# Laurentian-Acadian Conifer-Hardwood Alkaline Swamp Ecological System

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## Ecological Integrity Assessment

**Prepared by: Don Faber-Langendoen**

**Ecology Department**
**NatureServe**
**3467 Amber Road**
**Syracuse, NY 13215**

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# A. INTRODUCTION

## *A.1 ECOLOGICAL SYSTEM DESCRIPTION*

### A.1.1. Classification Summary

(from NatureServe 2005)

**CES201.575 Laurentian-Acadian Alkaline Conifer-Hardwood Swamp**
**Primary Division:** Laurentian-Acadian (201)
**Land Cover Class:** Woody Wetland
**Spatial Scale & Pattern:** Large patch
**Required Classifiers:** Natural/Semi-natural; Vegetated (>10% vasc.)
**Diagnostic Classifiers:** Depressional; Thuja occidentalis - Fraxinus nigra; Mesotrophic Water; Circumneutral Water

**Concept Summary:** These forested wetlands are found across northern New England and the upper Midwest and eastern to south-central Canada in basins where higher pH and/or nutrient levels are associated with a rich flora. The substrate is typically mineral soil, but there may be some peat; often, there is an organic epipedon over mineral soil. *Thuja occidentalis* is a diagnostic canopy species and may dominate the canopy or be mixed with other conifers or with deciduous trees, most commonly *Acer rubrum* or *Fraxinus nigra*. *Cornus sericea* is a common shrub. The herb layer tends to be more diverse than in acidic swamps. Small open fenny areas may occur within the wetland. Seepage may influence parts of the wetland, but the hydrology is dominated by the basin setting.

**Range:** Scattered locations from New England and adjacent Canada west to the Great Lakes and northern Minnesota.
**USFS Divisions (Bailey):** 201:C
**TNC Ecoregions:** 47:C, 48:C, 60:?, 63:C, 64:C
**Subnations:** ME, MI, MN, NY, PA, VT, WI

### A.1.2. Environment

*Climate, Hydrology and Geomorphology*

Swamps in the Laurentian-Acadian region occur in a temperate climate with moderately warm to cool summers and cold winters. Precipitation is fairly evenly distributed throughout the year, though droughts are more pronounced in the western parts of the range.

These forested swamps have mineral soils and a fluctuating water table. The water table may be at, near, or above the soil surface for a portion of the growing season (typically late spring/early summer); however it tends to drop or fluctuate in the latter part of the growing season (i.e. seasonally flooded to seasonally saturated). Wetlands with soil saturation or a water table within 30 cm of the soil surface through July and August can accumulate peat (Cooper 1990). Because the water table in swamps fluctuates, the soil is periodically aerated, allowing organic matter to decompose, and preventing the accumulation of peat. However, swamp soils often have a very high amount of organic matter in the soil profile due to high productivity and periodically saturated soils. (Sorenson et al. 2004, Sperduto and Nichols 2004).

Swamps are common in depressions (Verry 1997). The shape of the basin in which swamps occur and the amount and seasonality of groundwater discharge are primary factors that influence soil types (Sorenson et al. 2004). Swamps may occur at the headwaters of intermittent or small perennial streams, or streams may flow through broad valleys where a complex mosaic of wet meadows, swamps and marshes may occur. Swamps also occur near the fringes of lakes and ponds where the water table is high enough to support hydrophytic forest vegetation but fluctuates or is deep enough to restrict the development of organic soils (Verry 1997).

Geological substrate and topographic setting affects the chemical characteristics of the water. Alkaline swamps may be associated with calcium-rich bedrock types, such as limestone, dolomite, or marble. They are also more common in settings where prolonged flooding occurs, such as along floodplains and in isolated depressions. Acid swamps occur in poorly drained basins, typically where no inlet or outlets occur, the influence of groundwater is lessened, and surface runoff more important (Sorenson et al. 2004).

### A.1.3. Vegetation and Ecosystem

*Vegetation*

Swamps are characterized by an open to closed tree canopy layer. White cedar (*Thuja occidentalis*) and red maple (*Acer rubrum*) are typical diagnostic canopy specie. They may dominate the canopy or be mixed with other conifers and deciduous trees, most commonly black ash (*Fraxinus nigra*). Other associates include eastern hemlock (*Tsuga canadensis*), silver maple (*Acer saccharinum*), and yellow birch (*Betula alleghaniensis*). Common shrubs include red-osier dogwood (*Cornus sericea*), dwarf-raspberry (Rubus pubescens), winterberry (*Ilex verticillata*), and mountain holly (*Ilex montana*).

