USDA Natural Resources Conservation Service

Ecological site F094DY001WI
Peat Bogs

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General information

Provisional. A provisional ecological site description has undergone quality control and quality assurance review. It contains a working state and transition model and enough information to identify the ecological site.

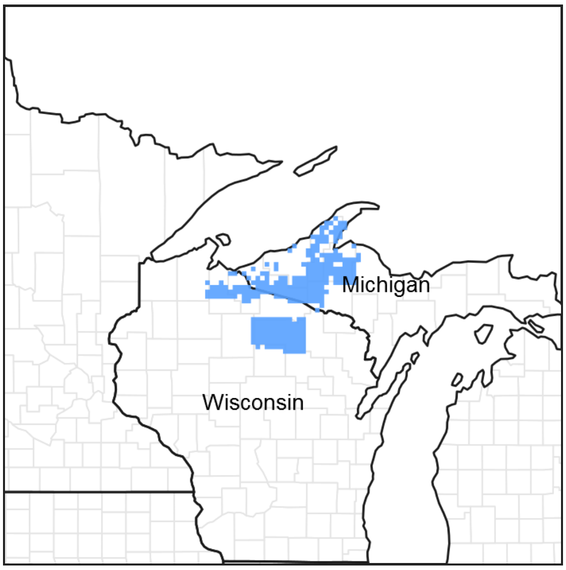

Figure 1. Mapped extent

Areas shown in blue indicate the maximum mapped extent of this ecological site. Other ecological sites likely occur within the highlighted areas. It is also possible for this ecological site to occur outside of highlighted areas if detailed soil survey has not been completed or recently updated.

MLRA notes

Major Land Resource Area (MLRA): 094D–Northern Highland Sandy Pitted Outwash

The Northern Highland Sandy Drift, aka MLRA 94D, lies mostly in northern Wisconsin with a few narrow outwash channels extending into the upper peninsula of Michigan. MLRA 94D encompasses 1.364 million acres and is surrounded by much larger, geologically different MLRAs. MLRA 94D is characterized mainly by sandy and gravelly soils formed in outwash sediments deposited by melt-water streams from late Wisconsin-Age glaciers, which receded from the area about 10,000 years before present (Attig 1985). Peat Bog ecological sites occupy about 110,000 acres in MLRA 94D.

Classification relationships

MLRA 94D is nearly identical to both Subsection 212X of the US Forest Service National Hierarchy of Ecological Units and the Wisconsin DNR Northern Highland ecological landscape. This reflects the near homogeneity of MLRA 94D and its clear differences with surrounding areas. However, Peat Bog ecological sites occurs across multiple MLRAs from Minnesota to New England. There are probably local or regional variations that need to accounted for, but the main concept of a highly acidic, low nutrient organic soil with a thick Sphagnum moss layer and a sparse forest cover holds true for the entire range.

Ecological site concept

Peat Bogs are wetland ecological sites characterized by low fertility and high acidity. The organic soils (Histosols) on this site typically have a thick layer (>12 inches or 30 cm) of living and dead Sphagnum moss at the surface. Both the nutrient status and pH are influenced by the interaction of two main factors: 1) the source of water for the site and 2) the acidifying effect of Sphagnum moss. The main source of water is precipitation; thus these sites are ombrotrophic, meaning rain-fed. Precipitation contributes relatively few mineral nutrients into the system compared to groundwater in minerotrophic systems, and those nutrients that arrive in rainfall are readily intercepted by the thick layer of Sphagnum moss (Rydin and Jeglum 2013). Mosses are porous and absorb many times their weight in water. Specialized cells then perform cation exchange, absorbing cationic nutrients and releasing hydrogen ions (Crum 1988). This cation exchange maintains electrical balance and acidifies the soil solution. Since the root zone is mainly undecomposed and partially decomposed peat, it is inherently low in available mineral plant nutrients (especially base-forming cations, namely K+— the potassium ion, Ca+2—the calcium ion, and Mg+2—the magnesium ion); also in short supply are two other primary plant nutrients (NH4+—ammonium and phosphate—PO4-2). It should be emphasized that in peatlands the fertility level is dependent on fresh inputs of nutrients from outside the site. Also, Peat Bogs have the tendency to immobilize and therefore become nutrient sinks for nitrogen, phosphorus, calcium and magnesium (Rydin and Jeglum 2013). Potassium, on the other hand, is more mobile and can be flushed from the site.

Even under low nutrient and high acidic conditions, peat continues to accumulate on these sites, mainly as the various Sphagnum species grow and die. There are numerous Sphagnum species that occupy the micro-sites on the hummocks and hollows found in Peat Bogs.

Associated sites

F094DY002WI	**Poor Fens** All peatland ecological sites typically have some species in common, especially Sphagnum mosses. This site and Peat Bogs differ in three main ways: 1)this site is not forested, Peat Bogs are forested; 2) this site is predominantly groundwater fed, Peat Bogs are precipitation fed and; 3) this has a higher pH and nutrient level.
F094DY004WI	**Mucky Peat Bogs** This site is similar to Peat Bogs, except that it is more productive and has greater than 50% canopy closure.

Similar sites

F094DY003WI	**Mucky Peat Swamps** This peatland ecological site is much richer than Peat Bogs.

Table 1. Dominant plant species

Tree	(1) *Picea mariana* (2) *Larix laricina*
Shrub	(1) *Ledum groenlandicum* (2) *Chamaedaphne calyculata*
Herbaceous	(1) *Sphagnum fuscum* (2) *Eriophorum spissum*

Physiographic features

Peat Bog ecological sites are found in small and large depressions on outwash plains, moraines and lake plains and comprise about 110,000 acres in this MLRA. Slopes range from 0 to 2 percent in Peat Bogs. The more sloping areas are raised bogs, in which the central part of Peat Bog often has a somewhat higher elevation than the edges. They formed when a dome-like volume of peat moss becomes buoyant above the water table because the bulk density of peat is less than that of water. Thus, the central area of a raised bog has a slightly convex profile and slopes downward toward the edges in all directions. The edges of most Peat Bogs transition to another peatland ecological site, i. e. a site with a slightly concave surface such as a Poor Fen or a Mucky Peat Bog (both are more species-rich sites). The topography of the surrounding area is nearly level to hilly. Often the topography of the underlying mineral sediments is nearly level to slightly concave because deeper depressions in this area were often filled by glacial deposits erosion. This back-filling by mineral sediments prevented large tracts of very deep peat (deeper than 10 feet) from forming in this region. However, there is usually a deeper area in every peatland where the peat originally started forming, then spread out over flat ground after filling the initial depression with lacustrine sediments or limnic (organic) deposits, then plant remains.

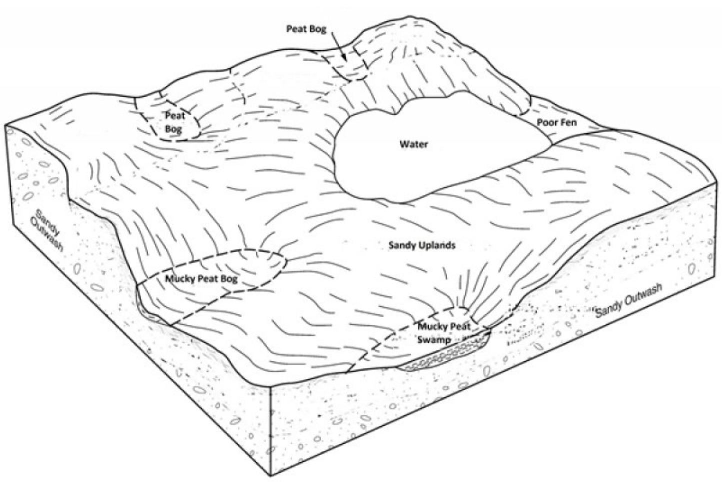

Figure 2. Peatland ecological sites on pitted outwash

Table 2. Representative physiographic features

Landforms	(1) Depression (2) Moraine (3) Outwash plain
Flooding frequency	None
Ponding duration	Very brief (4 to 48 hours) to long (7 to 30 days)
Ponding frequency	Occasional to frequent
Elevation	424–571 m
Slope	0–2%
Ponding depth	0–30 cm
Water table depth	0–30 cm
Aspect	Aspect is not a significant factor

