method measured water storage using three-dimensional contour maps created from intensively surveyed theodolite data from wetland basins. The other method estimated storage from surface area and mean depth of wetland basins. Comparisons of the two methods using regression analysis and t-tests found there was no difference in water storage volume estimates. These results provide evidence that the critical measurement in determining water volume was water depth. For this guidebook, water depth is measured as the depth of free water above or below the soil (organic soil) surface.

Rationale for selecting the function

The capacity of peatlands to store water is critical to the integrity of the ecosystem. Wetland hydrology is probably the single most important determinant of the establishment and maintenance of specific types of wetlands and wetland processes (Mitsch and Gosselink 2007). Water sources within peatlands vary, with organic flats having primary water inputs from precipitation and slopes having primary water inputs from groundwater. However, despite these differences in water sources, all peatlands typically have water depths at or near the soil surface nearly all year. Wetlands with relatively stable water depths at the soil surface have low decomposition rates and deep accumulations of organic soils. Wetlands typically have higher rates of vegetation productivity than rates of decomposition. Productivity is typically high because there is relatively high availability of resources for plant growth (i.e., light, nutrients, water). Characteristic hydrologic, physical, chemical, and biotic processes are altered when the wetland hydrologic regime changes. Disruptions of the characteristic hydrologic regime of these wetlands has the potential to alter, for example, the quality of water flowing to adjacent wetlands and water bodies by

- changing the period, season, and intensity of anaerobic conditions that drive many of the biogeochemical cycles
- creating conditions favorable for colonization of plants that are less efficient at retaining recycled nutrients
- altering characteristic concentrations of dissolved and suspended materials.

Alterations to the hydrologic regime modify the rate at which water moves between the surface water and groundwater, thereby affecting the groundwater level. Groundwater provides offsite baseflow and recharges the aquifer.

Therefore, for the purpose of rapid assessment for this guidebook, it is assumed that the measure of water depth from the soil surface provides a reliable and simple measure of water storage volume of sub-boreal peatlands. However, compared with other wetland types, peatlands consistently have the greatest accumulation of organic material primarily as a result of very low decomposition rates and relatively stable hydrologic regimes (i.e., water storage rates, water storage volumes, water depths).

Characteristics and processes that influence the function

For the purpose of the water storage function, it is assumed that site-level anthropogenic alterations are the primary cause of reduced functional capacity for peatlands within the Reference domain. Specifically, alterations that influence water storage include ditches, tiling, damming, groundwater extraction, and land use changes such as mining, farming, grazing, or haying within a wetland and adjacent uplands.

Anthropogenic alterations that increase or decrease water depth within a peatland beyond what is observed in referenced standard peatlands reduce the functional capacity of the wetland. A ditched or tiled peatland will have a lower free-water surface and store less water than before it was ditched or tiled, and the functional capacity for drained peatlands will be reduced. However, a peatland storing more water than reference standard levels (e.g., incoming ditches, tiling, or damming surface water outflows) will store water more like that of a pond or lake.

Reference standard peatlands had water depths consistently near the soil surface, between 5 to –5 cm (2 to –2 in.) throughout the growing season. Other reference wetlands were observed to have additional direct hydrologic inputs from pumping, incoming ditches, drainage tiles, or increased water storage from damming or were suspected to have additional hydrologic inputs indirectly from surrounding impervious surfaces (e.g., roads and urban development) or agriculture in adjacent uplands. These peatlands consistently had water depths near 20 cm (8 in.) above the soil surface. Another direct increase in water depth could occur for peatlands having fill material placed within the wetland. If the fill material displaces the water within the peatland to increase water depth. However, the effect of the placement of fill material in peatlands having no natural surface-water outlets is likely to be greater than in peatlands with natural surface-water outlets. The natural surface-water outlets would allow water depths to return to near normal depths. Indirect hydrologic inputs from changes in adjacent land cover from native vegetation to urban and agricultural uses can also increase water depths in wetlands. Runoff as overland flow is greater from impervious surfaces (e.g., roads, parking lots, roofs) and agricultural lands than from native vegetation.

Reference wetlands that were observed to be drained by ditching or tiling consistently had water depths 25 cm (10 in.) below the soil surface. Ditches and tiling can have direct or indirect effects on water depths within a wetland. Direct effects occur when ditches and tiling are placed within a wetland, and indirect effects can occur when ditches and tiling are outside the wetland in areas that impact surface and groundwater hydrology within the wetland. For both direct and indirect scenarios, ditch and tile density and depth are related to water storage functions.

Other less obvious onsite characteristics that could alter the functional capacity of a peatland to store water are roads and the removal of trees within and adjacent to peatlands. Road construction usually includes the placement and compaction of construction material to form a solid base for vehicles and typically has a lower hydraulic conductivity than existing substrates reducing water flow. Roads without culverts act as dams or levees and impede the flow of surface and groundwater moving into or through the peatland. Water depths were consistently higher on the hydrological up-gradient side of the road than on the down-gradient side of the road in Reference wetlands. Therefore, it can be expected that peatlands on both sides of the road will function at lower functional capacity than they would without the obstruction. Similarly, roads adjacent to the peatland may also restrict water inputs from ground water or surface water as overland flow and reduce the functional capacity of water storage.

FCI

The following variable is used to determine the FCI for the water storage function:

Water depth (V_{WD})

Reference standard peatlands have relatively stable water depths near the soil surface, and water depths can vary directly and indirectly with many natural and anthropogenic characteristics. The formula for calculating the FCI for water storage is given in Equation 1. The variable used for calculating the FCI for water storage depends on the depth of water in the peatland. Water storage in peatlands is typically altered by one of two types of management. They are typically flooded or drained, but not both. However, cranberry bogs and rice paddies are an exception that are both flooded and drained at different times of the year.

$$FCI = V_{WD} \tag{1}$$

The FCI relies on using water depth as an indicator of the capacity of a peatland to store water. Measuring water depth for V_{WD} uses the soil surface as the datum from which depth is measured.

If a peatland appears to have no direct anthropogenic alterations to hydrology (i.e., there are no obstructions to natural water storage or flow, no dams, no impoundments, no roads within the wetland, and there are no incoming or outgoing ditches and tiles), then Equation 1 should be used to assess the water storage function. V_{WD} is the mean water depth measured within the WAA or each partial wetland assessment area (PWAA) (See Chapter 3, Assessment Protocol, for more details.). In the absence of anthropogenic alterations to peatland hydrology, water depth for reference standard peatlands was consistently within 5 cm (2 in.) above or below the peat surface. Therefore, in the absence of any apparent anthropogenic hydrologic alteration, water depth is expected be measured between +5 and –5 cm (+2 and –2 in.), and the FCI would be 1.0. However, water depths can vary naturally beyond the observed +5 to -5 cm (+2 and –2 in.) range and can change daily (with extreme precipitation events), seasonally (summer and winter), and annually (wetter than normal and drier than normal years). Therefore, in the absence of any direct anthropogenic alterations to peatland hydrology and if water depth is beyond the +5 to –5 cm range (+2 and –2 in.), assessors should look to extreme weather or climate patterns and indirect alterations to hydrology from changes in adjacent land use for explanations and mitigation strategies to increase the storage capacity. Chapter 5 of the *Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Northcentral and Northeast Region* (V2.0) (USACE 2010) describes methods for evaluating extreme weather conditions.

Function 2: Biogeochemical cycling

Definition

The function is defined as the characteristic biotic and abiotic processes of peatlands that alter the concentration and form of imported nutrients and compounds in the wetland. These processes include conversion of nutrients and other elements and compounds from one form into another by assimilation into plant biomass, remineralization of those materials when the plant materials decompose, long-term storage of nutrients and compounds in mineral and organic soil fractions, and oxygen production. This includes the capacity of a peatland to sequester and store both carbon (C) and methylmercury (MeHg). MeHg sequestration is the ability of peatland to retain atmospheric mercury (Hg) which is converted by anaerobic sulphate-reducing bacteria to toxic MeHg. Hg enters the peatland from the atmosphere through precipitation, attached to dust particles, in plant foliage, and runoff from surrounding uplands and is converted to MeHg by sulphate-reducing bacteria under anaerobic conditions typically found in peatlands. Potential independent, quantitative measures that may be used in validating the FCI include direct measures of net annual productivity (g/m^2), annual accumulation of organic matter (g/m^2), annual decomposition of organic matter (g/m^2), amount of MeHg per volume of organic soil (e.g., ng/g) within the wetland or the transport of MeHg to surrounding environments (Mitchell et al. 2009).

Rationale for selecting the function

Biogeochemical functions are recognized as a primary function that must be considered in relationship to wetlands impacts (USEPA 2008; Mitsch and Gosselink 2007). A sustained supply of organic C in the soil provides for maintenance of the characteristic plant community including annual primary productivity, composition, and diversity (Bormann and Likens 1970; Whittaker 1975; Perry 1994). The plant community (producers) provides the food and habitat structure (energy and materials) needed to maintain the characteristic animal community (consumers) (Crow and MacDonald 1978; Fredrickson 1978; Wharton et al. 1982). In time, the plant and animal communities serve as a source of detritus that provides energy and materials needed to maintain the characteristic community of decomposers. The decomposers break down organic materials into simpler elements and compounds that can re-enter the nutrient cycle (Reiners 1972; Dickinson and Pugh 1974; Pugh and Dickinson 1974; Schlesinger 1977; Singh and Gupta 1977; Hayes 1979; Harmon et al. 1986; Vogt et al. 1986).

The sequestration and storage of MeHg is of particular importance because it is a potent neurotoxin that can be concentrated in peatland ecosystems and released through natural or anthropogenic disturbance. Peatlands function as nutrient sinks within many ecosystems. In intact peat, Hg remains sequestered with the organic matter and does not appreciably leach during seasonal aerobic and anaerobic cycles (Boening 2000). Disturbances not only release previously stored MeHg but produced significantly more MeHg than in undisturbed wetlands (Boening 2000; Grigal et al. 2000; Grigal 2003).

Characteristics and processes that influence the function

Biogeochemical cycling is a function of biotic and abiotic processes that result from conditions within and around the wetland. In wetlands, C is stored within, and cycled among, four major compartments: a) the soil, b) primary producers such as vascular and nonvascular plants, c) consumers such as animals, fungi, and bacteria, and d) dead organic matter, such as leaf litter or woody debris, referred to as detritus. Biogeochemical cycling often focuses on organic C cycling and is probably best known through the processes of plant photosynthesis and respiration. Oxygen (O) is needed for respiration, and the rate of diffusion of O in water is 1/10,000th of that in air. Wetland plants, called hydrophytes, are unique in that they have adapted to living in water or wet soil environments. Physiological adaptations in leaves, stems, and roots allow for greater gas exchange, permit respiration to take place, and allow the plant to harvest the stored chemical energy it has produced through photosynthesis. Although there is no clear starting or ending point for C cycling, it can be argued that it is the presence and duration of water in the wetland that determines the characteristic plant community of hydrophytes. In turn, it is the maintenance of the characteristic primary productivity of the plant community that sets the stage for all subsequent transformations of energy and materials at each trophic level within the wetland. It follows that alterations to hydrologic inputs, outputs, or storage, and/or changes to the characteristic plant community will directly affect the way in which the wetland can perform this function. The unique combination of hydrologic, geomorphic and climatic conditions that make the accumulation of organic soils possible also make these areas sinks and potential sources of MeHg, which attaches to the organic soil particles and is temporarily immobilized and stored.

Abiotic processes affecting retention and cycling of C are dependent primarily on the adsorption of materials to soil particles, the amount of water that passes through the wetland carrying dissolved C, the hydroperiod or retention time of water that maintains anaerobic conditions, and the importation of materials from surrounding areas (Grubb and Ryder 1972; Federico 1977; Beaulac and Reckhow 1982; Ostry 1982; Shahan 1982; Strecker et al. 1992). Natural soils, hydrology, and vegetation are important factors in maintaining these characteristic processes.

The ability of a peatland to perform this function also depends upon hydrologic conditions that maintain a water table near or slightly above the soil surface. A very shallow water table slows O from entering the soil, maintaining anaerobic conditions favorable for the bacteria that convert Hg to MeHg, and preventing transport of MeHg to other aquatic ecosystems.