The herb layer is often very diverse. Dominants include cinnamon fern (*Osmunda cinnamomea*), sensitive fern (*Osmunda regalis*), and spotted touch-me-not (*Impatiens capensis*). Small open fenny areas may occur within the wetland. Alkaline swamps are known for their diverse and uncommon plant species (Sorenson et al. 2004).

The spatial complexity of swamps supports numerous vegetation types which in turn support a variety of aquatic and terrestrial invertebrates. Hardwoods swamps can provide vernal pool habitat for many amphibians.

*Biogeochemistry*

Bedrock geology, soil characteristics, and surface and groundwater discharge of the contributing watershed basin determine the type and amount of nutrient flux in swamps. For example, thin coarse soils associated with granitic bedrock are nutrient poor and tend to be acidic whereas soils derived from limestone or shale outcrops have more nutrients and a higher pH. In the Laurentian-Acadian region, swamps receive much of their nutrients from surface and groundwater inputs and are stored in accumulated organic matter within the soil profile (Verry 1997).

*Ecosystem productivity*
Much information regarding productivity of swamps in the Laurentian-Acadian region is associated with general data from swamp environments. Swamps may be fairly productive ecological systems. More specifically, because some swamps contain perennial or intermittent water and receive periodic influx of nutrients from these waters, they often have higher primary productivity than adjacent upland systems.

The spatial complexity of patch types in the swamps results in a high edge-area ratio creating many ecotones with contrasting environmental processes and habitat types. This spatial heterogeneity supports numerous types of plant communities which provide for abundant secondary productivity of riparian areas (i.e. abundant support of fauna taxa).

### A.1.4. Dynamics

Swamps development in seepage areas, along riparian areas and in depressions is driven by the magnitude and frequency of flooding, valley and substrate type, and beaver activity. Seasonal and episodic flooding or seepage results in patterns of soil development that subsequently have a strong influence on the distribution of the swamps.

Hurricanes and thunderstorms may affect swamps and blow down trees, but the frequency of this disturbance is relatively rare and the low topographic position and short stature of the swamp trees relate to adjacent uplands may reduce the impact of this disturbance (Sorenson et al. 2004). Small gap disturbances are the primary disturbance agent, leading to tip-up mounds and accumulated coarse woody debris.

Beaver are an important hydrogeomorphic driver of swamp development. Beavers inhabit streams with a gentle gradient (< 15%) and in wide valleys (at least wider than the stream channel). Beaver dams impound surface water creating open water areas. When dams are initially created, they often flood and thus kill large areas of shrublands. These areas are eventually colonized by herbaceous emergent and submergent vegetation. Depending on the duration of saturation and flooding, these vegetation types are considered marshes or wet meadows. As local food supplies are diminished, beavers tend to abandon their dams and move up or downstream to find additional food supply as well as suitable dam sites (Baker 1987). The abandoned beaver ponds eventually fill with sediment and colonize by willows, thus completing the cycle. The presence of beaver creates a heterogeneous complex of swamps, wet meadows, marshes and riparian shrublands and increases species richness on the landscape. For example, Wright et al. (2002) note that beaver-modified areas may contribute as much as 25% of the species richness of herbaceous species in Adirondack Mountains of New York. Naiman et al. (1986) note that beaver-influenced streams are very different from those not impact by beaver activity by having numerous zone of open canopy, large accumulations of detritus and nutrients, more wetland areas, more anaerobic biogeochemical cycles, and in general are more resistance to disturbance. Sorenson et al. (2004), in a state-wide survey of hardwood swamps in Vermont, found that 21% of the swamps had some beaver activity that led to flooding.

It is not known what the density of beaver were in the Laurentian – Acadian region prior to the fur trade (Bernardos et al. 2004); however, Naiman et al. (1986) suggest that when beaver are not managed or harvested their activity may influence 20-40% of the total length of $2^{nd}$ to $5^{th}$ order streams in the boreal forest of Canada. It is apparent that active beaver colonies are important for ecosystem development in riparian based swamps, but their importance to the structure and function of isolated depression swamps is less clear.