Climatic features

The humid temperate climate belies the fact that Peat Bog and other peatland ecological sites are subject to localized extremes. First, the Histosols found on peatlands are generally colder soils than the surrounding upland mineral soils even during the growing season. Wet soils are slower to warm-up in spring due to the high amount of energy required to raise the temperature of water; and organic soils are even slower to warm to air temperatures because of insulating peat layers. Secondly, due the depressional landscape position the air temperature in Peat Bogs is affected by cold air drainage onto the site during any season; this can be especially harsh in winter. Cold air drainage occurs because of differential heating of air masses on a local basis. Colder air is denser, thus heavier than warmer air and flows to lower elevations following the terrain much like water, eventually collecting in depressions such as Peat Bogs. Also, temperature inversions frequently occur over depressions; they trap air close the surface, which can raise or lower temperatures beyond the normal range. Given this tendency toward extremes, frosts can occur with more frequency in Peat Bogs than on surrounding uplands and they can occur at any time during the growing season. Table 3 shows average frost-free and freeze-free periods for the entirety of MLRA 94D, frost-free and freeze-free periods in Peat Bogs are likely to be shorter due to the aforementioned cold air drainage phenomenon. Other extremes occur when the open expanse of these sites is windswept, which presents its own challenges of desiccation and damage. Thus 1) peatland ecological sites have a shorter growing season than average for the area, 2) they are prone to winterkill any plant not hardy to extremes and, 3) they are subject to disturbance by wind.

Table 3. Representative climatic features

Frost-free period (average)	109 days
Freeze-free period (average)	130 days
Precipitation total (average)	838 mm

Climate stations used

- (1) EAGLE RIVER [USC00472314], Eagle River, WI
- (2) REST LAKE [USC00477092], Manitowish Waters, WI
- (3) RHINELANDER [USC00477113], Rhinelander, WI
- (4) MINOCQUA [USC00475516], Minocqua, WI

Influencing water features

Peat Bog ecological sites are the driest of the peatland sites, they tend to occur on drainage divides. Thus they receive less groundwater water and surface water than other peatland sites. However, as with other peatlands they remain permanently saturated below 2 feet. This creates an anoxic zone where only anaerobic decomposition occurs. The zone above permanent saturation is frequently saturated, but with sufficient periods of aeration during the growing season for woody plants to persist and grow slowly. Ponding occurs in spring and after heavy rains but is confined mainly to hollows--low areas between three feet tall hummocks. Hummocks comprise most of the surface area and provide habitat for woody plants because of the aerated root zone. Even in very hummocky Peat Bogs the capillary fringe normally reaches the surface (Verry 1997).

The Hydrogeomorphic (HGM) classification (after Brinson 1993 and NRCS 2008) of Peat Bog ecological sites is variable: most sites are organic soil flats; some are clearly depressional; others appear to be lacustrine-fringe. The most important feature of Peat Bogs is that they are mainly precipitation-fed and they occur on interfluves. Deressional Peat Bogs are often perched at higher elevations on the landscape, with less than typical inflow from adjacent uplands for a depressional wetland. Small depressions on glaciated landscapes occur at various relative elevations. The highest of those depressions are seldom sources of headwaters streams, in contrast to downslope ecological sites such as Poor Fens and Mucky Peat Swamps, which have fluvial characteristics and are often sources of streams.

Lake-margin Peat Bogs occur as floating mats of vegetation or were formed in shallow bays that have filled with peat. The lakes, however, have enough sources of water (seepage and/or surface inlets) to maintain their water levels and aquatic environments. These lakes were not terrestrialized over time, i. e., they have not filled with peat. Sequential zones of plant communities from aquatic emergent species, such as bulrushes (Scirpus or Schoenoplectus spp.), bladderworts (Utricularia spp.) or American white water lily (Nyphaea odorata), to Poor Fen herbaceous vegetation to Peat Bog with small black spruce and tamarack, are a common occurrence around the numerous lakes in MLRA 94D. These lakes are stained dark by dissolved organic carbon (DOC). Compounds such as tannic acid, humic acid and fulvic acid emanate from peatlands. Stained water bodies warm up sooner in spring and have a shallower weed zone due to reduced light penetration. Some Peat Bog ecological sites have a small remnant pond within them; these ponds are also darkly stained by soluble organic compounds and are too acidified to support many vertebrate species (especially fish).

Water movement into Peat Bogs is mostly from direct precipitation or minor amounts of runoff from surrounding upland. Runoff, in this case, can be considered indirect precipitation, especially if the water has not picked up dissolved minerals from the adjoining land. Snowmelt provides most of the runoff. Water movement out of Peat Bogs is diffuse, mainly through evapo-transpiration during the growing season and slow seepage into porous underlying sediments. Generally, organic soils have very slow hydraulic conductivity in the lower layers, this creates a zone of continuous saturation without oxygen between the aerated root zone and the mineral substratum. Surface channel outflow is completely lacking in Peat Bogs; surface outflow channels in peatlands foster richer, more productive ecological sites . Occasionally, larger mammals (deer or beavers) create incised trails through Peat Bogs that appear to be channels but they usually have no effective outlet.

Soil features

The modal soil on this ecological site is a dysic, frigid, Typic Haplohemist (Greenwood series), which formed in in partially decomposed organic material with fresh inputs of recently deceased peat mosses (Sphagnum spp.) at the surface, just beneath the live moss. These sites have the potential to become predominantly Hemic Sphagnofibrists (e.g. Lobo soil series) as moss accumulates over time. Woody fragments can comprise up to 10% of the deeper soil layers, reflecting higher forest productivity levels of the past. There are areas within Peat Bogs where the organic soil material is less than 51 inches thick (which is in the Terric subgroup of Histosols; Dawson series), but those areas are virtually indistinguishable from areas of deeper organic soils in terms of vegetation and hummock and hollow micro-topography.

At present, soils in Peat Bogs have the lowest naturally occurring pH (3.0 to 4.4) of any soil in the region. The saturated hydraulic conductivity (Ksat) values range from 4.23 micrometers/second in the upper part to 0.01 micrometers/second in the lower tiers. Bulk density of organic soil material is lower in less decomposed layers, and the Histosols found in Peat Bogs are the least decomposed of any in the MLRA. They are predominantly fibric material (mostly undecomposed) in the upper 1 to 3 feet and hemic material (partially decomposed) to a depth of 40 to 80 inches or more. This organic soil material is very lightweight when dry, and buoyant on the water table; also it has very low bearing strength. This soil material is sponge-like and holds many times its weight in water.

Organic soils are noted for the large amount carbon they store, but they are also capable releasing carbon compounds into the environment. Carbon dioxide and methane gases are released during dry and wet cycles respectively; and DOC compounds can be leached from these soils. Peat Bog soils retain much of their acidity because drainage from these sites is slow and ET will concentrate acidity.

Figure 7. Peat moss hummock about 2 feet tall

Table 4. Representative soil features

Surface texture	(1) Peat
Drainage class	Very poorly drained
Permeability class	Very slow to moderate
Soil depth	203 cm
Surface fragment cover <=3"	0%
Surface fragment cover >3"	0%
Available water capacity (0-101.6cm)	25.4–38.1 cm
Calcium carbonate equivalent (0-101.6cm)	0%
Electrical conductivity (0-101.6cm)	0–2 mmhos/cm

Sodium adsorption ratio (0-101.6cm)	0
Soil reaction (1:1 water) (0-101.6cm)	3–4.4
Subsurface fragment volume <=3" (Depth not specified)	0%
Subsurface fragment volume >3" (Depth not specified)	0%

Ecological dynamics

Peat Bog ecological sites are an intergrade between forested and non-forested sites. Black spruce and tamarack are the only trees that will grow past shrub size on this site; and those two species grow very slowly on this site due to the nutrient-poor and highly acidic soils (Rydin and Jeglum 2013). The nutrient-poor conditions also causes fewer species overall on this site. In ecological terms, the site has low habitat diversity, meaning that it provides habitat for fewer species than the other peatland ecological sites. The plant species that grow in Peat Bogs have adaptations to the stressful conditions; moreover, those relatively few species are consistently present in Peat Bogs and mostly absent or in very low numbers on richer peatland ecological sites. The adaptations to the high- stress Peat Bog environment likely cause them to be less competitive on richer sites (Grime 1981).