Impoundment that leads to greater inundation of the peatland increased MeHg concentrations in an experimental system (Heyes et al. 2000). Vegetation also absorbs airborne Hg and contributes Hg to the peatland when leaf litter or needles fall from trees or when herbaceous organic material is incorporated into the organic soils of the peatland. Runoff from adjacent uplands carry Hg attached to organic particles or clay size soil particles. These soil particles settle out near the wetland edge accumulating more Hg than the interior. The wetland edge typically has a shorter hydroperiod and may become dry, releasing MeHg into aquatic ecosystems, while the interior portions of the wetland remain saturated near the soil surface.

The ideal approach for assessing biogeochemical cycling in a peatland would be to measure the rate at which C is transferred and transformed between and within trophic levels or measure the amount of MeHg accumulating and being transported from the peatland to surrounding ecosystems over several years. However, the time and effort required to make these measurements are well beyond a rapid assessment procedure. Reference data suggest that land use practices and current treatments within the wetland have great effect on the characteristic plant community structure (species composition and coverage), diversity, and primary productivity. Changes in hydrology through drainage, increased surface water flow, ponding, or changes to vegetation composition can have a direct and pronounced effect on the accumulation and decomposition of soil organic matter. Soil organic matter is a characteristic that affects soil oxidation-reduction reactions. Soil alterations also change the physical features to which native plants have adapted. Drainage increases the rate of decomposition of soil organic matter and, over time, changes the vegetative composition and, therefore, the type and amount of detrital matter that can store MeHg. It is assumed that measurements of these characteristics reflect the level of C cycling and the sequestration and storage of MeHg taking place within a wetland.

FCI

The following variables are used to determine the FCI for biogeochemical cycling:

- water table depth (V_{WD})
- vegetation composition (V_{COMP})

The formula for calculating the FCI for the function biogeochemical cycling in peatlands is given in Equation 2. The equation is equally dependent of the hydrology and the vegetation within the wetland.

$$FCI = \left(V_{WD} \times V_{COMP}\right)^{1/2} \tag{2}$$

In this equation, changes in the biogeochemical cycling capacity of peatlands relative to reference standard conditions depend on increased or decreased water depth or composition of vegetation communities. The FCI is based on the assumption that if natural hydrology and vegetation are in place, and anthropogenic hydrologic disturbance is not present in the peatland, then biogeochemical cycling will occur at an appropriate rate. In the first part of the equation, V_{WD} represents changes to the natural hydrologic regimes resulting in removal or retention of water. In contrast, if the vegetation composition deviates from that found under the least disturbed natural conditions, then abnormal amounts of C may accumulate or decompose in the wetland, and the FCI is reduced.

The two parts of the equation are combined using a geometric mean. The implications are that if one of the variables equals zero, then the function would receive an FCI of zero.

Function 3: Maintenance of characteristic plant communities

Definition

This function is defined as the degree to which a peatland supports a plant community that is similar in composition and quality to that found on reference standard peatlands in the Reference domain. Because this is a direct measure and comparison of the vegetative communities to reference standard sites, additional independent, quantitative measure of this function is not necessary.

Rationale for selecting the function

The ability to maintain a characteristic peatland plant community is important in part because of its uniqueness. In the peatland landscape, the dominant community type can range from all herbaceous species, shrubs, forest, moss, or any combination (MNDNR 2003a,b). Across the Reference domain, the dominant community types are hardwood forest and mixed hardwood/conifer forest. The peatland subclass constitutes a small percentage of the Reference domain. Because many plant species do not occur in other landforms, their maintenance and abundance are linked to the subclass. The presence of a characteristic plant community is also critical in maintaining various biotic and abiotic processes occurring in wetlands. For example, plant communities are the source of primary productivity, produce C and nutrients that may be exported to other ecosystems, and provide habitats and refugia necessary for various animal species (Harris and Gosselink 1990).

Overview of plant communities

The plant communities of peatlands are complex and vary across the landscape. Sites that have been relatively undisturbed for decades or hundreds of years are composed of moss, sedges, shrubs, or trees of various sizes and ages and generally show predictable species composition. Several vegetative communities have been described in peatlands. The MNDNR provides a comprehensive guide to the native plant communities of Minnesota (MNDNR 2003a,b). Several classes of wetland plant communities have been combined into this assessment method (Appendix B). Depending on the species that initially occupy a site after a major disturbance, succession can progress along different paths. The community at a recently disturbed site may be composed of only a few colonizing invasive species.

Factors that influence the plant community

Factors that influence the development and maintenance of a characteristic plant community in most wetlands including peatlands include physical site characteristics, hydrologic regime, fire frequency and intensity, weather events, anthropogenic disturbances (e.g., plowing), and various ecological processes such as competition, disease, browsing pressure, shade tolerance, and community succession. Alteration to these factors or processes in the wetland or to the landscape surrounding a wetland may directly affect the species composition and biodiversity of the site.

An appropriate hydroperiod is one of the most important factors necessary for the development and maintenance of a characteristic plant community. In peatlands, water delivery occurs as direct precipitation, groundwater discharge, and/or overland flow from the surroundings uplands (see Function 1). Activities that degrade the physical nature of a peatland, especially its hydroperiod, have the potential to have deleterious effects on the plant community and, if significant enough, may alter the plant community for extended periods and even permanently. For example, depositing fill in a wetland fundamentally changes the substrate and hydrologic regime and, if amounts are substantial, can result in conversion of the area from wetland to nonwetland. If the site is allowed to revegetate, the plant community probably will be composed of a different suite of species, likely those with less tolerance for wetness (i.e., FACU and UPL (Lichvar and Kartesz 2009)).

Alterations in adjacent or nearby areas can also have serious negative consequences for peatland plant communities. For example, clearing the natural vegetation in the upland watershed and adding impervious surfaces (roads, parking lots, etc.) can result in significantly more water entering a wetland and likely would shift the community to one dominated by more flood-tolerant species, such as cattail (*Typha spp.*). If the mean water depth increases beyond the ability of even these species to survive, the area essentially would become an open water basin with emergent vegetation existing only at the edges.

Alterations of hydrology creating either wetter conditions (e.g., impoundment) or drier conditions (e.g., artificial drainage) can promote invasion by exotics such as narrow-leaf cattail (*Typha angustifolia*), glossy buckthorn (*Frangula alnus*), or reed canary grass (*Phalaris arundinacea*), resulting in significant changes in the species composition of peatlands.

Davenport and others (2014) showed that plowing fens reduces total species, native graminoids, and shrub richness and increases invasive species. Fire occurs periodically in peatlands and can play a role in shaping the plant community. Fire intensity rather than fire frequency may be the primary factor that influences the plant community.

FCI

The following variable is used to determine the FCI for the plant community function: vegetation composition (V_{COMP}).

The assessment equation for calculating the FCI for the plant community function in peatlands is given in Equation 3. The FCI depends on the weighted average of the mean P-value for each plant community in the wetland assessment area WAA.

$$FCI = V_{COMP} \tag{3}$$

This equation represents the existing plant communities in the WAA and includes one variable that provides insight into its species composition, diversity, and stability. The equation assumes that the physical environment necessary to maintain the community (e.g., hydrology, soil characteristics) is also present. If not, any recent environmental changes that may affect the long-term persistence of the community should be reflected in reduced FCI for the Water Storage function. In the context of this function, the vegetation composition variable (V_{COMP}) reflects floristic quality, as well as seral stage and disturbance. For this function to receive a score of 1.0, the weighted mean of all peatland communities must ≥9. For this function to have an FCI value of zero, the weighted mean of all peatland plant communities would have to be zero. For this to occur, the WAA would have to be absent of vegetation (e.g., pavement or bare ground) or completely dominated by species with FACU and UPL wetland plant status (e.g., *Aralia nudicaulis*).

Function 4: Provide wildlife habitat

Definition

This function is defined as the capacity of a peatland to provide critical life requisites to selected components of the vertebrate wildlife community. Wetlands within the subclasses provide habitat for numerous species of amphibians, reptiles, birds, and mammals. Birds and amphibians were selected as the focus of this function. Birds were chosen because they are of considerable public and agency interest and they respond rapidly to changes in the quality and quantity of their habitats. In addition, birds are a diverse group, and individual species have strong associations with the different strata that characterize reference standard peatlands. Birds have been shown to be sensitive indicators and integrators of environmental change such as that brought about by human use and alteration of landscapes (Morrison 1986; Croonquist and Brooks 1991; O'Connell et al. 2000). Amphibians were chosen because of the importance of peatlands as breeding habitat. Various species of salamanders and frogs breed in a variety of habitats including shallow streams, wetlands that pond water, and even moist duff or leaf litter. In the adult stages, they often disperse into suitable habitat in the adjacent uplands.

A potential independent, quantitative measure of this function (Smith et al. 2013) is abundance of peatland specialist bird species (Calmé et al. 2002) and amphibian species richness and abundance. Data requirements for assessment validation include direct monitoring of wildlife communities using appropriate techniques for each taxon. Ralph et al. (1993) described field methods for monitoring bird populations. Gibbons and Semlitsch (1981) described procedures for sampling small animals including reptiles and amphibians. Heyer et al. (1994) and Dodd (2003) described monitoring procedures for amphibians.

Rationale for selecting the function

Wetlands are recognized as valuable habitats for a diversity of animal species including both vertebrates and invertebrates. Songbirds, such as Nelson's sparrow (*Ammodramus nelsoni*) and palm warbler (*Setophaga palmarum*), are associated with peatlands within the Reference domain. Further, because birds are highly mobile, they serve as a transfer mechanism for nutrients and energy from wetlands to other ecosystems. Several small mammals, including the southern bog lemming (*Synaptomys cooperi*) and water shrew (*Sorex palustris*), also are closely associated with wetlands and similar environments. Amphibians are common in most wetland ecosystems, but many are secretive and seldom seen. In some situations, they can be extremely abundant. Burton and Likens (1975) reported that amphibians constitute the single largest source of vertebrate biomass in some ecosystems. Because many amphibians require both wetland and adjacent upland habitats, they serve as a conduit for energy exchange between the two systems (Mitchell et al. 2004). Wharton et al. (1982), Johnson (1987), Whitlock et al. (1994), Crowley et al. (1996), Mitsch and Gosselink (2007), and Kingsbury and Gibson (2012) are good sources of information regarding animal communities of wetlands.

Many wildlife species associated with wetlands have experienced population declines. Within the United States, approximately one-third of the plant and animal species listed as threatened or endangered are associated with wetlands during some part of their life cycles (Dahl and Johnson 1991). Wetlands constitute a relatively small percentage of the landscape within the Reference domain, and the adjacent uplands in many areas are dominated by agricultural land, managed forests, and residential and commercial development. Therefore, peatlands likely are important for the maintenance of local populations of many species.

Overview of the wildlife community

Within the Reference domain, numerous game and nongame species from four vertebrate classes commonly use peatlands for shelter, as breeding or foraging areas, or as sources of drinking water. This general discussion includes information about reptiles and mammals although, as noted previously, birds and amphibians are the focus of the wildlife function.

Over 100 species of birds utilize peatland habitat in the Reference domain, including sandhill crane (*Grus canadensis*). Several mammals use peatlands within the Reference domain, including moose (*Alces alces*), white-tailed deer (*Odocoileus virginianus*), black bear (*Ursus americanus*), otter (*Lontra canadensis*), and mink (*Neovison vison*). Small mammals such as mice, voles, and shrews often use a variety of habitats, but two, the northern bog lemming (*Synaptomys borealis*) and heather vole (*Phenacomys intermedius*), tend to be associated with peatlands in the Reference domain (Glaser 1987; Nordquist 1992).

Characteristics and processes that influence the function

Hydrologic alterations to peatlands have the potential to impact a number of wildlife species. Animals with direct dependence on water, such as amphibians that use peatlands for reproduction, are highly vulnerable to filling or to wetland drainage (e.g., by ditching) for human developments. Even partial draining or filling could impact breeding activity because of the length of time needed for egg development and maturation of the young. There is considerable variability in development time among species. Most anurans require the presence of water for 2 to 3 months (Duellman and Trueb 1986). Some species, however, require substantially shorter periods of time. Conversely, artificially increasing the amount of time that surface water is present in a wetland by excavating or by augmenting runoff into the wetland can potentially reduce the suitability for amphibians by allowing fish populations to become established. Kingsbury and Gibson (2012) noted that predatory fish prey on breeding amphibians, their eggs, and tadpoles. They recommended that wherever wetlands free of fish exist, efforts should be made to avoid accidental or deliberate introductions.