### A.1.5. Landscape Condition

It is evident from the hydrogeomorphic setting of swamps that their integrity is partly determined by processes operating in the surrounding landscape and more specifically in the contributing watershed (Bedford 1996). The quality and quantity of ground and surface water input into swamps is almost entirely determined by the condition of the surrounding landscape. Various types of land use can alter surface runoff, recharge of local aquifers, and introduce excess nutrients, pollutants, or sediments. Assessments of swamps have considered the landscape properties of the local watershed to be a critical factor in assessing condition (Sorenson et al. 2004).

## *A.2. ECOLOGICAL INTEGRITY*

### A.2.1 Threats

*Hydrological Alteration*

Reservoirs, water diversions, ditches, roads, and human land uses in the contributing watershed can have a substantial impact on the hydrology as well as biotic integrity of swamps. Many of these activities tend to lower water tables. Vegetation responds to these changes by shifting from wetland dependent species to more mesic and xeric species typical of adjacent uplands.

Beaver can also affect hydrology. They can be a part of the natural dynamic of these swamp systems, especially for swamps in riparian areas, generating a range of habitat conditions, from partially open canopy caused by dead trees to open aquatic ponds, for as long as the dam lasts. But the presence of a road or culvert may also promote beaver activity in areas that would otherwise not be attractive to them (Sorenson et al. 2004). The equivocal and partial role they play in swamp development make them difficult to assess.

Land use in adjacent uplands can affect hillslope runoff processes which are important to sustaining alluvial or local aquifers. Water diversions and ditches can have a substantial impact on the hydrology as well as biotic integrity of swamps through a change in species composition (Cooper et al. 1998, Galatowitsch et al. 2000). An unaltered hydrologic regime is crucial to maintaining the diversity and viability of the swamp.

*Land Use*

Tree harvesting can have temporary to permanent effects on swamps. Removal of overstory trees may change the species composition, promoting early successional species, and change structure, removing trees that would otherwise contribute to coarse woody debris, tip up mounds. Permanent effects are associated with heavy logging equipment used when soils are not frozen, creating ruts or compacting the organic soils. Logging may also introduce invasive exotic species (Sorenson et al. 2004). Removing trees can also raise the water table (Roy et al. 1997).

*Nutrient enrichment*

Adjacent and upstream land uses all have the potential to contribute excess nutrients into swamp areas. Increased nutrients can alter species composition by allowing aggressive, invasive species to displace native species (Zedler and Kercher 2004). The impacts of nutrient enrichment have not been well documented in these swamps.

*Invasives*

Developing lists of both exotics and native invasives (tolerant taxa) can be a useful way to track disturbances to wetlands (Helgen and Gernes 2001). Currently, a list of native invasives is not available. Non-native species can displace native species, alter hydrology, alter structure, and affect food web dynamics by changing the quantity, type, and accessibility to food for fauna (Zedler and Kercher 2004). The most aggressive shrub invasive in hardwood swamps is glossy buckthorn (*Rhamnus frangula*). Other invasive shrubs include common buckthorn (*Rhamnus cathartica*), Morrow's honeysuckle (Lonicera morrowii), and barberry (*Berberis thunbergii* and *B. vulgaris*), but they are less tolerant of wet conditions and do not appear to spread as extensively (Sorenson et al. 2004), though alterations to wetland hydrology that dry out the swamps could promote their growth. In more open canopy conditions, invasive herbs such as reed canary grass (*Phalaris arundinacea*), purple loosestrife (*Lythrum salicaria*), and common reed (*Phragmites australis*) can be a problem (Sorenson et al. 2004). The two grasses have both native and exotic strains, and the latter are thought to be the more invasive strain.

*Deer*

Deer may be a threat to ground-layer diversity and tree regeneration. More documentation is needed on this threat in swamps.

*Fragmentation:* Human land uses both within the riparian area as well as in adjacent and upland areas can fragment the landscape and thereby reduce connectivity between riparian patches and between riparian and upland areas. This can adversely affect the movement of surface/groundwater, nutrients, and dispersal of plants and animals. Gravel mining can have a direct effect on riparian shrublands by physically removing vegetation and substrate thereby creating large gaps in connectivity in the floodplains of riparian shrublands (Baker 1987). Roads, bridges, and development can also fragment both riparian and upland areas. Intensive grazing and recreation can also create barriers to ecological processes.