Nevertheless, this site does provide habitat for some interesting plants and animals. Rare plant species such as arrow-grass (*Scheuchzeria palustris*) and grass-pink orchids (*Calopogon tuberosus*) occur on this site (Black and Judziewicz 2009). The seldom observed southern bog lemming (Synaptomys cooperi) can inhabit Peat Bogs, but is not restricted to that ecological site. Otherwise, mammals are relatively rare in Peat Bogs. This is significant considering the huge impact whitetail deer and other mammal herbivores have on other forested ecological sites. On the other hand, bog butterflies represent an interesting and charismatic group of insects adapted to Peat Bog ecological sites. This distinctive group of butterflies are important pollinators and herbivores in Peat Bogs as well as indicators of environmental quality. There are nine species of butterflies that use Peat Bogs as their primary habitat. They include the Bog Copper (Lycaena epixanthe), a small copper-colored butterfly that depends on cranberry plants for food and in return, pollinates the iconic plant. and the Bog Fritillary, a distinctively lined and spotted butterfly solely adapted to Peat Bog ecological sites. According to Swengel and Swengel (2014), the Brown elfin (Callophrys augustinus) is the most common Peat Bog butterfly, mainly because it also uses other habitats, and the Dorcas Copper (Lycaena dorcas) is the least common of nine Peat Bog inhabiting butterfly species. Butterfly conservation in Peat Bogs is aided by the fact these sites are the least degraded of any natural sites in the region—in large part due to limited utilitarian value and policies that recognize the value of undisturbed ecosystems and protecting rare species.

Given the low potential productivity for forestry and the restricted trafficability of this site, it is one of the least disturbed by human activity. The reference community phases (1.1 and 1.2) are by far the most abundant Peat Bog ecological sites, given the overall lack of conversion to other land uses. However off-site human actions can affect this site; these disturbances are caused mainly by water manipulation, intentional or other-wise. A dam or a road may flood or dry-out this site. Also, deposition from the atmosphere of heavy metals such mercury and lead is detectable in the upper soil layers of these sites. Drying the site causes subsidence, increases CO_2 emissions and heightens the risk of peat fires. On the other hand, inundation increases methane emissions from the site. Another threat to this ecological sites stems from climate change, which will likely cause changes in plant communities, and possibly release more carbon into the atmosphere.

Temperatures are predicted to rise over the coming decades and that increases the rate of organic matter decomposition. The possibility exists that these sites may become drier and more productive of woody vegetation. Then again, if subsidence occurs these sites may pond more frequently and become habitat for cattails (Typha spp.) or invasive species like *Phragmites australis*.

The two community phases in the reference state actually represent endpoints on a continuum of vegetation change caused by the ombrotrophication process; which, as previously stated, is the trend toward a thicker moss layer which causes less groundwater influence on the root zone and more rainwater influence. Hypothetically, they cycle back and forth, if they are driven by one of the predominant ecological processes described in the state and transition model. However, these changes are a development process that takes place well past the human scale of observation, i.e., hundreds of years. Each Peat Bog site that hasn't undergone a rapid transformation to another state, contains stratigraphic record of the long ago plant communities buried in the peat. In addition, those remains contain pollen and other debris transported to the site and preserved in same way the plants growing on the site were preserved in the peat. These buried remains can be identified and their age determined through radiocarbon-dating; they represent a truly valuable resource to understand the changes in plant communities in the area over long time scales, possibly thousands of years and also representing different climatic conditions.

State and transition model

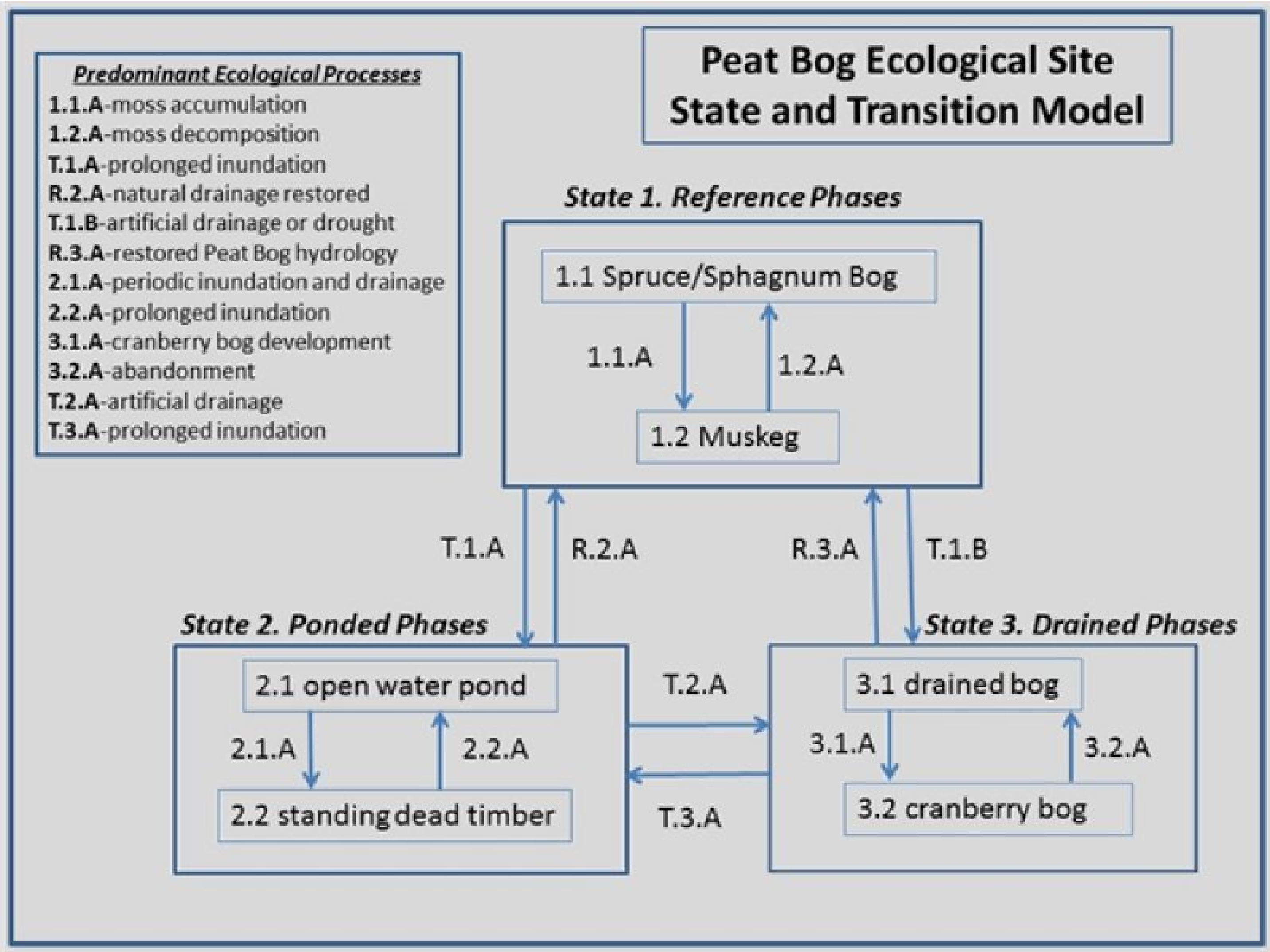

Figure 8. Peat Bog STM

State 1
Reference Community Phases

There are two distinct reference community phases of this ecological site. They are the Spruce/Sphagnum Bog phase and the Muskeg phase. The Spruce/Sphagnum Bog phase correlates to the PmLLe habitat type in the preliminary version of Habitat Type Classification. They are distinguished by the thickness of the live and dead moss ground layer and the amount of black spruce and tamarack canopy closure and whether or not the trees are growing or stagnant (i. e., site index below 20—less than 20 feet tall at age 50). There are many trees over 20 feet tall on Spruce/Sphagnum Bog sites and very few trees over 20 feet on Muskeg sites.