Besides the direct effects of hydrologic change on animals, indirect effects can occur through changes in the plant community. Sites with unaltered hydrology that have not been subjected to significant disturbance for long periods support a characteristic vegetation composition and structure as described in the Plant community function. Wildlife species have evolved with and adapted to these conditions. Thus, altering the hydroperiod has the potential to change the composition and structure of the wildlife community. Factors other than hydrology, including droughts and catastrophic storms, fire frequency and intensity, competition, disease, browsing pressure, shade tolerance, community succession, and natural and anthropogenic disturbances also affect the plant community directly and the wildlife community indirectly.

Habitat structure is one of the most important determinants of wildlife species composition and diversity (Wiens 1969; Anderson and Shugart 1974; Niemi and Hanowski 1992). This is especially well documented with birds that tend to show affinities for habitats based on physical characteristics, such as the size and density of overstory trees, density of shrub and ground cover, and other factors. MacArthur and MacArthur (1961) first documented the positive relationship between the vertical distribution of foliage (i.e., the presence of different layers or strata) and avian diversity, and other researchers have since corroborated their findings. Hunter (1990) provides a good overview of the importance of forest plant community structure to wildlife.

Land use surrounding the wetland also has a major impact on the wetland wildlife community. Historically, the Reference domain was largely forested, and the wildlife community evolved in a landscape with wetlands surrounded by vast tracts of forests. Human activities have dramatically altered the Reference domain, and much of the area is now devoted to crop production and pasture, residential and commercial developments, and other open land uses. Consequently, peatlands now often occur as isolated patches within an open landscape matrix. Adverse effects of the fragmentation of formerly forested landscapes have been well documented for avian species and communities (Askins et al. 1987; Keller et al. 1993; Kilgo et al. 1997) and for reptiles and amphibians (Laan and Verboon 1990; Semlitsch 1998; Rothermel and Semlitsch 2002; Kingsbury and Gibson 2012). Research into the effects of fragmentation on mammals has also been completed (Nilon 1986; VanDruff and Rowse 1986; Nilon and VanDruff 1987).

Biological and genetic diversity are reduced as habitat fragmentation and urbanization occur in an area. Larger and more specialized animal species, especially those having large home ranges, are affected from the onset of the fragmentation (VanDruff et al. 1996). Habitat specialists are often the first to be extirpated from an area or region. Eventually, however, even generalist species are impacted if fragmentation is extreme. Urbanization often accompanies habitat fragmentation. Urbanization reduces the number of native wildlife species in an area while increasing the abundance of exotic species (VanDruff et al. 1996; McKinney 2002).

Semlitsch and Jensen (2001) noted that suitable terrestrial habitat surrounding the breeding site is critical for feeding, growth, maturation, and maintenance of juvenile and adult populations of pond-breeding salamanders. Kingsbury and Gibson (2012) concurred, stating that "a seasonal wetland without appropriate surrounding upland habitat will lose its amphibian and reptile fauna." Semlitsch and Jensen (2001) suggested that the terrestrial habitat be referred to as part of the "core habitat" used by the animals, because it is as essential as the breeding site itself. This is different from the traditional concept of the "buffer zone" commonly recommended around wetlands to protect various wetland functions (Boyd 2001).

Semlitsch and Bodie (2003) reviewed the literature on terrestrial habitats used by amphibians. Habitat features such as leaf litter were important for foraging, refuge, or over-wintering. Shade and litter (for refuge and food) were considered to be essential habitat features. The abundance of litter is related to the age of forest stands. The litter layer in an older forest usually is much thicker than in a younger forest due to the differential amount of foliage produced. Young stands do not begin to contain significant amounts of litter and coarse woody debris until natural thinning begins. Shade, which is critical to some amphibian species in slowing or preventing dehydration (Spight 1968; Rothermel and Semlitsch 2002), is provided to some extent in all forest stands but likely is not effective until tree canopies begin to close (Rothermel and Semlitsch 2002). In the absence of more specific information regarding how amphibians might respond to different conditions, it is assumed here that nearly all forested areas, savannas, shrub habitats, and native grasslands will provide at least minimally suitable terrestrial habitat for dispersing amphibians. Managed pine forest is considered suitable only if soils, litter, and ground-layer vegetation have not been disturbed extensively (e.g., by bedding) such that cover has been eliminated and animal movement impeded. Areas devoted to row crops and closely mowed or grazed pastures are not suitable (Boyd 2001).

In addition to the structural characteristics of contiguous habitats, the size of such areas also is important to many amphibian and reptile species. The width of suitable contiguous habitat needed for any given wetland area depends upon a number of variables including wetland size, topography, climate, surrounding land use, and the species of herpetofauna present (Semlitsch and Jensen 2001). Boyd (2001) compiled information regarding animal use of areas adjacent to wetlands to evaluate the adequacy of the Massachusetts Wetland Protection Act. She concluded that the 30 m (100 ft) buffer required by the Act provided protection for 77% of the species known to be dependent on wetlands but recommended that even larger areas be considered because numerous species sometimes travel much greater distances. Semlitsch and Bodie (2003) synthesized the literature on terrestrial habitats used by amphibians and reptiles associated with wetlands and concluded that core terrestrial habitat extends 159–290 m (522–950 ft) from the wetland edge for most amphibians and 127–289 m (417–948 ft) for most reptiles, although some species may move much farther. For example, certain frogs sometimes move up to 1,600 m (5,250 ft) from the aquatic edge. The mean maximum distances moved (calculated from numerous studies of various herpetofauna) for various groups included 218 m (715 ft) for salamanders considered separately from other amphibians, 368 m (1,207 ft) for frogs, 304 m (997 ft) for snakes, and 287 m (942 ft) for turtles.

Terrestrial areas immediately adjacent to wetlands are also important to the integrity of the wetland ecosystem itself. Such areas serve to reduce the amounts of silt, contaminants, and pathogens that enter the wetland and to moderate physical parameters such as temperature (Rhode et al. 1980; Young et al. 1980; Hupp et al. 1993; Snyder et al. 1995; Daniels and Gilliam 1996; Semlitsch and Jensen 2001; Semlitsch and Bodie 2003). These functions directly or indirectly affect amphibians through improved water quality and provide benefits to the entire wildlife community. Semlitsch and Bodie (2003) recommended a 30–60 m (100–200 ft) wide "buffer" around the wetland for this purpose alone.

Birds are also known to be impacted adversely by habitat fragmentation due to increased predation, nest parasitism by the brown-headed cowbird (*Molothrus ater*), and possibly other factors (Askins et al. 1987; Keller et al. 1993; Kilgo et al. 1997). Several of the species associated with peatlands and adjacent forests within the Reference domain are considered “interior” (Hamel 1992) or “area-sensitive” species (Robbins et al. 1989). Area-sensitive species tend to have lower reproductive output in smaller habitat patches, or they simply avoid small patches altogether. While landscape considerations are important for birds as well as amphibians, there is a substantial difference in scale, with patch size requirements for some individual bird species exceeding 5,000 ha (12,355 acres). In spite of that very large value, most impacts on birds are thought to occur relatively close to an edge (within 100–300 m (328–984 ft)) (Brittingham and Temple 1983; Strelke and Dickson 1980; Wilcove 1985).

FCI

The following variables are used to determine the FCI for the Provide wildlife habitat function:

- wetland tract area (V_{TRACT})
- interior core area (V_{CORE})
- habitat connections ($V_{CONNECT}$)
- surrounding land use ($V_{LANDUSE}$)
- water depth (V_{WD})
- vegetation composition (V_{COMP}).

The assessment equation for calculating the FCI for the Provide wildlife habitat function in peatlands depends, in part, on the size of the wetland. If the size of the wetland tract is ≥100 ha (247 acres), then Equation 4 is used. If the size of the wetland is <100 ha (247 acres), then Equation 5 is used. Both equations combine four variables, but Equation 5 substitutes $V_{CONNECT}$ and $V_{LANDUSE}$ for V_{TRACT} and V_{CORE}.

$$FCI = \left[V_{WD} \times V_{COMP} \times \left(\frac{V_{TRACT} + V_{CORE}}{2} \right) \right]^{1/3} \tag{4}$$

$$FCI = \left[V_{WD} \times V_{COMP} \times \left(\frac{V_{CONNECT} + V_{LANDUSE}}{2} \right) \right]^{1/3} \tag{5}$$

Both of these equations are assumed to reflect the ability of peatlands to provide critical life requisites for wildlife, with an emphasis on amphibians and birds. If the variable subindex scores are similar to those found under reference standard conditions, then it is likely that the entire complement of amphibians and birds characteristic of peatlands within the Reference domain will be present.

The first part of each equation is an expression of the hydrologic integrity of the wetland and involves the variable V_{WD}. In the context of this function, a characteristic hydrologic regime is essential as a source of water for breeding amphibians and to support the plant community upon which the animal community depends. The second part of the equations reflects seral stage, cover potential, food production potential, nest-site potential, availability of dispersal habitat, and other factors that depend on stand structure, maturity, and connectivity represented by V_{COMP}. The final part of Equation 4 uses the average of V_{TRACT} and V_{CORE}, which represents the availability of suitable habitat within large peatland complexes. Species that depend on large areas of wetland habitat can usually move to adjacent areas of the wetland to avoid many types of wetland disturbance and impacts. As large peatland complexes become fragmented by roads or altered by conversion to other types of land use, these large complexes are converted to smaller areas; wildlife species dependent on these large wetland areas are unable to move to adjacent areas, and the interior areas that are isolated from surrounding impacts are lost. The final part of Equation 5 uses the average of $V_{CONNECT}$ and $V_{LANDUSE}$, which represents the availability of suitable habitat beyond the wetland boundary. This terrestrial buffer helps protect wetland water quality, provides critical habitat for some species of amphibians, and is important in protecting some species of birds from nest predators and nest parasites. Hydrologic integrity, vegetative composition, and surrounding land use are each assumed to be critical to providing wetland wildlife habitat in both equations; therefore, each component is used as a multiplier in the equation. The three parts of the equation are combined using a geometric mean. The implications are that if one of the three parts of the equation equals zero, then the function would receive an FCI of zero.

3 Assessment Protocol

Introduction

Previous chapters of this regional guidebook document the variables, measures, and models used to assess the functions of peatlands in the Northcentral and Northeastern Region. This chapter outlines a protocol for collecting and analyzing the data necessary to assess the functional capacity of a wetland in the context of a Section 404 permit review or similar assessment scenario. The typical assessment scenario is a comparison of preproject and postproject conditions in the wetland. In practical terms, this translates into an assessment of the functional capacity of the WAA under both preproject and postproject conditions and the subsequent determination of how FCI have changed as a result of the project. Data for the preproject assessment are collected under existing conditions at the project site, while data for the postproject assessment are normally based on the conditions expected to exist following proposed project impacts. A conservative and well-documented approach is required in defining postproject conditions. This recommendation is based on the often-observed lack of similarity between predicted or engineered postproject conditions and actual postproject conditions. This chapter discusses each of the following tasks required to complete an assessment of peatlands:

1. Define assessment objectives.
2. Characterize the project area.
3. Screen for red flags.
4. Define the Wetland Assessment Area.
5. Determine the wetland subclass.
6. Collect the data.
7. Analyze the data.
8. Apply assessment results.

Define assessment objectives

Begin the assessment process by unambiguously identifying the purpose of the assessment. This can be as simple as stating "The purpose of this assessment is to determine how the proposed project will impact wetland functions." Other potential objectives could be as follows:

1. Compare several wetlands as part of an alternatives analysis.
2. Identify specific actions that can be taken to minimize project impacts.
3. Document baseline conditions at a wetland site.
4. Determine mitigation requirements.
5. Determine mitigation success.
6. Determine the effects of a wetland management technique.

Frequently, multiple reasons are identified for conducting an assessment. Carefully defining the purpose(s) facilitates communication and understanding among the people involved in the assessment and makes the goals clear to other interested parties. In addition, defining the purpose helps to clarify the approach that should be taken. The specific approach will vary to some degree depending upon whether the project is a Section 404 permit review, an Advanced Identification (ADID), Special Area Management Plan (SAMP), or some other scenario.

Characterize the project area

Characterizing the project area involves describing the area in terms of pertinent factors such as climate, surficial geology, geomorphic setting, surface and groundwater hydrology, vegetation, soils, land use, proposed impacts, and any other characteristics and processes that have the potential to influence how wetlands in the project area perform functions. The characterization should be written and accompanied by maps and figures that show project area boundaries, jurisdictional wetlands, the boundaries of the WAA (discussed later in this chapter), proposed impacts, roads, ditches, buildings, streams, soil types, plant communities, threatened or endangered species habitat, and other important features. Some sources of information useful in characterizing a project area are aerial photographs, topographic and National Wetlands Inventory (NWI) maps, and county soil surveys.