### A.2.2. Justification of Metrics

As reviewed above, the literature suggests that the following attributes are important measures of the ecological integrity of this system:

- Landscape condition, given the critical role of the contributing watershed or surrounding landscape.
- Biotic condition, as measured by the species composition, canopy structure and diversity
- Impacts to hydrology and soil conditions
- Proportion of native or exotic invasives that could alter species composition.
- Degree of fragmentation in the riparian as well as upland areas.

### A.2.3. Ecological Integrity Metrics

A synopsis of the ecological metrics and ratings is presented in Tables 1 and 2. The three tiers refer to levels of intensity of sampling required to document a metric. Tier 1 metrics are able to be assessed using remote sensing imagery, such as satellite or aerial photos. Tier 2 typically require some kind of ground sampling, but may require only qualitative or semi-quantitative data. Tier 3 metrics typically require a more intensive plot sampling or other intensive sampling approach. A given measure could be assessed at multiple tiers, though some tiers are not doable at Tier 1 (i.e., they require a ground visit). A given metric could be assessed at multiple tiers, though some metrics cannot be measured at Tier 1 (i.e., they require some kind of ground visit). The focus for this System is primarily on metrics using both Tier 1 and Tier 2 metrics.

The Scorecard (see Tables 1 and 2) contains two types of metrics: Core and Supplementary. Separating the metrics into these two categories allows the user to adjust the Scorecard to available resources, such as time and funding, as well as providing a mechanism to tailor the Scorecard to specific information needs of the user.

*Core metrics* are shaded gray in Tables 1 and 2 and represent the minimal metrics that should be applied to assess ecological integrity. Sometimes, a Tier 3 Core metric might be used to replace Tier 2 Core Metrics. For example, if a Vegetation Index of Biotic Integrity is used, then it would not be necessary to use similar Tier 2 Core metrics such as Percentage of Native Graminoids, Percentage of Native Plants, etc.

*Supplementary metrics* are those which should be applied if available resources allow a more in depth assessment or if these metrics add desired information to the assessment. Supplementary metrics are those which are not shaded in Tables 1 and 2.

For each metric, a rating is developed, scored as A – (Excellent) to D – (Poor). The background, methods, and rationale for each metric are provided in section B. Each metric is rated, and then various metrics are rolled together into one of four categories: Landscape Context, Biotic Condition, Abiotic Condition, and Size.

Table 1. Overall Set of Metrics for the Laurentian-Acadian Conifer-Hardwood Alkaline Swamp. Tier: 1 = Remote Sensing, 2 = Rapid or Extensive, 3 =Intensive. Shaded metrics are core metrics. Unshaded are supplementary metrics.

| Category | Essential Ecological Attribute | Indicator & Metric | Tier |
|---|---|---|---|
| LANDSCAPE CONDITION | Landscape Composition | Adjacent Land Use | 1 |
| | | Buffer Width | 1 |
| | Landscape Pattern | Percentage of unfragmented landscape within 1 km. | 1 |
| | | Distance to nearest road | 1 |
| BIOTIC CONDITION | Community Structure | Stand Live Basal Area | 2 |
| | | Coarse Woody Debris (volume) | 3 |
| | Community Composition | Saplings / Seedlings of Native Woody Species | 2 |
| | | Percent of Cover of Native Plant Species | 2 |
| | | Floristic Quality Assessment (Mean C) | 3 |
| ABIOTIC CONDITION | Energy/ Material Flow | Land Use Within the Wetland | 2 |
| | | Sediment Loading Index | 1 |
| | Hydrology | Water Table Depth (Tier 2) | 2 |
| | | Water Table Depth (Tier 3) | 3 |
| | | Hydrological Alterations | 2 |
| | | Surface Water Runoff Index | 1 |
| | Chemical / Physical Processes | Soil Organic Carbon | 3 |
| | | Soil Bulk Density | 3 |
| | | Nutrient/ Pollutant Loading Index | 1 |
| SIZE | Absolute Size | Absolute Size | 1,2 |
| | Relative Size | Relative Size | 1,2 |