Community 1.1
Spruce/Sphagnum Bog

Figure 9. Peat Bog reference site with smoky gold tamarack

Figure 10. Bog laurel is a common subshrub in Peat Bogs

This phase has slow growing black spruce and tamarack cover that approaches 50% canopy closure. The black spruce typically grows in scattered patches, but they can form dense patches that have reproduced by layering. Most coniferous species have the ability to produce adventitious roots on lower branches that that touch the ground, these branches then grow into trees. Thus creating a thicket of smaller trees surrounding the larger parent tree. Between the black spruce thickets are Sphagnum covered hummocks and hollows. The hummocks may be up to 3 feet above the hollows and are roughly ovoid in shape; they are supported mainly by root systems of ericaceous shrubs such as leatherleaf, Labrador tea, bog laurel and bog rosemary. Both hummocks and hollows are typically less than six feet across, presenting numerous microsites for plants with somewhat different moisture requirements to grow in close proximity. There is frequent ponding in the hollows and hummocks are seldom, if ever, ponded. Sphagnum species differentiate into those that grow on hummocks (e.g., S. fuscum, S. magellanicum, S. capillifolium) and those that grow in hollows (e.g., S. cuspidatum, S. majus). There are a number of highly representative forb and graminoid species that occur with great regularity on this site. They are adapted to low pH and low nutrient conditions. They include cotton grasses (Eriophorum spp.), three-seeded sedge (*Carex trisperma*), few-seeded sedge (*C. oligosperma*), pitcher plant (*Sarracenia purpurea*) and three-leaf false Solomon's seal (*Maianthemum trifolium*). Besides the ever-present ericaceous subshrubs alluded to earlier, the tree-like shrub bog birch (*Betula pumila*) is a common associate on this site. Cranberry vines (Vaccinium oxycoccus and V. macrocarpon) are on found only on the hummocks.

Table 5. Ground cover

Tree foliar cover	20-50%
Shrub/vine/liana foliar cover	30-60%
Grass/grasslike foliar cover	5-10%
Forb foliar cover	3-5%
Non-vascular plants	80-90%
Biological crusts	0%

Litter	1-5%
Surface fragments >0.25" and <=3"	0%
Surface fragments >3"	0%
Bedrock	0%
Water	1-25%
Bare ground	0-1%

Table 6. Canopy structure (% cover)

Height Above Ground (M)	Tree	Shrub/Vine	Grass/ Grasslike	Forb
<0.15	1-2%	0-5%	2-5%	1-5%
>0.15 <= 0.3	1-5%	5-10%	3-8%	1-5%
>0.3 <= 0.6	1-5%	15-25%	3-8%	1-2%
>0.6 <= 1.4	1-5%	10-20%	2-5%	0%
>1.4 <= 4	10-25%	0%	0%	0%
>4 <= 12	5-10%	0%	0%	0%
>12 <= 24	1-5%	0%	0%	0%
>24 <= 37	0%	0%	0%	0%
>37	0%	0%	0%	0%

Community 1.2
Muskeg

This phase is very hummocky, more so than phase 1.1, with moss thickness greater than 20 inches and approaching 40 inches in places. Hollows seem to be filling in on these sites. There is little or no visible ponding, although the mosses may saturate by capillarity. Sphagnum species that occur on dry sites on top of hummocks include S. fuscum and S. recurvum. Black spruce still occurs in small patches and the lower branches appear to be buried in moss; they are reproducing by layering. There are fewer Tamarack trees. These sites are typically raised bogs, convex domes of peat moss with sparse forest cover. This phase has the lowest productivity of any woodland site in the MLRA. There are open bogs that also have sparse forest but have not developed the raised bog effect; these sites are possibly on a development trajectory toward muskeg or they are intergrade to Poor Fens. That is, they lack forest cover due to excess groundwater infusion and yet mosses are the dominant vegetation due nutrient scarcity. If these open bog sites have a predominant pH of 4.4 or less, they are essentially an intergrade between phase 1.1 and phase 1.2 or they are the result of one the transitions in the model.

Table 7. Ground cover

Tree foliar cover	5-20%
Shrub/vine/liana foliar cover	60-80%
Grass/grasslike foliar cover	5-10%
Forb foliar cover	1-5%
Non-vascular plants	95-100%
Biological crusts	0%
Litter	1-5%
Surface fragments >0.25" and <=3"	0%
Surface fragments >3"	0%
Bedrock	0%
Water	0-5%

Bare ground	0%

Table 8. Canopy structure (% cover)

Height Above Ground (M)	Tree	Shrub/Vine	Grass/ Grasslike	Forb
<0.15	0-2%	2-5%	1-5%	1-2%
>0.15 <= 0.3	0-2%	8-15%	2-5%	1-2%
>0.3 <= 0.6	0-2%	15-25%	2-5%	1-2%
>0.6 <= 1.4	1-2%	25-35%	0-5%	0%
>1.4 <= 4	1-2%	0%	0%	0%
>4 <= 12	3-10%	0%	0%	0%
>12 <= 24	0%	0%	0%	0%
>24 <= 37	0%	0%	0%	0%
>37	0%	0%	0%	0%

Pathway 1
Community 1.1 to 1.2

1.1.A-moss accumulation: Sphagnum moss accumulates over time because it has a competitive advantage over vascular plants in obtaining nutrients in ombrotrophic (precipitation-fed) bogs. Mosses are non-vascular and rootless; they absorb nutrients through the living green tissue at the ground surface. They also use the roots and branches of ericaceous shrubs as scaffolding on which to grow. Mosses die from the bottom up; non-green tissue below the surface is dead and is either accumulating as peat, maintaining a steady-state or decomposing rapidly enough to decrease in biomass. Sphagnum species that grow on hummocks have been shown to decompose at a slower rate than those in hollows leading to phase 1.2 Muskeg.

Pathway 2
Community 1.2 to 1.1

Even though Sphagnum mosses are resistant to decay due to high C/N ratios, they can be decomposed slowly under oxidizing conditions. Also, increases in temperature and pH spur bacterial decomposition of peat moss. Typically, Fungi are the main decomposers of Sphagnum mosses, because fungi are better than bacteria to the low pH on these sites. There are very few invertebrate decomposers of peat moss, but conditions that favor certain nematode species known to ingest mosses can increase Sphagnum decomposition. Also, if moisture conditions become dry enough peat fires may speed the process of peat moss oxidation. Moss species that grow on hummocks decay more slowly than those that grow in hollows and this accentuates the extremely hummocky micro-topography of Muskeg.

State 2
Ponded Phases

Disturbance in peatlands typically involves too much or too little water, either artificially or naturally. Too much water in a Peat Bog leads to State 2. Ponded Phases. Ponding of moderate duration is relatively common in most peatlands, even in Peat Bogs. However, ponding that leads to vegetation change is less common, especially in Peat Bogs. Such long-term ponding occurs as a result of disruption of normal outflow rates. There are both natural and man-made reasons for extended periods of ponding and these areas are highly variable in size. The most common man-made cause of ponding is road-building. Road beds prevent lateral flow in Peat Bogs that can lead water-filled road ditches that back up into the Peat Bog. Given that nutrients are lacking and acidity is high, ponded areas do not rapidly fill-in with vegetation. Some bog ponds are naturally occurring remnants of larger water bodies and never were actual Peat Bog sites (see Photo 3). Large patterned peatlands have ponded areas that were Peat Bog sites in the past; they were created by internal bog processes such as cryoturbation and remain ponded for many years (Heinselman 1963). Patterned peatlands are not common in this MLRA, but some of those natural bog processes that create ponds are replicated at a smaller scale on Peat Bog sites in this area. Peat fires, which occurred during drought periods, are another cause of excavations which lead to long-term ponding. Also, snowmobile trails through Peat Bogs are often ponded when thawed.