Screen for red flags

Red flags are features within or in the vicinity of the project area to which special recognition or protection has been assigned on the basis of objective criteria (Table 4). Many red flag features, such as those based on national criteria or programs, are similar from region to region. Other red flag features are based on regional or local criteria. Screening for red flag features represents a proactive attempt to determine if the wetlands or other natural resources in and around the project area require special consideration or attention that may preempt or postpone an assessment of wetland functions. An assessment of wetland functions may not be necessary if the project is unlikely to occur as a result of a red flag feature. For example, if a proposed project has the potential to impact a threatened or endangered species or habitat, an assessment of wetland functions may be unnecessary since the project may be denied or modified strictly on the basis of the impacts to threatened or endangered species or habitat.

Table 4. Red flag features and respective program/agency authority.

Red Flag Features	Authority[1]
Native Lands and areas protected under American Indian Religious Freedom Act	A
Hazardous waste sites identified under CERCLA or RCRA	I
Areas protected by a coastal zone management plan	E
Areas providing critical habitat for species of special concern	B, C, F
Areas covered under the Farmland Protection Act	K
Floodplains, floodways, or floodprone areas	J
Areas with structures/artifacts of historic or archeological significance	G
Areas protected under the Land and Water Conservation Fund Act	K
Areas protected by the Marine Protection Research and Sanctuaries Act	B, D
National wildlife refuges and special management areas	C
Areas identified in the North American Waterfowl Management Plan	C, F
Areas identified as significant under the RAMSAR Treaty	H
Areas supporting rare or unique plant communities	C, H
Areas designated as sole-source groundwater aquifers	I, L
Areas protected by the Safe Drinking Water Act	I, L
City, County, State, and National Parks	D, F, H, L
Areas supporting threatened or endangered species	B, C, F, H, I
Areas with unique geological features	H
Areas protected by the Wild and Scenic Rivers Act	D
Areas protected by the Wilderness Act	D

[1]Program Authority/Agency

A = Bureau of Indian Affairs

B = National Marine Fisheries Service

C = U.S. Fish and Wildlife Service

D = National Park Service

E = State Coastal Zone Office

F = State Departments of Natural Resources, Fish and Game, etc.

G = State Historic Preservation Office

H = State Natural Heritage Offices

I = U.S. Environmental Protection Agency

J = Federal Emergency Management Agency

K = Natural Resources Conservation Service

L = Local Government Agencies

Define the WAA

The WAA is an area of wetland within a project area that is relatively homogeneous with respect to the site-specific criteria used to assess wetland functions (e.g., hydrology, vegetation structure, habitat). In many project areas, there will be just one WAA representing a single regional ecosystem assessment method (e.g., Peatlands of the Northcentral and Northeast Region), as illustrated in Figure 14. However, as the size and heterogeneity of the project area increase, it may be necessary to define and assess multiple WAA within the project area.

At least three situations necessitate defining and assessing multiple WAA within a project area. The first situation exists when widely separated wetland patches defined by the same regional assessment occur in the project area (Figure 15). The second situation exists when more than one regional assessment method is necessary to assess different ecosystems (e.g., riverine wetlands and peatlands) within a project area (Figure 16). The third situation exists when a physically contiguous wetland area defined by the same regional assessment exhibits spatial heterogeneity with respect to hydrology, vegetation, soils, disturbance history, or other factors that translate into a significantly different value for one or more of the site-specific variable measures. These differences may be a result of natural variability (e.g., zonation on large river floodplains) or cultural alteration (e.g., logging, surface mining, hydrologic alterations) (Figure 17). Designate each of these areas as a separate WAA and conduct a separate assessment on each area.

There are elements of subjectivity and practicality in determining what constitutes a significant difference in portions of the WAA. Field experience with the regional wetland subclass under consideration should provide a sense of the range of variability that typically occurs, and the understanding necessary to make reasonable decisions about defining multiple partial wetland assessment areas (PWAA). For example, in peatlands, different plant communities or recent artificial drainage in a portion of a wetland area is criterion for designating two PWAA. The presence of relatively minor differences resulting from natural variability should not be used as a basis for dividing a contiguous wetland into multiple PWAA. However, zonation caused by different hydrologic regimes or disturbances caused by rare and destructive natural events (e.g., ice storms) should be used as a basis for defining PWAA.

Figure 14. A single WAA within a project.

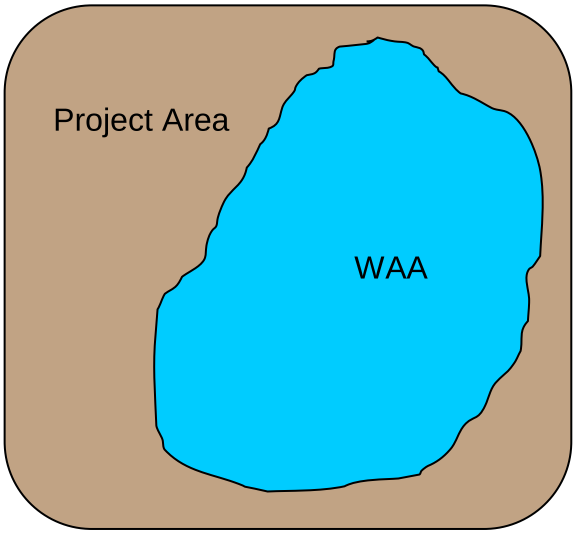


Figure 15. Spatially separated WAA from the same peatland within a project.

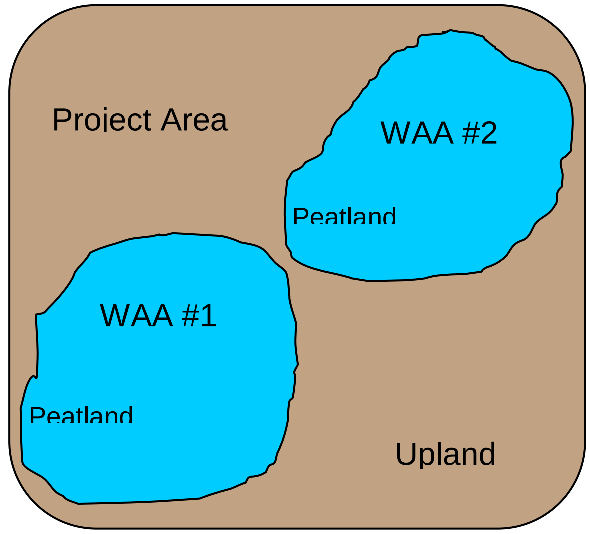


Figure 16. More than one regional assessment method within a project area.

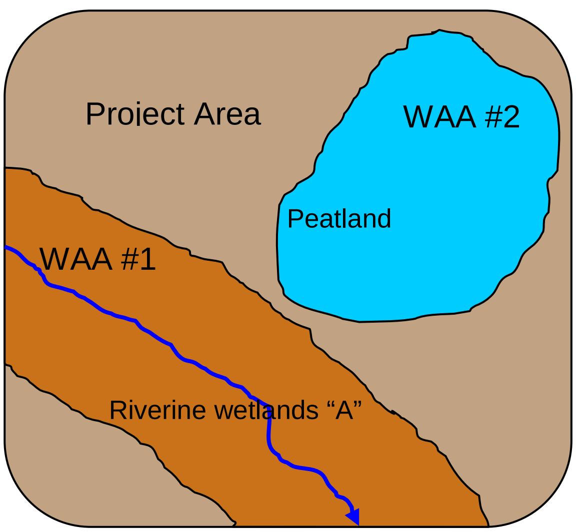
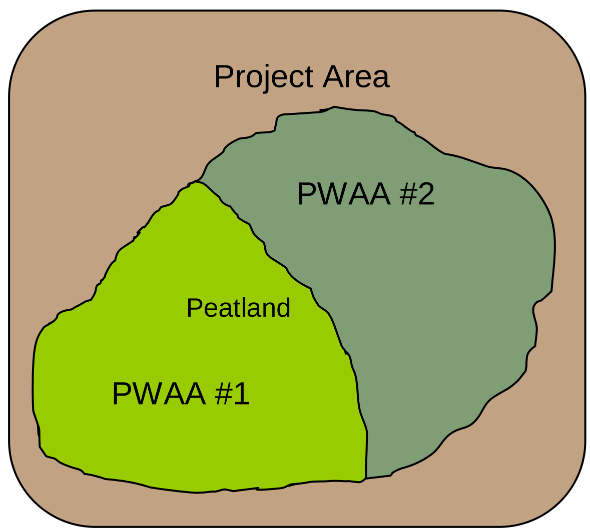


Figure 17. PWAA defined on the basis of differences in site-specific characteristics.



Determine the wetland subclass

This guidebook describes peatlands found across the Northcentral and Northeast (Figure 2). The data for scaling variables in this guidebook were collected in eastern Minnesota and western Wisconsin but should be applicable across the Reference domain. Adjustments to variable scaling should be made following guidance provided in Smith et al. 2013 and Berkowitz et. al. 2014. Determining the correct subclass is essential to completing a meaningful HGM assessment. Subclasses are based on hydrogeomorphic characteristics. Peatlands incorporate organic flats, slopes, and depressions classes. Peatlands in the Reference domain were defined previously as wetlands, dominated by organic soils at least 20 cm (8 in.) thick, that are supported by precipitation, groundwater, and/or runoff inputs from the surrounding uplands and are not dominated by riverine processes. Appendix B: Determining the texture of soil materials high in organic carbon, may be helpful in identifying organic soils and peatlands. Current aerial photographs, topographic maps, soils maps, NWI maps, local knowledge, or other available information can be used to help identify peatlands and distinguish them from riverine (floodplain) systems. In some cases, however, it will not be possible to determine the wetland subclass from remotely sensed data or maps, and onsite investigation will be necessary. Some extremely disturbed sites will be difficult to evaluate even during an onsite examination. In these cases, historical aerial photographs or knowledge of local experts may be helpful in determining the wetland subclass.

Collect the data

The first step in data collection is to identify and delineate the project area and WAA on aerial photographs and topographic maps. The most recent and highest quality images and maps available must be used. It usually will be necessary to verify decisions made from photo interpretation in the field during field reconnaissance.

Variables used to assess wetland functions were defined and discussed in Chapter 2. Variable data is collected at various spatial scales. The first four variables (V_{TRACT}, V_{CORE}, $V_{CONNECT}$, and V_{SLUSE}) are variables that describe conditions within or near the wetland or WAA. These variables are evaluated using aerial photographs, maps, and field reconnaissance of the area surrounding the WAA. A walking reconnaissance of the WAA or PWAA is needed to evaluate V_{WD} and V_{COMP}. In some cases, detailed, site-specific data collected within sample plot(s) or subplots at representative locations within the WAA are needed to determine V_{WD} and V_{COMP}. The data sheets shown in Figure 18 are organized to facilitate data collection at each spatial scale. Instructions for measuring each variable are given below.

Figure 18. Field data sheet for peatland wetland.

Ver. 1-22-2015

FCI/FCU Calculator for the Northcentral and Northeastern Peatlands Guidebook

In the yellow cells enter the project name, location, and the number of the Wetland Assessment Area (WAA) being sampled. Use the drop down menus to indicate whether this WAA represents the Project Site or Mitigation Site, before project or after project. Then go to the Data Entry tabs to enter WAA data (WAA Data Entry Tab) and individual field measurements for each plot (Plot Data Entry Tabs). For information on determining how to split a project into WAAs, see "Organic Slope, Flats and Depressional Wetlands of the Northcentral and Northeastern Region" (Noble *et al.*, 2015).

Site Type and Timing (select from dropdown):

Project Name:

Location:

Sampling Dates:

WAA number:

V_{TRACT}: Size of Peatland containing the WAA (ha):

(that is not separated by 50m (164 ft) on unsuitable habitat).

WAA size (ha):

Division of WAA into PWAAs:

WAA is divided into PWAAs based on community type. Fill out PWAA information below, starting with PWAA1 and not skipping rows. One PWAA tab will need to be completed for each:

PWAA Number	Community Type Name or Designation	Size (ha)
1		
2		
3		
4		
5		

Please Fill Out Site and Project Information Above

Functional Results Summary:

Function	Functional Capacity Index	Functional Capacity Units
Water Storage		
Biogeochemical Cycling		
Plant Community		
Wildlife Habitat		

Variable Subindex Summary:

Variable	Name	Subindex
V_{TRACT}	Wetland Tract Area	
V_{CORE}	Interior Core Area	
$V_{LANDUSE}$	Weighted average of surrounding landuse scores.	
$V_{CONNECT}$	Weighted average of scores for wetland perimeter connected to suitable habitat of different widths.	
V_{WD}	Average depth of water above organic soil surface.	
V_{COMP}	Vegetation composition score. Weighted average of the C-values for dominant plants (≥20% aerial cover), regardless of strata.	