Table 2. Overall Set of Metrics for the Laurentian-Acadian Conifer-Hardwood Alkaline Swamp System, with Definition and Metric Ratings. Tier: 1 = Remote Sensing, 2 = Rapid or Extensive, 3 =Intensive. Shaded metrics are core metrics. Unshaded are supplementary metrics.

| Category | Essential Ecological Attribute | Indicator & Metric | Tier | Definition | *Metric Rating Criteria* | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | **Excellent** | **Good** | **Fair** | **Poor** |
| LANDSCAPE CONDITION | Landscape Composition | Adjacent Land Use | 1 | Addresses the intensity of human dominated land uses within 100 m of the wetland. | Average Land Use Score = 1.0-0.95 | Average Land Use Score = 0.80-0.95 | Average Land Use Score = 0.4-0.80 | Average Land Use Score = < 0.4 |
| | | Buffer Width | 1 | Wetland buffers are vegetated, natural (non-anthropogenic) areas that surround a wetland. | Wide > 100 m | Medium. 50 m to <100 m | Narrow. 25 m to 50 m | Very Narrow. < 25 m |
| | Landscape Pattern | Percentage of unfragmented landscape within 1 km. | 1 | An unfragmented landscape has no barriers to the movement and connectivity of species, water, nutrients, etc. between natural ecological systems. | Embedded in 90-100% unfragmented, roadless natural landscape; internal fragmentation absent | Embedded in 60-90% unfragmented natural landscape; internal fragmentation minimal | Embedded in 20-60%% unfragmented natural landscape; Internal fragmentation moderate | Embedded in < 20% unfragmented natural landscape. Internal fragmentation high |
| | | Distance to nearest road | 1 | Addresses the potential impacts to the site of roads or major trails, which are a specific type of altered habitat effect. | Very Far > 300 m | Far. 100 m to 300 m | Near. 50 m to 99 m | Very Near. < 50m |
| BIOTIC CONDITION | Community Composition | Stand Live Basal Area | 3 | Assesses the overall stand structure based on basal area of live trees. | >20 | >20 | 10-20 | <10 |
| | | Coarse Woody Debris | 3 | assesses the overall coarse woody debris based on volume of down stems (fallen logs and large branches). | >100 | >100 | 30-100 | <30 |

| Category | Essential Ecological Attribute | Indicator & Metric | Tier | Definition | *Metric Rating Criteria* | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | **Excellent** | **Good** | **Fair** | **Poor** |
| | | Saplings / Seedlings of Native Woody Species | 3 | Assesses the degree to which native tree seedlings are successfully establishing in the regeneration layer | Good Regeneration: ≥ 100 points | Good Regeneration: ≥ 100 points | Fair Regeneration: 25-99 points | Poor Regeneration: >25 points |
| | | Percent of Cover of Native Plant Species | 2 | Percent cover of the plant species that are native, relative to total cover (sum by species) | 100% cover of native plant species | 85-< 100% cover of native plant species | 50-85% cover of native plant species | <50% cover of native plant species |
| | | Floristic Quality Assessment (Mean C) | 3 | The mean conservatism of all the native species growing in the wetland. | Mean C > 4.5 | Mean C = 3.5-4.5 | Mean C = 3.0 – 3.5 | Mean C < 3.0 |
| ABIOTIC CONDITION | Energy/ Material Flow | Land Use Within the Wetland | 2 | Addresses the intensity of human dominated land uses within the wetland. | Average Land Use Score = 1.0-0.95 | Average Land Use Score = 0.80-0.95 | Average Land Use Score = 0.4-0.80 | Average Land Use Score = < 0.4 |
| | | Sediment Loading Index | 1 | A measure of the varying degrees to which different land uses contribute excess sediment via surface water runoff and overland flow into a wetland. | Average Score = 0.9 – 1.0 | Average Score = 0.8 – 0.89 | Average Score = 0.75 – 0.79 | Average Score = < 0.7 |