Community 2.1
Open water pond

Figure 11. Ponded phase in a Peat Bog ecological site

The Open Water Pond phase provides aquatic habitat, although the list of species is shortened due to the highly acidic water. Also, the water is darkly stained by dissolved organic carbon. The stain limits light penetration, and therefore photosynthesis. Essentially, bog ponds are not very productive and harbor few if any fish or other vertebrate species. Remnant ponds within lake-fill bogs are common in Peat Bogs. These ponds are slowly filling in with peat at the highly variable rate of 100 to 900 years per foot (Crum 1988). Ponds are often ringed by floating mats of vegetation consisting common bog plants and their intertwining root systems, but no trees. Further away from the water, trees like black spruce and tamarack can root and grow slowly. Ponding caused by artificial means is of little habitat value, and those areas are a nuisance because they add to mosquito and biting midge breeding sites.

Table 9. Ground cover

Tree foliar cover	0-1%
Shrub/vine/liana foliar cover	0-2%
Grass/grasslike foliar cover	5-20%
Forb foliar cover	5-20%
Non-vascular plants	5-20%
Biological crusts	0%
Litter	0-3%
Surface fragments >0.25" and <=3"	0%

Surface fragments >3"	0%
Bedrock	0%
Water	80-100%
Bare ground	1-5%

Table 10. Woody ground cover

Downed wood, fine-small (<0.40" diameter; 1-hour fuels)	–
Downed wood, fine-medium (0.40-0.99" diameter; 10-hour fuels)	–
Downed wood, fine-large (1.00-2.99" diameter; 100-hour fuels)	–
Downed wood, coarse-small (3.00-8.99" diameter; 1,000-hour fuels)	–
Downed wood, coarse-large (>9.00" diameter; 10,000-hour fuels)	–
Tree snags** (hard***)	–
Tree snags** (soft***)	–
Tree snag count** (hard***)	2-25 per hectare
Tree snag count** (hard***)	

*** Decomposition Classes: N - no or little integration with the soil surface; I - partial to nearly full integration with the soil surface.**

**** >10.16cm diameter at 1.3716m above ground and >1.8288m height--if less diameter OR height use applicable down wood type; for pinyon and juniper, use 0.3048m above ground.**

***** Hard - tree is dead with most or all of bark intact; Soft - most of bark has sloughed off.**

Table 11. Canopy structure (% cover)

Height Above Ground (M)	Tree	Shrub/Vine	Grass/ Grasslike	Forb
<0.15	0%	0%	–	–
>0.15 <= 0.3	0%	0%	–	–
>0.3 <= 0.6	0%	0-1%	–	–
>0.6 <= 1.4	0%	0-5%	–	–
>1.4 <= 4	0-1%	0%	–	–
>4 <= 12	0-1%	0%	–	–
>12 <= 24	0%	0%	–	–
>24 <= 37	0%	0%	–	–
>37	0%	0%	–	–

Community 2.2
Standing Dead Timber

Figure 12. Remnant natural ponds affect nearby Peat Bog sites

This is a site prone to periodic inundation and drainage over many decades. These water level fluctuations often coincide with changes in the water level of ponds within the Peat Bog. Causes of this may be beaver activity, flowage level changes or past and present drainage practices, combined with variations in precipitation. We may be not able to observe the cyclic nature of these changes due to the extended time frame. But the legacy of those fluctuations is observed in the vegetation, with living plants at ground level while most of the older woody vegetation has succumbed to the periodic high water conditions. Eventually the water level may have subsided, allowing trees and shrubs to regenerate on parts of these sites. Again, this reflects the cyclic nature of the moisture conditions on this type of site, and this site is a subset of Peat Bogs because this cyclic pattern is not found on all Peat Bogs sites. Standing dead timber is important as a site phase for the value it has to birds as perches and nest sites. Other wildlife, like herptiles, benefit when trees start to break up and add woody debris to ponded sites. Timber on Peat Bog sites is typically too small for use by birds of prey or herons but smaller passerine species are frequent users. Decomposition is slow so these perches last several decades, time enough for replacement by other drown-out timber sites.

Table 12. Soil surface cover

Tree basal cover	5-25%
Shrub/vine/liana basal cover	20-40%
Grass/grasslike basal cover	1-10%
Forb basal cover	1-5%
Non-vascular plants	80-90%
Biological crusts	0%
Litter	0-5%
Surface fragments >0.25" and <=3"	0%
Surface fragments >3"	0%
Bedrock	0%

Water	10-20%
Bare ground	0-1%

Table 13. Woody ground cover

Downed wood, fine-small (<0.40" diameter; 1-hour fuels)	–
Downed wood, fine-medium (0.40-0.99" diameter; 10-hour fuels)	–
Downed wood, fine-large (1.00-2.99" diameter; 100-hour fuels)	–
Downed wood, coarse-small (3.00-8.99" diameter; 1,000-hour fuels)	–
Downed wood, coarse-large (>9.00" diameter; 10,000-hour fuels)	–
Tree snags** (hard***)	–
Tree snags** (soft***)	–
Tree snag count** (hard***)	49-74 per hectare
Tree snag count** (hard***)	

*** Decomposition Classes: N - no or little integration with the soil surface; I - partial to nearly full integration with the soil surface.**

**** >10.16cm diameter at 1.3716m above ground and >1.8288m height--if less diameter OR height use applicable down wood type; for pinyon and juniper, use 0.3048m above ground.**

***** Hard - tree is dead with most or all of bark intact; Soft - most of bark has sloughed off.**

Table 14. Canopy structure (% cover)

Height Above Ground (M)	Tree	Shrub/Vine	Grass/ Grasslike	Forb
<0.15	0-1%	5-10%	1-5%	1-5%
>0.15 <= 0.3	0-1%	10-20%	1-5%	1-5%
>0.3 <= 0.6	1-5%	20-30%	1-5%	1-5%
>0.6 <= 1.4	1-5%	10-20%	1-5%	0%
>1.4 <= 4	3-10%	5-10%	0%	0%
>4 <= 12	5-10%	0%	0%	0%
>12 <= 24	0%	0%	0%	0%
>24 <= 37	0%	0%	0%	0%
>37	0%	0%	0%	0%

Pathway 1
Community 2.1 to 2.2

Open water pond

Standing Dead Timber

Cycles of ponding and drainage that over time are likely to produce adjacent remnants of both phases—Open Water and Standing Dead Timber. Cycle frequency is a major concern for optimizing habitat; too fast or too slow of a cycle will likely reduce habitat diversity. This observation falls in line with the intermediate disturbance hypothesis. Trees need time to attain maturity so the drained period must be at 50-100 years. There has been an increase in drowned-out timber due to inadvertent damming by roads; this has replaced beaver activity as a primary cause of ponding cycles. Both hydrostatic and hydrodynamic forces are responsible for periodic inundation and drainage.

Pathway 2
Community 2.1 to 2.2

Open water pond

Standing Dead Timber

Permanent ponding of a Peat Bog is likely a man-made condition, natural conditions fluctuate frequently. Typically the surface of Peat Bog must be re-contoured mechanically to achieve a permanently ponded condition. This can done with dug-out areas, dikes and water control structures. The reasons for going to this expense include: ponds for cranberry operations, impoundments for large wildlife areas, scrapes or dug-outs for small-scale wildlife enhancement, drainage ditches and retention ponds for road construction. In this region, there are numerous water control structures on lakes and flowages, any one of which may inundate a Peat Bog. Inadvertent ponding may also result from trail compaction in Peat Bogs.