Figure 18. Field data sheet for peatland wetland (Continued).

Northcentral & Northeastern Peatlands HGM Field Data Sheet and Calculator
Site and WAA Data Form

Team:		UTM Easting:	
Project Name:		UTM Northing:	
Location:		Sampling Date:	
WAA Number:		WAA Size(ha):	

Sample Variables 1-4 for the entire WAA using aerial photography, topographic maps, soil survey maps, etc.

1	**V_{TRACT}**	Area of continuous peatlands, including the WAA, accessible to wildlife. (Used only of tracts 100 ha or greater) This variable is entered on the FCI Calculator page so the WAA may be divided into PWAA Communities.	Enter On FCI Tab
2	**V_{CORE}**	Percent of the wetland tract within a buffer of 300 m.	
		Size of peatland tract including the WAA (ha) (Recorded on the FCI Calculator Tab).	Enter On FCI Tab
		Size of Core area at least 300 m from the edge of the wetland tract.	
3	**$V_{CONNECT}$**	Weighted average of scores for wetland perimeter connected to suitable habitat of different widths. (Used only in on peatland tracts <100 ha.) Enter a 0 if a given buffer width range isn't present in the wetland.	
		Length of wetland perimeter (meters) with a buffer at least 150 m wide (1)	
		Length of wetland perimeter (meters) with a buffer ≥30 m and <150 m wide (0.66)	
		Length of wetland perimeter (meters) with a buffer ≥10 m and <30 m wide (0.33)	
		Length of wetland perimeter with a buffer <10 m wide (0)	
		Total wetland perimeter	
4	**V_{SLUSE}**	Surrounding Landuse. Weighted average of habitat score for surrounding area 500 m beyond buffer. (Used only in peatlands <100 ha). Soils determination is not required.	

Land Use (Choose From Drop List)	Habitat Score	% in Surround-ing Area	Running Percent (not >100)

Notes:

Figure 18. Field data sheet for peatland wetland (Continued).

Northcentral & Northeastern Peatlands HGM Field Data Sheet and Calculator
Partial Wetland Assessment Area Data Form

Team:		UTM Easting:	
Project Name:		UTM Northing:	
Location:		Sampling Date:	
WAA Number:	PWAA Number: of	PWAA Size (ha):	
Plant Community Type:			

Sample Variables 5 and 6 within the PWAA.

5 V_{WD} Average depth of water above (positive numbers) or below (negative numbers) the level of the soil surface (cm). Measure in 3 - 8 representative locations within the PWAA.

6 V_{COMP} Weighted average of the C-values for plants that have ≥20% aerial cover, regardless of strata. If no species have 20% cover, check the box and use the percent cover of the 5 most common species and the percent of bare ground. Total cover can exceed 100% because of overlap within strata or multiple strata. The contributions of each species toward the weighted average will depend on the total aerial cover listed, but if there are species with 20% cover, additional speices with <20% cover will not be considered in the cover or V_{COMP} calculations. Bare ground will not be assumed, and must be listed. If a species is not available in the drop down list, it may be added in the yellow cells. Species with asterisks have a modified C-value.

☐ **Check here if no species have ≥20% cover.**

Plant Scientific Name (choose from drop down)	Indicator Status	Common Name	C-Value	Aerial Cover	Relative Cover	Contribution

Variable	Value	VSI
V_{TRACT}		
V_{CORE}		
$V_{CONNECT}$		
$V_{LANDUSE}$		
V_{WD}		
V_{COMP}		

Notes:

Landscape-scale and wetland-scale variables

Wetland tract area (V_{TRACT})

Measure/Units: Size of the contiguous wetland area measured in hectares. Paved roads, regional canals, and discontinuities are considered breaks in a wetland tract. Use the following procedure to measure V_{TRACT}:

1. Determine the total wetland area in hectares using field reconnaissance, topographic maps, aerial photographs, and/or GIS techniques.
2. Record the total wetland area on the field data sheet or calculator. If the wetland tract area is <100 ha (247 acres), then this variable and V_{CORE} are not used in FCI calculations. Proceed to the measure of $V_{CONNECT}$. If V_{TRACT} is ≥100 ha (247 acres), then proceed to the measure of V_{CORE}.

Interior core area (V_{CORE})

Measure/Units: Percentage of the interior of the wetland tract within a 300 m (990 ft) buffer. Use the following procedure to measure V_{CORE}:

1. This variable is only used if V_{TRACT} is ≥100 ha (247 acres).
2. Using field reconnaissance, topographic maps, aerial photographs, or GIS techniques, measure the area within a 300 m (990 ft) buffer from the wetland tract boundary.
3. Determine the size of the interior core area in hectares. Record the total wetland area on the field data sheet or calculator. The calculator will determine the percentage of core area.
4. If the calculator is not used, then calculate the percentage of V_{CORE} by dividing the interior core area by V_{TRACT} and multiply by 100.

Habitat connections ($V_{CONNECT}$)

Measure/Units: Weighted average of the wetland's perimeter and width that is connected to suitable habitat. Use the following procedure to measure $V_{CONNECT}$:

1. This variable is only used if V_{TRACT} is <100 ha (247 acres).
2. Determine the total length in meters of the wetland perimeter using field reconnaissance, topographic maps, aerial photographs, or GIS techniques.
3. Determine the length of the wetland perimeter that has suitable habitat that is >150 m (492 ft) wide. Enter the length of the wetland perimeter into the calculator. If the entire perimeter has suitable habitat >150 m (492 ft)

wide, then the subindex score is 1.0, and the rest of the steps can be skipped. If less than the entire length has suitable habitat >150 m (492 ft) wide, continue with step 4. If no suitable habitat exists that is greater than 150 m (492 ft) wide, 0.0 should be entered into the appropriate cell in the calculator.

4. Determine the length of wetland perimeter with suitable habitat with a width ≥30 m and ≤150 m (98.4–492 ft). Enter the length of the wetland perimeter into the calculator. If no suitable habitat exists for this zone, 0.0 should be entered into the appropriate cell in the calculator.
5. Determine the length of wetland perimeter with suitable habitat with a width ≥10 m and <30 m (32.8–98.4 ft) wide. If no suitable habitat exists for this zone, 0.0 should be entered into the appropriate cell in the calculator.
6. Enter the remaining length of the wetland perimeter that has not been accounted for in the previous buffer zones into the last cell in the calculator for $V_{CONNECT}$.
7. The calculator will determine the weighted average percent habitat connectivity, and the variable subindex will be calculated automatically.
8. If the calculator is not used, the weighted average will need to be calculated, and then use Figure 8 and 9 to convert the weighted average to a subindex score for $V_{CONNECT}$.

Surrounding land use ($V_{LANDUSE}$)

Measure/Units: Weighted average of surrounding land use score for the zone 500 m (1640 ft) wide outside the 150 m (492 ft) $V_{CONNECT}$ zone that provides potential adjacent wildlife habitat to the peatland. Use the following procedure to measure $V_{LANDUSE}$:

1. This variable is only used if V_{TRACT} is <100 ha (247 acres).
2. Use topographic maps or other sources to delineate the area outside the 150 m (126 ft) $V_{CONNECT}$ zone that is 500 m (1640 ft) wide.
3. Using GIS techniques, recent aerial photos, or field reconnaissance, determine the percentage of the V_{SLUSE} zone represented by each combination of land use categories shown in Table 3.
4. If using the calculator, select the land use category from the drop-down menu on the spreadsheet calculator, and enter the percent in catchment in the yellow cell. Continue until the running percentage equals 100. Runoff scores, the weighted average, and the variable subindex score will be calculated automatically.

5. If not using the calculator, determine the Habitat score for each land use category present outside the 150 m (492 ft) $V_{CONNECT}$ zone and inside the 500 m (1640 ft) buffer (Table 3).
6. Determine a weighted (by area) average runoff score for the catchment.
7. Use Figure 7 to determine the subindex score for V_{LSLUSE}.

Wetland-scale or plot-scale variables

1. Identify vegetative communities within the wetland or WAA as separate PWAAs.
2. Using the same methods for vegetation sampling as described in the Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Northcentral and Northeast Region, Section 2 Hydrophytic Vegetation Indicators, Guidance on vegetation sampling and analysis, identify plant species that make up 20% or more of each PWAA.

Vegetation composition (V_{COMP})

Measure/Units: Weighted average of the P-value score of the plant communities within the WAA. Use the following procedure to measure V_{WD}:

1. Identify the plant communities within the WAA; if more than one plant community is present, sample as separate PWAA.
2. Within each PWAA, identify and record the species and percent cover of all species, including sphagnum moss, that have 20% or more aerial cover regardless of strata across the entire plant community being assessed. When vegetation cover is high, the percent cover of the species listed may sum to >100% due to overlapping foliage. If no species covers at least 20% of the PWAA, then identify the five most common species as well as the percentage of bare ground. Defined plots are not necessary; however, if greater repeatability or documentation is necessary, then one or more 0.04 ha (0.1 acre) plot(s) can be placed in representative locations within the PWAA depending on the size and complexity of the plant community. If multiple plots are used, the percent cover of each species should be averaged across all plots. Additional information related to the number, size, and shape of plots can be found in Appendix B.
3. Assign the P-value score for each species identified.
4. Using the percent areal cover and P-value for each species, determine the weighted average for each PWAA sampled.

5. If the WAA includes more than one PWAA, weight the results of step 4 by the percentage of the WAA covered by each PWAA to determine the subindex score for the WAA.
6. Or, select the vegetative composition section on the spreadsheet calculator. The percent cover of each PWAA in the WAA will automatically be added. Insert all of the species identified using the procedure described above or select from the dropdown menu for each plant community, and the weighted average and variable subindex will be calculated automatically.

Water depth (V_{WD})

Measure/Units: Weighted average depth of surface water or depth to the water table. Use the following procedure to measure V_{WD}:

1. Measure the height of the surface water or depth to the water table from the soil surface at a minimum of three representative locations within each plant community identified within the WAA. If the water is above the soil surface, measure the depth of water. If the water table is below the soil surface, excavate a small hole to a depth of 40 cm (16 in.) and measure the depth to the water table. A peat corer is an excellent tool for excavating organic soils, but a tile spade, large diameter soil probe, peat sampler, or other tools can be used. It is recommended that if the soil is excavated, the vegetation data should be collected before the depth to the water table is measured in the soil pits to allow the water table to equilibrate. The density of peat at the peat surface in inundated peatlands is usually very low, and the boundary between the peat surface and the standing water can be diffuse. Care must be taken to measure from the peat surface where the peat has an abrupt increase in density. The peat surface is easily depressed by your body weight. To avoid making erroneous measurements, measure water depth away from where you are standing.
2. Average all measurements and use Figure 12 to determine the subindex score for V_{WD}. The calculator will provide a weighted average score for V_{WD} based on the weighted average of the size of the vegetative communities.

Analyze the data

The first step in analyzing the field data is to transform the field measure of each assessment variable into a variable subindex on a scale of 0 to 1.0. This can be done using the assessment calculator or the graphs and tables in Chapter 2. The second step is to insert the variable subindices into the equations for each function and calculate the FCI. This can be done manually or automatically using an assessment calculator. Finally, multiply the FCI for each function by the total size of the WAA to calculate the number of functional capacity units (FCU) for each function (Smith et al. 2013.

Apply assessment results

Once the assessment and analysis phases are complete, the results can be used to compare the level(s) of function in the same WAA at different points in time or in different WAA at the same point in time. The information can be used to address the specific objectives identified at the beginning of the study, such as a) determining project impacts, b) comparing project alternatives, c) determining mitigation requirements, and d) evaluating mitigation success.

To evaluate project-related impacts, at least two assessments will generally be needed. The first assesses the number of FCU provided by the wetland in its preproject condition. The second assesses the number of FCU provided by the wetland in a postproject state, based on proposed project plans and the associated changes to each of the assessment variables. The difference between preproject and postproject conditions, expressed in numbers of FCU, represents the potential loss or gain of functional capacity due to the project. Similarly, in a mitigation scenario, the difference between the current condition and future condition of a wetland, with mitigation actions implemented and successfully completed, represents the potential gain in functional capacity as a result of restoration activities. However, since the mitigation project is unlikely to become fully functional immediately upon completion, a time lag should be incorporated into the analysis to account for the time necessary for the mitigation site to achieve full functional development.