| Category | Essential Ecological Attribute | Indicator & Metric | Tier | Definition | *Metric Rating Criteria* | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Excellent | Good | Fair | Poor |
| | Hydrology | Water Table Depth (Tier 2) | 2 | Estimates water table depth using hydric soil indicators from a single site visit. | Seasonal high water table and/or soils saturated for long durations; Hydric Soils present; Water table is within 0.5 m of soil surface.<br><br>Surface soil horizons are gleyed or have a chroma value of 2 or less in mottled soils, or 1 less in unmottled soils; Depth to mottles is within 40 cm | Seasonal high water table and/or soils saturated for long durations; Hydric Soils present; Water table is within 0.5 m of soil surface.<br><br>Surface soil horizons are gleyed or have a chroma value of 2 or less in mottled soils, or 1 less in unmottled soils; Depth to mottles is within 40 cm | Seasonal high water table may be present; mottling is present but > 40 cm deep soil chroma values are >2<br><br>Hydric Soils NOT present<br><br>Indicators of remnant hydric conditions may be present (e.g., distinct boundaries between mottles and matrix) | No redoximorphic features present.<br><br>Hydric Soils NOT present<br><br>Indicators of remnant hydric conditions may be present (e.g., distinct boundaries between mottles and matrix) |
| | | Water Table Depth (Tier 3) | 3 | Determines average water table depth based on measurements from shallow groundwater wells. | Water table depth in June-early July is 0-30 cm | Water table depth in June-early July is 0-30 cm | Water table depth in June-early July is > 30 cm OR water table is above soil surface through July and August (indicates increased hydrological input) | Water table depth in June-early July is > 30 cm OR water table is above soil surface through July and August (indicates increased hydrological input) |
| | | Hydrological Alterations | 2 | The degree to which onsite or adjacent land uses and human activities have altered hydrological processes. | No alterations. No dikes, diversions, ditches, flow additions, or fill present in wetland that restricts or redirects flow | Low intensity alteration such as roads at/near grade, small diversion or ditches (< 1 ft. deep) or small amount of flow additions | Moderate intensity alteration such as 2-lane road, low dikes, roads w/culverts adequate for stream flow, medium diversion or ditches (1-3 ft. deep) or moderate flow additions. | High intensity alteration such as 4-lane Hwy., large dikes, diversions, or ditches (>3 ft. deep) capable to lowering water table, large amount of fill, or artificial groundwater pumping or high amounts of flow additions |

| Category | Essential Ecological Attribute | Indicator & Metric | Tier | Definition | *Metric Rating Criteria* | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | **Excellent** | **Good** | **Fair** | **Poor** |
| | | Surface Water Runoff Index | 1 | A measure of the varying degrees to which different land uses alters surface water runoff and overland flow into a wetland. | Average Score = 0.9 – 1.0 | Average Score = 0.8 – 0.89 | Average Score = 0.75 – 0.79 | Average Score = < 0.7 |
| | Chemical / Physical Processes | Soil Organic Carbon | 3 | Measures the amount of soil organic carbon present in the soil. | Soil C is equivalent to natural range of variability | Soil C is nearly equivalent to natural range of variability | Soil C is significantly lower than natural range of variability | Soil C is significantly lower than natural range of variability |
| | | Soil Bulk Density | 3 | A measure of the compaction of the organic soil horizons. | Bulk density value for wetland is at least 0.2 (g/cm3) less than Root Restricting Bulk Density value for the soil texture found in the wetland. | Bulk density value for wetland is at least 0.2 (g/cm3) less than Root Restricting Bulk Density value for the soil texture found in the wetland. (same as Very Good) | Bulk density for wetland is between 0.2 to 0.1 (g/cm3) less than Root Restricting Bulk Density value for the soil texture found in the wetland. | Bulk density for wetland is = or > than Root Restricting Bulk Density value for the soil texture found in the wetland. |
| | | Nutrient/ Pollutant Loading Index | 1 | the varying degrees to which different land uses contributed excess nutrients and pollutants via surface water runoff and overland flow into a wetland. | Average Score = 0.9 – 1.0 | Average Score = 0.8 – 0.89 | Average Score = 0.75 – 0.79 | Average Score = < 0.7 |
| SIZE | Absolute Size | Absolute Size | 1,2 | The current size of the wetland | > 10 acres | 5 to 10 acres | 1 to 5 acres | < 1 acre |
| | Relative Size | Relative Size | 1,2 | The current size of the wetland divided by the total potential size of the wetland multiplied by 100. | Wetland area = onsite Abiotic Potential | Wetland area < Abiotic Potential; Relative Size = 90 – 100% ; (< 10% of wetland has been reduced, destroyed or severely disturbed due to roads, impoundments, development, human-induced drainage, etc. | Wetland area < Abiotic Potential; Relative Size = 75 – 90%; 10-25% of wetland has been reduced, destroyed or severely disturbed due to roads, impoundments, development, human-induced drainage, etc | Wetland area < Abiotic Potential; Relative Size = < 75%; > 25% of wetland has been reduced, destroyed or severely disturbed due to roads, impoundments, development, human-induced drainage, etc |