State 3
Drained Phases

The drained phases are mostly artificial, however, under severe drought conditions a Peat Bog site may resemble an artificially drained site. In the past, attempts were made to drain peat bogs for agricultural purposes; some sites are still affected by old ditch-works. Currently, lake-margin Peat Bog hydrology is artificially affected by dams, and other Peat Bog sites are affected by ditches and roads that cut through them. Man-made structures like roads that create large impervious embankments inevitably alter horizontal drainage patterns. Many peatland sites, including Peat Bogs, exhibit the wet-side/dry-side effect caused by a road within the site. Peat Bogs that have been affected by drainage are more likely to be colonized by invasive species (Cohen and Kost 2008).

Community 3.1
Drained Bog

This phase is relatively rare in this area, but it does occur occasionally. Road development through Peat Bogs will often require some drainage, and peat is often excavated during road construction to secure a solid roadbed. Peat harvesting or mining, also requires draining Peat Bog sites. Excavated peat has value as a soil amendment or as a horticultural potting soil. In the past, there were a lot more consumptive uses of peat, namely as a fuel. Today the highest value use for a Peat Bog is as a carbon sink. A natural event such as drought can simulate drained bog conditions. Prolonged drought will lower the water table, resulting in desiccation of the upper moss layer and in some cases, subsidence, in which the surface is lowered and the peat volume shrinks due to oxidation. These conditions increase the risk of peat fires.

Table 15. Ground cover

Tree foliar cover	0-10%
Shrub/vine/liana foliar cover	40-60%
Grass/grasslike foliar cover	5-20%
Forb foliar cover	1-10%
Non-vascular plants	25-50%
Biological crusts	1-5%
Litter	10-20%
Surface fragments >0.25" and <=3"	0%
Surface fragments >3"	0%
Bedrock	0%
Water	0%
Bare ground	0-25%

Community 3.2

Cranberry Bog

There are about 2000 acres of converted Peat Bogs in this MLRA. This is a tiny fraction of the total area of this ecological site, but nevertheless represents a significant investment in cranberry culture. The cold climate and low nutrient status of the site discourages any other cropland development.

Table 16. Ground cover

Tree foliar cover	0%
Shrub/vine/liana foliar cover	95-99%
Grass/grasslike foliar cover	1-5%
Forb foliar cover	0-1%
Non-vascular plants	0-1%
Biological crusts	0-1%
Litter	0-1%
Surface fragments >0.25" and <=3"	0%
Surface fragments >3"	0%
Bedrock	0%
Water	3-5%
Bare ground	1-5%

Pathway 1
Community 3.1 to 3.2

Cranberry beds are created in drained Peat Bogs. To make a cranberry bed, a rectangular area of about 5 acres is ditched and diked with roads built on the dikes around the bed. Within the bed, the upper layers up peat moss are removed, then the area is leveled, crowned slightly down the middle and sanded, then vines are planted by hand spreading on the surface. In this area, cranberry production is the only reason Peat Bogs are drained for cropland, but the cost of creating cranberry beds is very high, therefore few acres are converted annually. Peat Bogs sites adjacent to cranberry bogs are likely to be affected by altered hydrology and possibly affected other cranberry culture operations such as pesticide or fertilizer drift.

Transition 1
State 1 to 2

T.1.A-prolonged inundation: This transition is not a frequent occurrence within this ecological site because peat tends to be buoyant and upper layers seem float within the water table, ultimately raising the surface above water. Prolonged inundation leads to State 2. Ponded Phases. There are cases where these sites have been ponded for an extended period, but this usually follows a major disturbance such as a fire or intentional flooding, such as from a dam and reservoir or flooding by beaver activities. Extended drought conditions lead to fire hazards, even in Peat Bogs. Peat fires can lower the surface elevation enough to make ponding inevitable when the water table returns to normal. Compaction can also lower the surface enough to cause ponding of the site, regardless of peatland buoyancy. Dams and reservoirs impound water, changing local hydrology enough to not only cause ponding is some areas but can cause subsidence or erosion in other area—mats of vegetation have been known to break off and float away in some impoundments. There are also many naturally occurring ponds in Peat Bogs in which the water level can increase due to excess precipitation and thereby increase the ponded area. These ponds are either remnants from the lake-fill process or ponded areas in larger patterned Peat Bogs that form due the freeze-thaw cryoturbation and other hydrostatic forces.

Transition 1.A
State 1 to 2

Prolonged inundation: This transition is not a frequent occurrence within this ecological site because peat tends to be buoyant and upper layers seem float within the water table, ultimately raising the surface above water.

Prolonged inundation leads to State 2. Ponded Phases. There are cases where these sites have been ponded for an extended period, but this usually follows a major disturbance such as a fire or intentional flooding, such as from a dam and reservoir or flooding by beaver activities or road building. Extended drought conditions lead to fire hazards, even in Peat Bogs. Peat fires can lower the surface elevation enough to make ponding inevitable when the water table returns to normal. Compaction can also lower the surface enough to cause ponding of the site, regardless of peatland buoyancy. Dams and reservoirs impound water, changing local hydrology enough to not only cause ponding is some areas but can cause subsidence or erosion in other area—mats of vegetation have been known to break off and float away in some impoundments. There are also many naturally occurring ponds in Peat Bogs in which the water level can increase due to excess precipitation and thereby increase the ponded area. These ponds are either remnants from the lake-fill process or ponded areas in larger patterned Peat Bogs that form due the freeze-thaw cryoturbation and other hydrostatic forces.

Transition 1.B
State 1 to 3

Artificial drainage or drought: Artificial manipulation of water tables in Peat bogs is more common than a drawdown caused by prolonged drought. Either artificial drainage or drought can lead to State 3. Drained Bog Phases. However, artificial drainage of peatlands is regulated. Highway construction and cranberry bog development are the major causes of artificial drainage. Well-engineered roads are required by modern society and cranberry production is a high-value enterprise. Good designs, that cause the least disturbance, are preferred.

Transition 1
State 1 to 3

T.1.B-artificial drainage or drought: Artificial manipulation of water tables in Peat bogs is more common than a drawdown caused by prolonged drought. Either artificial drainage or drought can lead to State 3. Drained Bog Phases. However, artificial drainage of peatlands is regulated. Highway construction and cranberry bog development are the major causes of artificial drainage. Well-engineered roads are required by modern society and cranberry production is a high-value enterprise. Good designs, that cause the least disturbance, are preferred.

Restoration pathway 2.A
State 2 to 1

Natural drainage: Drainage can occur through long term seepage and seasonal evapotranspiration if the water inflows are reduced. Forest restoration is inherently slow on these sites. They are colder and wetter and not optimal for forest growth or rapid reforestation. There are many sites that fail to regenerate forests and merely produce open bogs or Sphagnum lawns (Terwilliger and Pastor 1999). These sites remain open for decades. Forest restoration activities occur on similar sites in Europe, but we have little incentive to convert open bogs to forests.

Transition 1
State 2 to 3

Artificial drainage: Water control structures, levees and ditches can be used to manipulate the water table on these sites. The transition from ponded state to drained state is part of the cranberry production cycle. Areas that hold water are drained to flood cranberry beds for frost protection, weed control and the annual fruit harvest.

Restoration pathway 3.A
State 3 to 1

Restored wetland hydrology: Restoring hydrology seems feasible, but it is only part of story, native plant communities are very slow to recover on these sites. Invasive species can be a primary concern; hybrid cattails, reed canary grass, purple loosestrife, and exotic Phragmites are prevalent and spreading. There are two varieties of *Phragmites australis*, they have very different characteristics yet they are the same species (Swearingen and Saltonstall 2010). The exotic strain is invasive, meaning it forms dense monocultures and crowds out native species. Whereas the native Phragmites is less aggressive and is subject to fungal infection that reduces its vigor so that stands of native Phragmites are recognizable by the lower height and density of plants as well as the morphological characteristics of stems and leaves. The native Phragmites often has black stains on its stems from the fungal infection, while the non-native subspecies is not stained.

Transition 3.A
State 3 to 2

Prolonged inundation: Ponds are created from drained areas for several reasons. Ponds may be needed for cranberry operations, water is held in reserve near cranberry beds and used as needed. Sometimes beds have been retired from production and these areas tend to pond as well. Otherwise the transition from a drained phase to a ponded phase might part of new impoundment area for wildlife or a wetland mitigation project.