For more information on the calculation of FCU and their use in project assessments, see Smith et al. (2013). Spreadsheets that can be used to help evaluate project impacts and estimate mitigation requirements are available on the web at http://el.erdc.usace.army.mil/wetlands/datanal.html. The spreadsheets were developed by Frank Hanrahan based on concepts presented by the U.S. Fish and Wildlife Service (1980) and King and Adler (1992).

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Appendix A: Glossary

Assessment model: A model that defines the relationship between ecosystem and landscape scale variables and functional capacity of a wetland. The model is developed and calibrated using reference wetlands from a Reference domain.

Assessment objective: The reason an assessment of wetland functions is conducted. Assessment objectives normally fall into one of three categories: documenting existing conditions, comparing different wetlands at the same point in time (e.g., alternatives analysis), and comparing the same wetland at different points in time (e.g., impacts analysis or mitigation success).

Assessment team (A-Team): An interdisciplinary group of regional and local scientists responsible for classification of wetlands within a region, identification of reference wetlands, construction of assessment models, definition of reference standards, and calibration of assessment models.

Catchment: The geographic area where surface water would flow or run off into the headwater wetland.

Direct measure: A quantitative measure of an assessment variable.

Exotics: See **Invasive species**.

Facultative species (FAC): Commonly occurs as either a hydrophyte or nonhydrophyte.

Facultative upland species (FACU): Occasionally is a hydrophyte, but usually occurs in uplands.

Facultative wetland species (FACW): Usually is a hydrophyte, but occasionally found in uplands.

Functional assessment: The process by which the capacity of a wetland to perform a function is measured. This approach measures capacity using a variable or combinations of variables to determine a functional capacity index.

Functional capacity index (FCI): An index of the capacity of a wetland to perform a function relative to other wetlands in a regional wetland subclass. FCI are by definition scaled from 0.0 to 1.0. An index of 1.0 indicates the wetland is performing a function at the highest sustainable functional capacity, the level equivalent to a wetland under reference standard conditions in a Reference domain. An index of 0.0 indicates the wetland does not perform the function at a measurable level and will not recover the capacity to perform the function through natural processes.

Functional capacity: The rate or magnitude at which a wetland ecosystem performs a function. Functional capacity is dictated by characteristics of the wetland ecosystem and the surrounding landscape, and interaction between the two.

Highest sustainable functional capacity: The level of functional capacity achieved across the suite of functions performed by a wetland under reference standard conditions in a Reference domain. This approach assumes the highest sustainable functional capacity is achieved when a wetland ecosystem and the surrounding area are undisturbed.

Hummock: A low mound, ridge, or microtopographic high. In wet areas, plants growing on hummocks may avoid some of the deleterious effects of inundation or shallow water tables.

Hydrogeomorphic wetland class: The highest level in the hydrogeomorphic wetland classification. There are five basic hydrogeomorphic wetland classes: depression, riverine, slope, fringe, and flat.

Hydroperiod: The annual duration of flooding (in days per year) at a specific point in a wetland.

Indicator: Observable characteristics that correspond to identifiable variable conditions in a wetland or the surrounding landscape.

Invasive species: Generally, exotic species without natural controls that out-compete native species.

Jurisdictional wetland: Areas that meet the soil, vegetation, and hydrologic criteria described in the *Corps of Engineers Wetlands Delineation Manual* (Environmental Laboratory 1987) or its successor. Not all wetlands are regulated under Section 404.

Mitigation: Restoration or creation of a wetland to replace functional capacity that is lost as a result of project impacts.

Obligate upland (UPL): Rarely is a hydrophyte, almost always in uplands.

Obligate wetland (OBL): Almost always is a hydrophyte, rarely in uplands.

Organic matter: Plant and animal residue in the soil in various stages of decomposition.

Organic soil material: Soil material that is saturated with water for long periods or artificially drained and, excluding live roots, has an organic carbon content of 18% or more with 60% or more clay, or 12% or more organic carbon with 0% clay. Soils with an intermediate amount of clay have an intermediate amount of organic carbon. If the soil is never saturated for more than a few days, it contains 20% or more organic carbon.

Oxidation: The loss of one or more electrons by an ion or molecule.

Partial wetland assessment area (PWAA): A portion of a WAA that is identified a priori or while applying the assessment procedure to an area relatively homogeneous and different from the rest of the WAA with respect to one or more variables. Differences may be natural or result from anthropogenic disturbance.

Project alternative(s): Different ways in which a given project can be done. Alternatives may vary in terms of project location, design, method of construction, amount of fill required, etc.

Project area: The area that encompasses all activities related to an ongoing or proposed project.

P-value: category that reflects a plant species' fidelity to peatlands within the reference domain.

Red flag features: Features of a wetland or surrounding landscape to which special recognition or protection is assigned on the basis of objective criteria. The recognition or protection may occur at a Federal, State, regional, or local level and may be official or unofficial.

Reduction: The gain of one or more electrons by an ion or molecule.

Reference domain: All wetlands within a defined geographic area that belong to a single regional wetland subclass.

Reference standards: Conditions exhibited by a group of reference wetlands that correspond to the highest level of functioning (highest sustainable capacity) across the suite of functions of the regional wetland subclass. By definition, highest levels of functioning are assigned an index of 1.0.

Reference wetlands: Wetland sites that encompass the variability of a regional wetland subclass in a Reference domain. Reference wetlands are used to establish the range of conditions for construction and calibration of functional indices and to establish reference standards.

Region: A geographic area that is relatively homogeneous with respect to large-scale factors such as climate and geology that may influence how wetlands function.

Regional wetland subclass: Regional hydrogeomorphic wetland classes that can be identified based on landscape and ecosystem scale factors. There may be more than one regional wetland subclass for each of the hydrogeomorphic wetland classes that occur in a region, or there may be only one.

Site potential: The highest level of functioning possible, given local constraints of disturbance history, land use, or other factors. Site capacity may be equal to or less than levels of functioning established by reference standards for the Reference domain, and it may be equal to or less than the functional capacity of a wetland ecosystem.

Soil surface: The soil surface is the top of the mineral soil; for soils with an Organic horizon, the soil surface is the top of the part of the Organic horizon that is at least slightly decomposed. Fresh leaf or needle fall that has not undergone observable decomposition is excluded from soil and may be described separately (Carlisle 2000).

Variable subindex: A measure of how a variable in a wetland compares to the reference standards of a regional wetland subclass in a Reference domain.

Variable: An attribute or characteristic of a wetland ecosystem or the surrounding landscape that influences the capacity of the wetland to perform a function.

Watershed: The geographic area that contributes surface runoff to a common point, known as the watershed outlet.

Wetland assessment area (WAA): The wetland area to which results of an assessment are applied.

Wetland ecosystems: In Section 404 of the Clean Water Act: “areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas” (Corps Regulation 33 CFR 328.3 and EPA Regulations 40 CFR 230.3). In a more general sense, wetland ecosystems are three-dimensional segments of the natural world where the presence of water at or near the surface creates conditions leading to the development of redoximorphic soil conditions and the presence of a flora and fauna adapted to the permanently or periodically flooded or saturated conditions.

Wetland functions: The normal activities or actions that occur in wetland ecosystems, or simply, the things that wetlands do. Wetland functions result directly from the characteristics of a wetland ecosystem and the surrounding landscape and their interaction.

Wetland: In Section 404 of the Clean Water Act: “areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal conditions do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.” The presence of water at or near the surface creates conditions leading to the development of redoximorphic soil conditions and the presence of a flora and fauna adapted to the permanently or periodically flooded or saturated conditions.

Appendix B: Supplementary Materials

This appendix contains additional guidance on measuring variables. It is designed to provide tools and direction to aid in collection of variables. This appendix contains the following:

1. Plant species and P-value for reference sites – Table B1
2. Comparison of Minnesota Dept. of Natural Resources (MDNR) plant communities and HGM subclasses for peatlands – Table B2
3. Plot size and shapes – Figure B1
4. Comparison charts for visual estimates of plant cover – Figures B2 and B3 herbaceous cover
5. Determining the texture of soil materials high in organic carbon.

Plant list

Table B1 is a list of dominant plant species identified during the data collection for the peatlands guidebook. This list can be used to aid in species identification. Common names are from USDA Plants Data Base (http://plants.usda.gov/).

Table B1. A list of the dominant plant species identified during the data collection for the peatlands guidebook.

Species	Common Name	Strata	P-value
Acer negundo	ash-leaf maple	shrub	1
Acer rubrum	red maple	canopy	3
Acer spicatum	mountain maple	herbaceous	1
Agrostis gigantea	black bent	herbaceous	1
Agrostis scabra	rough bent	herbaceous	2
Alisma subcordatum	American water-plantain	herbaceous	4
Alnus incana	speckled alder	shrub	10
Ambrosia artemisiifolia	annual ragweed	herbaceous	0
Amorpha fruticosa	false indigo-bush	shrub	4
Amphicarpa bracteata	American hog-peanut	herbaceous	10
Andromeda polifolia	bog-rosemary	shrub	9
Andropogon gerardii	big bluestem	herbaceous	2
Anemone quinquefolia	nightcaps	herbaceous	2
Aralia nudicaulis	wild sarsaparilla	shrub	4
Athyrium filix-femina	subarctic lady fern	herbaceous	4
Barbarea vulgaris	garden yellow-rocket	herbaceous	1

Species	Common Name	Strata	P-value
Betula alleghaniensis	yellow birch	canopy	7
Betula papyrifera	paper birch	canopy	2
Betula pumila	bog birch	shrub	10
Bidens aristosa	bearded beggarticks	herbaceous	3
Brachyelytrum erectum	bearded shorthusk	herbaceous	1
Brasenia schreberi	watershield	herbaceous	7
Calamagrostis canadensis	bluejoint	herbaceous	10
Calamagrostis stricta	slim-stem reed grass	herbaceous	10
Calla palustris	water-dragon	herbaceous	8
Campanula aparinoides	marsh bellflower	herbaceous	5
Carex comosa	bearded sedge	herbaceous	4
Carex gracillima	graceful sedge	herbaceous	2
Carex interior	inland sedge	herbaceous	10
Carex lacustris	lakebank sedge	herbaceous	5
Carex lasiocarpa	woolly-fruit sedge	herbaceous	10
Carex leptalea	bristly-stalk sedge	herbaceous	10
Carex magellanica	boreal-bog sedge	herbaceous	8
Carex oligosperma	few-seed sedge	herbaceous	10
Carex pauciflora	few-flower sedge	herbaceous	10
Carex pellita	woolly sedge	herbaceous	4
Carex rostrata	swollen beaked sedge	herbaceous	8
Carex scoparia	pointed broom sedge	herbaceous	4
Carex sterilis	dioecious sedge	herbaceous	10
Carex stricta	Walter's sedge	herbaceous	10
Carex tetanica	rigid sedge	herbaceous	7
Carex trichocarpa	hairy-fruit sedge	herbaceous	7
Carex trisperma	three-seed sedge	herbaceous	10
Carex utriculata	northwest territory sedge	herbaceous	7
Carpinus caroliniana	American hornbeam	shrub	5
Cerastium fontanum	common mouse-ear chickweed	herbaceous	0
Chamaedaphne calyculata	leatherleaf	shrub	10
Cirsium arvense	Canadian thistle	herbaceous	0
Cirsium muticum	swamp thistle	herbaceous	10
Cirsium vulgare	bull thistle	herbaceous	0
Cladium mariscoides	smooth saw-grass	herbaceous	10
Comandra umbellata	bastard-toadflax	herbaceous	2
Comarum palustre	purple marshlocks	herbaceous	7
Cornus alba	red osier	shrub	3
Cornus obliqua	pale dogwood	shrub	4
Cornus racemosa	gray dogwood	shrub	2
Corylus americana	American hazelnut	herbaceous	1