Additional community tables

Table 17. Community 1.1 forest overstory composition

Common Name	Symbol	Scientific Name	Nativity	Height (M)	Canopy Cover (%)	Diameter (Cm)	Basal Area (Square M/Hectare)
Tree							
black spruce	PIMA	*Picea mariana*	Native	0.3–13.7	15–40	2.5–10.2	–
tamarack	LALA	*Larix laricina*	Native	0.9–13.7	5–10	2.5–15.2	–

Table 18. Community 1.1 forest understory composition

Common Name	Symbol	Scientific Name	Nativity	Height (M)	Canopy Cover (%)
Grass/grass-like (Graminoids)					
boreal bog sedge	CAMAI2	*Carex magellanica ssp. irrigua*	Native	0.3–0.6	0–5
hairy sedge	CALA16	*Carex lacustris*	Native	0.3–0.8	0–5
tussock cottongrass	ERVAS	*Eriophorum vaginatum var. spissum*	Native	0.2–0.5	1–5
threeseeded sedge	CATR10	*Carex trisperma*	Native	0.2–0.5	1–2
softleaf sedge	CADI6	*Carex disperma*	Native	0.2–0.5	1–2
silvery sedge	CACA11	*Carex canescens*	Native	0.2–0.5	0–1
Forb/Herb					
threeleaf false lily of the valley	MATR4	*Maianthemum trifolium*	Native	–	1–2
purple pitcherplant	SAPU4	*Sarracenia purpurea*	Native	0.1–0.3	0–1
Shrub/Subshrub					
leatherleaf	CHCA2	*Chamaedaphne calyculata*	Native	0.2–0.6	20–35
bog Labrador tea	LEGR	*Ledum groenlandicum*	Native	0.3–0.9	10–20
bog laurel	KAPO	*Kalmia polifolia*	Native	0.2–0.6	2–5
velvetleaf huckleberry	VAMY	*Vaccinium myrtilloides*	Native	0.2–0.5	1–2
catberry	ILMU	*Ilex mucronata*	Native	0.6–1.2	0–2
bog birch	BEPU4	*Betula pumila*	Native	0.6–1.2	0–1
Vine/Liana					
small cranberry	VAOX	*Vaccinium oxycoccos*	Introduced	0–0.1	1–2
Nonvascular					
sphagnum	SPFU70	*Sphagnum fuscum*	Native	0–0.1	20–30
Magellan's sphagnum	SPMA70	*Sphagnum magellanicum*	Native	0–0.1	20–30
sphagnum	SPAN11	*Sphagnum angustifolium*	Native	0–0.1	10–20
sphagnum	SPAN11	*Sphagnum angustifolium*	Native	0–0.1	10–20
sphagnum	SPCA70	*Sphagnum capillifolium*	Native	0–0.1	5–10
sphagnum	SPFLF	*Sphagnum flexuosum var. flexuosum*	Native	0–0.1	5–10
polytrichum moss	POST70	*Polytrichum strictum*	Native	0–0.1	2–5

Table 19. Community 1.2 forest overstory composition

Common Name	Symbol	Scientific Name	Nativity	Height (M)	Canopy Cover (%)	Diameter (Cm)	Basal Area (Square M/Hectare)
Tree							
black spruce	PIMA	*Picea mariana*	Native	0.3–6.1	5–15	2.5–7.6	–
tamarack	LALA	*Larix laricina*	Native	0.6–9.1	0–5	2.5–10.2	–

Table 20. Community 1.2 forest understory composition

Common Name	Symbol	Scientific Name	Nativity	Height (M)	Canopy Cover (%)
Grass/grass-like (Graminoids)					
tussock cottongrass	ERVAS	*Eriophorum vaginatum var. spissum*	Native	0.3–0.5	1–4
threeseeded sedge	CATR10	*Carex trisperma*	Native	0.2–0.5	1–2
silvery sedge	CACA11	*Carex canescens*	Introduced	0.2–0.5	1–2
softleaf sedge	CADI6	*Carex disperma*	Native	0.2–0.5	1–2
Forb/Herb					
threeleaf false lily of the valley	MATR4	*Maianthemum trifolium*	Native	0.1–0.2	1–2
purple pitcherplant	SAPU4	*Sarracenia purpurea*	Native	0.2–0.3	0–2
Fern/fern ally					
crested woodfern	DRCR4	*Dryopteris cristata*	Native	0.2–0.5	1–2
Shrub/Subshrub					
leatherleaf	CHCA2	*Chamaedaphne calyculata*	Native	0.3–0.8	30–40
bog Labrador tea	LEGR	*Ledum groenlandicum*	Native	0.5–0.8	20–30
bog laurel	KAPO	*Kalmia polifolia*	Native	0.3–0.6	5–10
Vine/Liana					
small cranberry	VAOX	*Vaccinium oxycoccos*	Native	0–0.1	1–2
Nonvascular					
sphagnum	SPFU70	*Sphagnum fuscum*	Native	0–0.1	25–40
Magellan's sphagnum	SPMA70	*Sphagnum magellanicum*	Native	0–0.1	25–40
sphagnum	SPAN11	*Sphagnum angustifolium*	Native	0–0.1	20–30
sphagnum	SPCA70	*Sphagnum capillifolium*	Native	0–0.1	20–30
sphagnum	SPFLF	*Sphagnum flexuosum var. flexuosum*	Native	0–0.1	10–20
polytrichum moss	POST70	*Polytrichum strictum*	Native	0–0.1	5–10

Table 21. Community 2.1 forest overstory composition

Common Name	Symbol	Scientific Name	Nativity	Height (M)	Canopy Cover (%)	Diameter (Cm)	Basal Area (Square M/Hectare)
Tree							
tamarack	LALA	*Larix laricina*	Native	0.9–6.1	0–5	2.5–15.2	–
Tree Fern							
black spruce	PIMA	*Picea mariana*	–	0.9–4.6	0–1	2.5–10.2	–

Table 22. Community 2.1 forest understory composition

Common Name	Symbol	Scientific Name	Nativity	Height (M)	Canopy Cover (%)
Grass/grass-like (Graminoids)					
broadleaf cattail	TYLA	*Typha latifolia*	Native	0.6–1.2	1–10
common spikerush	ELPAP	*Eleocharis palustris var. palustris*	Native	0.2–0.8	0–10
needle spikerush	ELAC	*Eleocharis acicularis*	Native	0.3–0.6	0–5
Forb/Herb					
largeleaf pondweed	POAM5	*Potamogeton amplifolius*	Native	0–0.1	0–10
American white waterlily	NYOD	*Nymphaea odorata*	Native	0–0.1	0–10

Table 23. Community 2.2 forest overstory composition

Common Name	Symbol	Scientific Name	Nativity	Height (M)	Canopy Cover (%)	Diameter (Cm)	Basal Area (Square M/Hectare)
Tree							
black spruce	PIMA	*Picea mariana*	Native	0.6–6.1	10–20	2.5–10.2	–
tamarack	LALA	*Larix laricina*	Native	0.6–9.1	5–15	2.5–10.2	–

Table 24. Community 2.2 forest understory composition

Common Name	Symbol	Scientific Name	Nativity	Height (M)	Canopy Cover (%)
Grass/grass-like (Graminoids)					
woolgrass	SCCY	*Scirpus cyperinus*	Native	0.6–0.9	5–10
Fern/fern ally					
eastern marsh fern	THPA	*Thelypteris palustris*	Native	0.3–0.9	0–5
Shrub/Subshrub					
leatherleaf	CHCA2	*Chamaedaphne calyculata*	Native	0.3–0.9	20–40
bog Labrador tea	LEGR	*Ledum groenlandicum*	Native	0.3–0.9	5–20
Nonvascular					
sphagnum	SPAN11	*Sphagnum angustifolium*	Native	0–0.1	40–60
Magellan's sphagnum	SPMA70	*Sphagnum magellanicum*	Native	0–0.1	20–40
sphagnum	SPCA70	*Sphagnum capillifolium*	Native	0–0.1	20–40

Inventory data references

Reference Site 1: Muskellunge Lake area, Oneida County, Wisconsin.
GPS Location of Site: Latitude 45.798375 Longitude -89.464587
Legal Description: 2140 feet south and 1030 feet east of the northwest corner of Section 11, T. 38 N. – R. 8 E.
Site Properties: This site is part of large peatland complex with Poor Fen (non-forested) and Mucky Peat Bog ecological sites; the Peat Bog site is sparsely forested and has a thicker moss cap. The hummock to hollow ratio is about 70% to 30%. The hummocks were about 45 cm (18.1 inches) above the hollows. The hollows were ponded to a depth of about 12 cm (4.7 inches).
Soil Properties: The soil was sampled on the lower edge of a hummock. The fibric material (peat) moss-derived surface layer is 42 cm thick (16.5 inches), the pH is 4.0. That pH seems a little high for this site, but that reflects the time of year. It was sampled on cool fall day, when Sphagnum metabolism was lower and the dilution factor was higher due to low ET and high precipitation. The next layer is predominantly hemic material (mucky peat) with a thin sapric material (muck) layer at the bottom edge, with a total thickness of about 67 cm thick (26.4 inches), the pH is 4.3, again a little higher than it would be during the growing season. The mineral substratum starts at 109 cm (42.9 inches) and is stratified olive gray (5Y 5/2) sand and loamy sand to a depth of greater 150 cm (59 inches). The pH of this mineral sediment is 5.0.
Dominant Species: Black spruce and tamarack at about 30% canopy cover and 1-5% cover of seedlings and saplings. Leatherleaf dominant on the hummocks with Labrador tea, bog laurel, bog rosemary, small cranberry, cotton grass, and three-leaf false Solomon’s seal also present. The Sphagnum ground cover is 100% with S. magellanicum the most abundant species (and most obvious due to its red coloration) present.
Site index data: for 3 black spruce trees the average site index = 27; for 3 tamarack trees the average site index = 31 (Carmean et al. 1989 site index curves).

Reference Site 2: Tomahawk Airport area, Lincoln County, Wisconsin.
GPS Location of Site: Latitude 45.470287 Longitude -89.818947
Legal Description: 660 feet west and 1065 feet north of the southeast corner of Section 35, T. 35 N. – R. 5 E.
Site Properties: This site is a very wet Peat Bog that is about 40% phase 1.1 and 60% phase 1.2 with a Poor Fen ecological site surrounding the entire site. Surface water is flowing out of the Poor Fen site in non-channelized sheet toward a floodplain site; water in the Peat Bog does not appear to be flowing.
Soil Properties: The surface layer is fibric material (peat) about 38 cm (14 inches) thick with a pH of 3.9. The subsurface layer is about 2/3 hemic material (mucky peat) and 1/3 sapric material (muck) with a pH of 4.4. Again, the timing of the sample influences the pH as in the first site. This layer extends to 131 cm (52.4 inches). The

mineral substratum is brown (7.5YR 5/2) sand to depth of greater than 150 cm (59 inches).
Dominant Species: Black spruce and tamarack about 40% canopy cover and about 5% seedlings and saplings. The shrub layer is predominantly leatherleaf with bog rosemary and bog laurel and the ground layer is 100% Sphagnum moss with lake sedge in the hollows.
Site Index Data: for 4 black spruce trees the average site index = 24; for 3 tamarack trees the average site index = 28 (Carmean et al. 1989 site index curves).

Reference Site 3: Wharton Lake Road area, Vilas County, Wisconsin.
GPS Location of Site: Latitude 46.000733 Longitude -89.44335
Legal Description: 1380 feet north and 1900 feet east of the southwest corner of Section 25, T. 41 N. – R. 8 E.
Site Properties: This site is part of peatland ecological site complex which includes Mucky Peat Bog ecological sites and an open water bog pond which is likely a remnant of an incomplete lake-fill process. The hummock to hollow ratio is about 75% to 25%. The tops of the hummocks are about 80 cm (31.5 inches) above the hollows. The hollows were saturated to the surface with about 10% ponded. The hummocks were aerated to depth of about 30 cm (12 inches).
Soil Properties: The soil was sampled on the side of a hummock. The moss-derived fibric material surface layer was 76 cm thick, the pH was 4.2 (higher than expected). The next layer was hemic material 10 cm thick followed by sapric material 20 cm thick with a pH of 4.4. This was underlain by hemic material to a depth of greater than 2 meters with a pH of 4.4. The pH of this site is uniformly higher than expected, possibly because recent spring rains and proximity to the mineral soil about 100 feet away.
Dominant Species: Black spruce is the sole canopy species with about 25% cover, black spruce seedlings and saplings cover about 15% of the site. There were a few tamarack seedlings on this site and one red pine seedling was noted. Red pine is common on the adjacent uplands and red pine seeds which sprout on moss hummocks but will seldom grow to tree size on this type of site. The seed source for the tamaracks was likely nearby Mucky Peat Bog ecological site where the tamarack trees were growing well. The hummocks were covered with the typical ericaceous shrub species: leatherleaf, bog laurel and Labrador tea. Tussock cottongrass and small cranberry were also common on hummocks. For the mosses, Sphagnum fuscum was dominant on dry hummock tops, S. magellanicum and S. capillifolium were prevalent along the sides of hummocks and S. angustifolium was common in the saturated hollows (indicative of the slightly higher than average pH for this site).
Site Index Data: The average site index for 3 of the larger black spruce trees on this site was less than 20 feet, indicating a stagnant growth rate.

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Approval

Suzanne Mayne-Kinney, 3/29/2024

Rangeland health reference sheet

Interpreting Indicators of Rangeland Health is a qualitative assessment protocol used to determine ecosystem condition based on benchmark characteristics described in the Reference Sheet. A suite of 17 (or more) indicators are typically considered in an assessment. The ecological site(s) representative of an assessment location must be known prior to applying the protocol and must be verified based on soils and climate. Current plant community cannot be used to identify the ecological site.

Author(s)/participant(s)	
Contact for lead author	
Date	05/06/2024
Approved by	Suzanne Mayne-Kinney
Approval date	
Composition (Indicators 10 and 12) based on	Annual Production

Indicators

1. **Number and extent of rills:**

2. **Presence of water flow patterns:**

3. **Number and height of erosional pedestals or terracettes:**

4. **Bare ground from Ecological Site Description or other studies (rock, litter, lichen, moss, plant canopy are not bare ground):**

5. **Number of gullies and erosion associated with gullies:**

6. **Extent of wind scoured, blowouts and/or depositional areas:**

7. **Amount of litter movement (describe size and distance expected to travel):**

8. **Soil surface (top few mm) resistance to erosion (stability values are averages - most sites will show a range of values):**

9. **Soil surface structure and SOM content (include type of structure and A-horizon color and thickness):**

10. **Effect of community phase composition (relative proportion of different functional groups) and spatial**

distribution on infiltration and runoff:

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11. **Presence and thickness of compaction layer (usually none; describe soil profile features which may be mistaken for compaction on this site):**

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12. **Functional/Structural Groups (list in order of descending dominance by above-ground annual-production or live foliar cover using symbols: >>, >, = to indicate much greater than, greater than, and equal to):**

    Dominant:

    Sub-dominant:

    Other:

    Additional:

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13. **Amount of plant mortality and decadence (include which functional groups are expected to show mortality or decadence):**

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14. **Average percent litter cover (%) and depth (in):**

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15. **Expected annual annual-production (this is TOTAL above-ground annual-production, not just forage annual-production):**

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16. **Potential invasive (including noxious) species (native and non-native). List species which BOTH characterize degraded states and have the potential to become a dominant or co-dominant species on the ecological site if their future establishment and growth is not actively controlled by management interventions. Species that become dominant for only one to several years (e.g., short-term response to drought or wildfire) are not invasive plants. Note that unlike other indicators, we are describing what is NOT expected in the reference state for the ecological site:**

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17. **Perennial plant reproductive capability:**