Species	Common Name	Strata	P-value
Corylus cornuta	beaked hazelnut	shrub	1
Cyperus bipartitus	shining flat sedge	herbaceous	4
Dasiphora frutiocosa	golden-hardhack	herbaceous	7
Didiplis diandra	water-purslane	herbaceous	5
Dryopteris cristata	crested wood fern	herbaceous	7
Dulichium arundinaceum	three-way sedge	herbaceous	8
Echinochloa crus-galli	large barnyard grass	herbaceous	1
Eleocharis palustris	common spike-rush	herbaceous	5
Elymus canadensis	nodding wild rye	herbaceous	0
Epilobium coloratum	purple-leaf willowherb	herbaceous	3
Equisetum arvense	field horsetail	herbaceous	1
Equisetum fluviatile	water horsetail	herbaceous	7
Equisetum sylvaticum	woodland horsetail	herbaceous	10
Erechtites hieraciifolius	American burnweed	herbaceous	0
Erigeron canadensis	Canadian horseweed	herbaceous	0
Eriophorum vaginatum	tussock cotton-grass	herbaceous	10
Eriophorum virginicum	tawny cotton-grass	herbaceous	10
Eutrochium maculatum	spotted trumpetweed	herbaceous	10
Fallopia convolvulus	black-bindweed	herbaceous	0
Fragaria virginiana	Virginia strawberry	herbaceous	1
Fraxinus nigra	black ash	shrub	2
Fraxinus pennsylvanica	green ash	shrub	2
Galium aparine	sticky-willy	herbaceous	1
Galium boreale	Northern bedstraw	herbaceous	4
Galium tinctorium	stiff marsh bedstraw	herbaceous	5
Galium triflorum	fragrant bedstraw	herbaceous	2
Gaultheria hispidula	creeping-snowberry	herbaceous	8
Geum aleppicum	yellow avens	herbaceous	3
Glyceria canadensis	rattlesnake manna grass	herbaceous	7
Glyceria striata	fowl manna grass	herbaceous	10
Gymnocarpium dryopteris	northern oak fern	herbaceous	2
Helianthus grosseserratus	saw-tooth sunflower	herbaceous	1
Humulus lupulus	common hop	herbaceous	0
Hypericum prolificum	shrubby St. John's-wort	herbaceous	0
Ilex verticillata	common winterberry	shrub	6
Impatiens capensis	spotted touch-me-not	herbaceous	2
Juniperus virginiana	eastern red cedar	canopy	0
Kalmia polifolia	bog-laurel	shrub	9
Laportea canadensis	Canadian wood-nettle	herbaceous	3
Larix laricina	American larch	shrub	10
Ledum groenlandicum	rusty Labrador-tea	shrub	10

Species	Common Name	Strata	P-value
Lemna minor	common duckweed	herbaceous	5
Liatris ligulistylis	Rocky Mountain blazing star	herbaceous	2
Lotus corniculatus	Birds-foot trefoil	herbaceous	0
Lycopus uniflorus	northern water-horehound	herbaceous	5
Lythrum salicaria	purple loosestrife	herbaceous	1
Maianthemum canadense	false lily-of-the-valley	herbaceous	4
Maianthemum stellatum	starry false Solomon's-seal	herbaceous	10
Maianthemum trifolium	three-leaf false Solomon's-seal	herbaceous	9
Menyanthes trifoliata	buck-bean	herbaceous	9
Mitella diphylla	two-leaf bishop's-cap	herbaceous	1
Muhlenbergia richardsonis	matted muhly	herbaceous	8
Nabalus alba	White rattlesnake root	herbaceous	2
Nemopanthus mucronatus	catberry	shrub	8
Nymphaea odorata	American white water-lily	herbaceous	6
Onoclea sensibilis	sensitive fern	herbaceous	4
Osmorhiza claytonii	Clayton’s sweetroot	herbaceous	1
Osmunda cinnamomea	cinnamon fern	herbaceous	10
Osmunda regalis	royal fern	herbaceous	10
Panicum capillare	common panic grass	herbaceous	1
Parietaria pensylvanica	Pennsylvania pellitory	herbaceous	0
Parnassia glauca	fen grass-of-Parnassus	herbaceous	9
Parthenocissus quinquefolia	Virginia creeper	herbaceous	1
Persicaria amphibia	water smartweed	herbaceous	4
Persicaria hydropiper	mild water-pepper	herbaceous	1
Persicaria lapathifolia	dock-leaf smartweed	herbaceous	2
Persicaria maculosa	lady's-thumb	herbaceous	1
Persicaria pensylvanica	pinkweed	herbaceous	1
Persicaria sagittata	arrow-leaf tearthumb	herbaceous	4
Phalaris arundinacea	reed canary grass	herbaceous	1
Phegopteris connectilis	narrow beech fern	herbaceous	1
Phleum pratense	common timothy	herbaceous	0
Phragmites australis	common reed	herbaceous	1
Picea mariana	black spruce	shrub	10
Pilea fontana	lesser clearweed	herbaceous	4
Pilea pumila	Canadian clearweed	herbaceous	3
Pinus strobus	eastern white pine	canopy	3
Plantago major	great plantain	herbaceous	0
Poa compressa	Canada bluegrass	herbaceous	0
Poa palustris	fowl blue grass	herbaceous	5
Poa prantensis	Kentucky blue grass	herbaceous	1
Potentilla norvegica	Norwegian cinquefoil	herbaceous	1

Species	Common Name	Strata	P-value
Pycnanthemum virginianum	Virginia mountain-mint	herbaceous	6
Quercus macrocarpa	bur oak	canopy	0
Quercus rubra	northern red oak	canopy	1
Ranunculus hispidus	bristly buttercup	herbaceous	6
Rhamnus cathartica	European buckthorn	shrub	1
Rhynchospora capillacea	needle beak sedge	herbaceous	10
Ribes cynosbati	Eastern prickly gooseberry	shrub	1
Rosa blanda	Smooth rose	shrub	1
Rubus allegheniensis	Allegheny blackberry	herbaceous	1
Rubus arcticus	northern blackberry	herbaceous	9
Rubus idaeus	common red raspberry	herbaceous	4
Rubus pubescens	dwarf red raspberry	herbaceous	10
Rudbeckia hirta	black-eyed Susan	herbaceous	0
Sagittaria latifolia	duck-potato	herbaceous	3
Salix bebbiana	gray willow	shrub	10
Salix discolor	pussy willow	shrub	3
Salix interior	sandbar willow	canopy	2
Salix pedicellaris	bog willow	shrub	8
Salix petiolaris	meadow willow	shrub	10
Salix pyrifolia	balsam willow	shrub	8
Sambucus racemosa	red elder	shrub	0
Sarracenia purpurea	purple pitcherplant	herbaceous	10
Schoenoplectus acutus	hard-stem club-rush	herbaceous	6
Schoenoplectus fluviatilis	river club-rush	herbaceous	4
Schoenoplectus tabernaemontani	soft-stem club-rush	herbaceous	4
Scirpus cyperinus	cottongrass bulrush	herbaceous	10
Scirpus microcarpus	red-tinge bulrush	herbaceous	6
Solidago canadensis	Canadian goldenrod	herbaceous	2
Solidago flexicaulis	zig-zag goldenrod	herbaceous	1
Solidago gigantea	late goldenrod	herbaceous	3
Sonchus arvensis	field sowthistle	herbaceous	0
Sparganium erectum	simple-stem burr-reed	herbaceous	7
Sphagnum spp.	Sphagnum moss	moss	10
Spiraea alba	white meadowsweet	shrub	5
Spiraea tomentosa	steeplebush	herbaceous	7
Stellaria graminea	grass-leaf starwort	herbaceous	0
Stuckenia pectinata	sago false pondweed	herbaceous	3
Symphyotrichum lanceolatum	white panicled American-aster	herbaceous	5
Symphyotrichum puniceum	purple-stem American-aster	herbaceous	10
Thalictrum dasycarpum	purple meadow-rue	herbaceous	10
Thalictrum dioicum	early meadow-rue	herbaceous	1

Species	Common Name	Strata	P-value
Thelypteris palustris	eastern marsh fern	herbaceous	10
Thuja occidentalis	eastern arborvitae	canopy	10
Tilia americana	American basswood	canopy	0
Toxicodendron vernix	poison sumac	shrub	7
Typha angustifolia	narrow-leaf cat-tail	herbaceous	1
Typha latifolia	broad-leaf cat-tail	herbaceous	2
Typha x glauca	cat-tail	herbaceous	1
Ulmus americana	American elm	canopy	3
Urtica dioica	stinging nettle	herbaceous	1
Utricularia macrorhiza	greater bladderwort	herbaceous	5
Vaccinium angustifolium	late lowbush blueberry	shrub	4
Vaccinium macrocarpon	large cranberry	herbaceous	9
Vaccinium oxycoccos	small cranberry	herbaceous	10
Viola cucullata	marsh blue violet	herbaceous	6
Viola macloskeyi	smooth white violet	herbaceous	10
Zizia aptera	heart-leaf Alexanders	herbaceous	1

Minnesota ecological system and HGM subclasses

Table B2 lists classes of Minnesota wetlands, organized by ecological system.

Table B2. Classes of Minnesota wetlands, organized by ecological system. The probable HGM classification is indicated for each wetland community, as well as possible alternative classifications.

Ecological System	Class Code	Class	Slope	Depression	Organic Flat (Subclass: Multiple Water Sources)	Organic Flat (Subclass: Water Source Primarily Precipitation)
Wet Forest						
	WFn53	Northern Wet Cedar Forest	X	X		
	WFn55	Northern Wet Ash Swamp	X			
	WFn64	Northern Very Wet Ash Swamp		X		O
	WFs55	Southern Wet Aspen Forest				
	WFs57	Southern Wet Ash Forest	X			
	WFw54	Northwestern Wet Aspen Forest				
Forested Rich Peatland*						
	FPn62	Northern Rich Spruce Swamp (Basin)		O	X	
	FPn63	Northern Cedar Swamp	X		X	
	FPn71	Northern Rich Spruce Swamp (Water Track)	O		X	
	FPn72	Northern Rich Tamarack Swamp (Eastern Basin)		X	X	
	FPn81	Northern Rich Tamarack Swamp (Water Track)	O		X	
	FPn82	Northern Rich Tamarack Swamp (Western Basin)			X	
	FPs63	Southern Rich Conifer Swamp			X	
	FPw63	Northwestern Rich Conifer Swamp			X	
Acid Peatland*						
	APn80	Northern Spruce Bog				X
	APn81	Northern Poor Conifer Swamp				X
	APn90	Northern Open Bog				X
	APn91	Northern Poor Fen				X

Ecological System	Class Code	Class	Slope	Depression	Organic Flat (Subclass: Multiple Water Sources)	Organic Flat (Subclass: Water Source Primarily Precipitation)
Open Rich Peatland						
	OPn81	Northern Shrub Shore Fen			X	
	OPn91	Northern Rich Fen (Water Track)	X		O	
	OPn92	Northern Rich Fen (Basin)			X	
	OPn93	Northern Extremely Rich Fen	X		O	
	OPp91	Prairie Rich Fen	X		O	
	OPp93	Prairie Extremely Rich Fen	X			
Forested Rich Peatland*						
	FPn73	Northern Rich Alder Swamp		X	X	
Wet Meadow/ Carr						
	WMn82	Northern Wet Meadow/Carr	X			
	WMs83	Southern Seepage Meadow/Carr	X			
	WMs92	Southern Basin Wet Meadow/Carr		O		
	WMp73	Prairie Wet Meadow/Carr	X	O		
Marsh						
	MRn83	Northern Mixed Cattail Marsh		X		
	MRn93	Northern Bulrush-Spikerush Marsh				
	MRu94	Lake Superior Coastal Marsh				
	MRp83	Prairie Mixed Cattail Marsh		X		
	MRp93	Prairie Bulrush-Arrowhead Marsh				
Wetland Prairie						
	WPn53	Northern Wet Prairie	X			
	WPs54	Southern Wet Prairie	X			
Mesic Hardwood Forest						
	MHn44	Northern Wet-Mesic Boreal Hardwood-Conifer Forest	X			

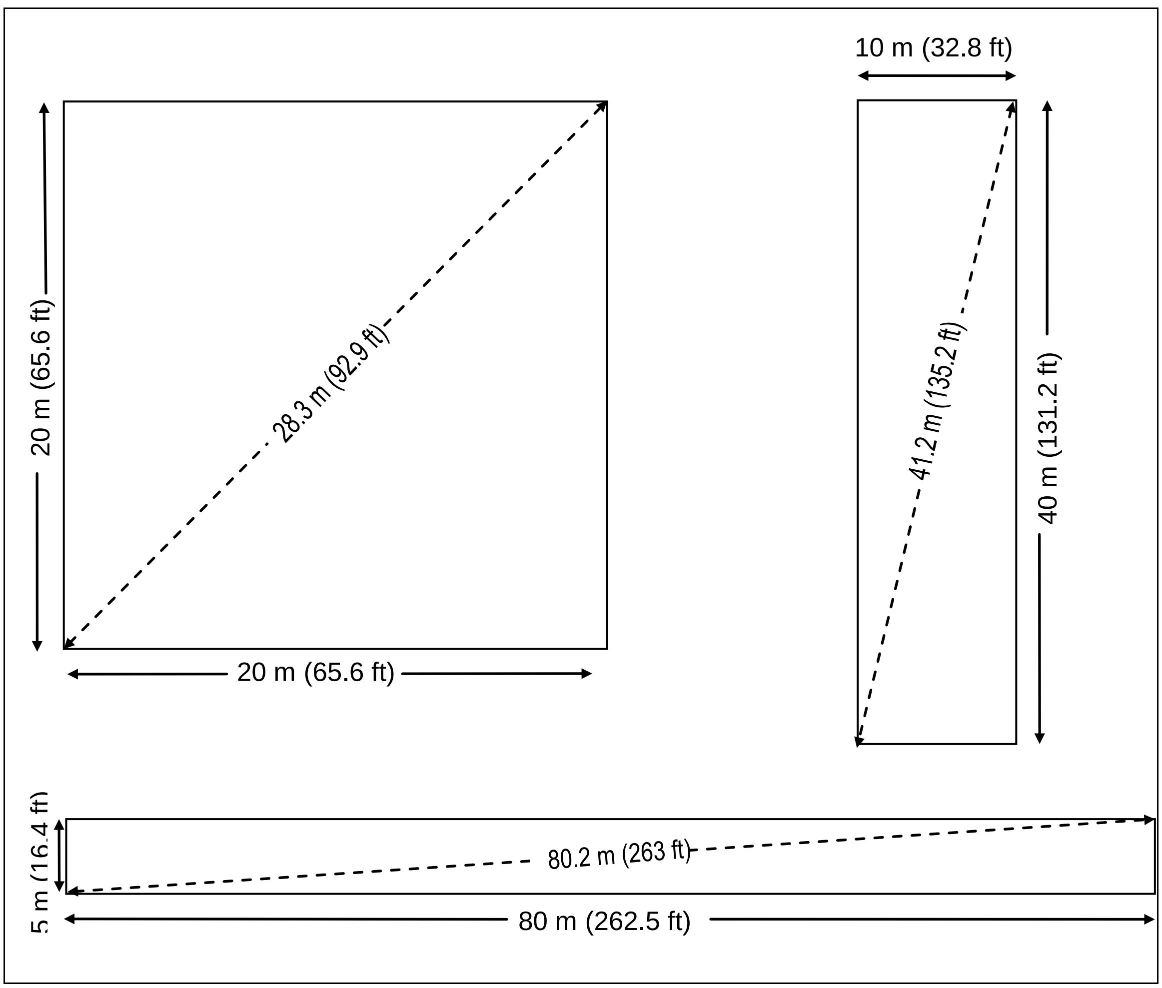
Ecological System	Class Code	Class	Slope	Depression	Organic Flat (Subclass: Multiple Water Sources)	Organic Flat (Subclass: Water Source Primarily Precipitation)
	MHn46	Northern Wet-Mesic Hardwood Forest				
	MHc47	Central Wet-Mesic Hardwood Forest	O			
	MHs49	Southern Wet-Mesic Hardwood Forest				
	MHw36	Northwestern Wet-Mesic Hardwood Forest				

* Ecological system occurs in Wetland Forests and Wetland Grasslands, Shrublands, and Marshes

Vegetation sampling plots

Figure B-1 presents examples of plot shapes that equal 0.04 ha (0.1 acre).

Figure B-1. Examples of plot shapes that equal 0.04 ha (0.1 acre).



A 0.04 ha (0.1 acre) circular plot is usually the easiest to use in an all-herbaceous plant community. Circular plots should have a radius of 11.3 m (37 ft). A square or rectangular plot(s) may be easier to use in plant communities dominated by shrubs or trees. The size and shape of the plant community may require a rectangular plot or some other shape. Figure B1 shows examples rectangular plots measuring 10 × 40 m (33 × 131 ft) and 5 × 80 m (16 × 262 ft), which also cover 0.04 ha (0.1 acre) but may fit better within a narrow, linear plant community. Any combination of plot sizes and shapes that equals 0.04 ha (0.1 acre) is recommended. If the plant community is smaller than 0.04 ha (0.1 acre), the entire community may be sampled.

Visual estimation of cover

The following charts and diagrams contain guidance on estimating percent cover. The following tools can be used to aid in the estimation of vegetation composition (V_{COMP}). The estimation of cover can be difficult and requires practice to achieve repeatable results. The tools provided below can be used to improve accuracy and repeatability. Figure B-2 presents comparison charts for visual estimates of herbaceous cover. Figure B-3 presents comparison charts for visual estimation of foliage cover.

Figure B-2. Comparison charts for visual estimates of herbaceous cover (Gretag/Macbeth 2000).

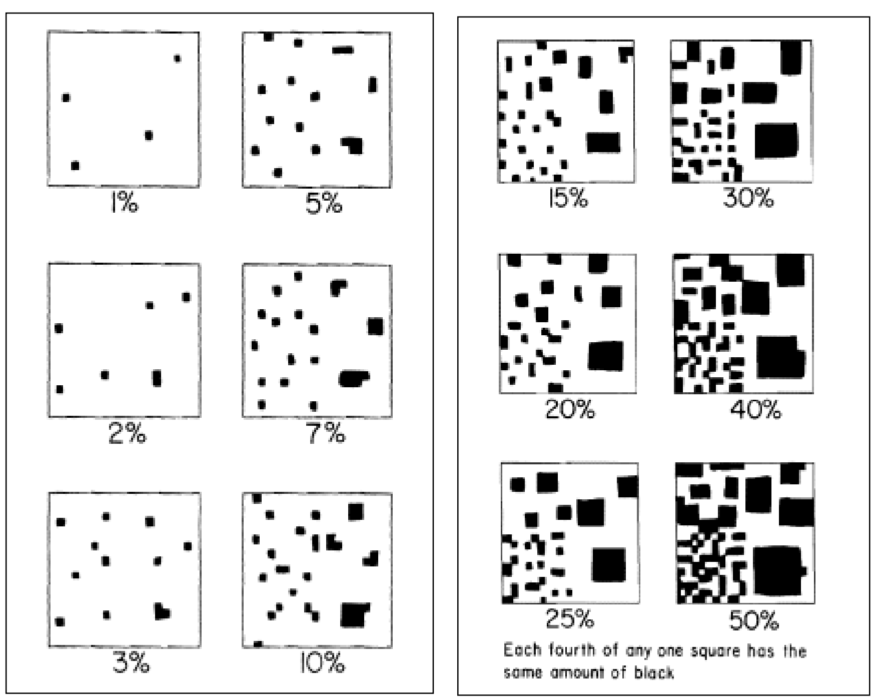
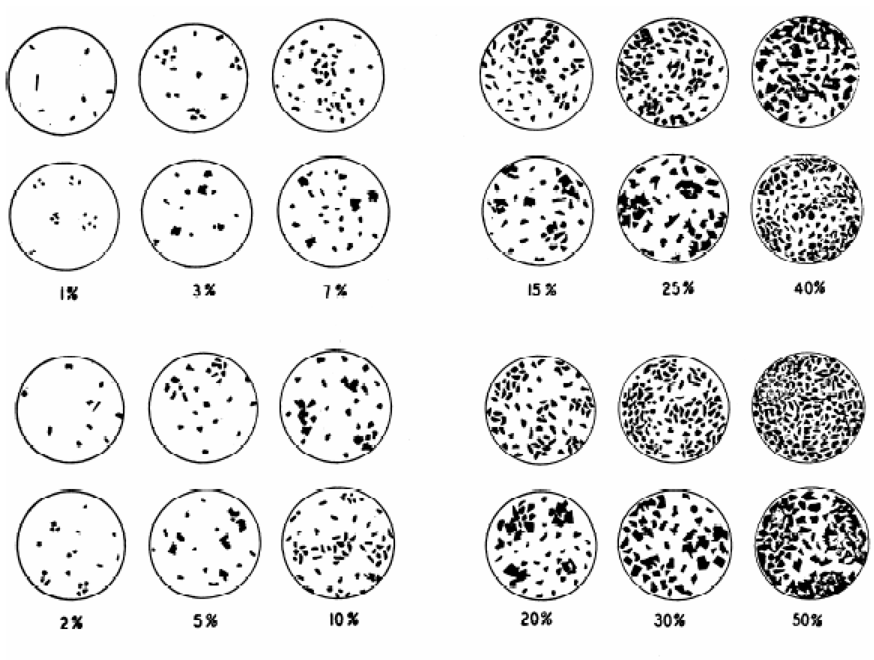


Figure B-3. Comparison charts for visual estimation of foliage cover.

Comparison Charts for Visual Estimation of Foliage Cover[1]



[1] Developed by Richard D. Terry and George V. Chilingar. Published by the Society of Economic Paleontologists in its *Journal of Sedimentary Petrology* 25(3): 229-234, September 1955.

Determining the texture of soil materials high in organic carbon

Material high in organic carbon could fall into three categories: organic, mucky mineral, or mineral. In lieu of laboratory data, the following estimation method can be used for soil material that is wet or nearly saturated with water. This method may be inconclusive with loamy or clayey textured mineral soils. Gently rub the wet soil material between forefinger and thumb. If upon the first or second rub the material feels gritty, it is mineral soil material. If after the second rub the material feels greasy, it is either mucky mineral or organic soil material. Gently rub the material two or three more times. If after these additional rubs it feels gritty or plastic, it is mucky mineral soil material; if it still feels greasy, it is organic soil material. If the material is organic soil material, a further division should be made, as follows.

Organic soil materials are classified as sapric, hemic, or fibric based on the percentage of visible fibers observable with a hand lens in an undisturbed state and after rubbing between thumb and fingers 10 times (Table 5). If there is a conflict between unrubbed and rubbed fiber content, rubbed content is used. *Live roots are not considered*. In saturated organic materials, the terms sapric, hemic, and fibric correspond to the textures muck, mucky peat, and peat, respectively (Table B3). The terms muck, mucky peat, and peat should only be used for organic accumulations associated with wetness.

Table B3. Proportion of fibers visible with a hand lens.

Soil Texture	Unrubbed	Rubbed	Horizon Descriptor
Muck	<33%	<17%	Sapric
Mucky peat	33-67%	17-40%	Hemic
Peat	>67%	>40%	Fibric

Adapted from USDA Natural Resources Conservation Service (1999)

Another field method for determining the degree of decomposition for organic materials is a system modified from a method originally developed by L. von Post and described in detail in ASTM standard D 5715-00 (http://www.astm.org/). This method is based on a visual examination of the color of the water that is expelled and the soil material remaining in the hand after a saturated sample is squeezed (Table B4). If a conflict occurs between results for sapric, hemic, or fibric material using percent visible fiber (Table B3) and degree of humification (Table B4), then percent visible fiber should be used.

Table B4. Determination of degree of decomposition of organic materials.

Degree of Humification	Nature of Material Extruded on Squeezing	Nature of Plant Structure in Residue	Horizon Descriptor
H1	Clear, colorless water; no organic solids squeezed out	Unaltered, fibrous, undecomposed	Fibric
H2	Yellowish water; no organic solids squeezed out	Almost unaltered, fibrous	
H3	Brown, turbid water; no organic solids squeezed out	Easily identifiable	
H4	Dark brown, turbid water; no organic solids squeezed out	Visibly altered but identifiable	Hemic
H5	Turbid water and some organic solids squeezed out	Recognizable but vague, difficult to identify	
H6	Turbid water; 1/3 of sample squeezed out	Indistinct, pasty	
H7	Very turbid water; 1/2 of sample squeezed out	Faintly recognizable; few remains identifiable, mostly amorphous	Sapric
H8	Thick and pasty; 2/3 of sample squeezed out	Very indistinct	
H9	No free water; nearly all of sample squeezed out	No identifiable remains	
H10	No free water; all of sample squeezed out	Completely amorphous	

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14. ABSTRACT

The Hydrogeomorphic (HGM) Approach is a method for developing functional indices and the protocols used to apply these indices to the assessment of ecosystem functions at a site-specific scale. The HGM Approach was initially designed to be used in the context of the Clean Water Act Section 404 Regulatory Program permit review to analyze project alternatives, minimize impacts, assess unavoidable impacts, determine mitigation requirements, and monitor the success of compensatory mitigation. However, a variety of other potential uses have been identified, including the determination of minimal effects under the Food Security Act, design of restoration projects, and management of wetlands.

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