## *A.3. SCORECARD PROTOCOLS*

A point-based approach is used to roll up the metrics into Category scores. Points are assigned for each rating level (A, B, C, D) within a measure. The default set of points are A = 5.0, B = 4.0, C = 3.0, D = 1.0. Sometimes, within a category, one measure is judged to be more important than the other(s). For such cases, each metric will be weighted according to its perceived importance. Points for the various measures are then added up and divided by the total number of metrics. The resulting score is used to assign an A-D rating for the category. After adjusting for importance, the Category scores could then be averaged to arrive at an Overall Ecological Integrity Score, but this approach has not yet been developed for this system.

It is not always possible to develop a four grade rating system for each metric, because we lack sufficient detail on how the metric changes or what the thresholds might be. In some cases, the ratings may combine A and B. The point scoring approach is A/B = 5, C=3, D = 1.

At this time, roll-ups are provided for each of the four categories, but they are not rolled up into an overall Ecological Integrity Index.

Supplementary metrics are not included in the Rating Protocol. However, they could be incorporated if the user desired.

### A.3.1. Landscape Context Rating Protocol

Rate the Landscape Context metrics according to their associated protocols (see Table 2 and details in Section B). Use the scoring table below (Table 3) to roll up the metrics into an overall Landscape Context Rating.

<u>Rationale for scoring table:</u> Adjacent land use, buffer width, and distance to nearest road are judged to be more important than the amount of fragmentation within 1 km of the wetland since a wetland with no other natural communities bordering it is very unlikely to have a strong biological connection to other natural lands at a further distance.

Table 3. Landscape Context Metrics and Ratings for this System. Scores for the ratings are show in each cell.

| **Measure** | **Tier** | **A** | **B** | **C** | **D** | **Weight** | **Score** (weight x rating) |
|---|---|---|---|---|---|---|---|
| Adjacent Land Use | 1 | 5 | 4 | 3 | 1 | 0.3 | |
| Buffer Width | 1 | 5 | 4 | 3 | 1 | 0.3 | |
| Percentage of unfragmented landscape within 1 km. | 1 | 5 | 4 | 3 | 1 | 0.1 | |

| **Measure** | **Tier** | **A** | **B** | **C** | **D** | **Weight** | **Score** (weight x rating) |
|---|---|---|---|---|---|---|---|
| Distance to nearest road or major trail | 1 | 5 | 4 | 3 | 1 | 0.3 | |
| **Landscape Context Rating**<br>A=4.5 - 5.0<br>B=3.5 - 4.4<br>C=2.5 - 3.4<br>D=1.0 – 2.4 | | | | | | | **Total = sum of N scores** |

## A.3.2. Biotic Condition Rating Protocol

Rate the Biotic Condition metrics according to their associated protocols (see Table 2 and details in Section B). Use the scoring table below (Table 4) to roll up the metrics into an overall Biotic Condition rating.

Rationale for Scoring: If available, the Floristic Quality Assessment (FQA) metric is judged to be more important than other compositional metrics.

If a formal Vegetation Index of Biotic Integrity is developed across the range of this System based on rigorous Tier 3 indicators (e.g., DeKeyser et al. 2003, Mack 2004), then this table will be upgraded, and the rating of Biotic Condition = the VIBI rating. If a VIBI is not used then scoring is based on whether or not a Floristic Quality Assessment (FQA) is used (since it is a Tier 3 metric). If FQA is included then the weights without parentheses apply to the Biotic Condition metrics. If FQA is not included then the weight in parentheses is used for the Tier 2 metrics.

Table 4. Biotic Condition Rating Calculations. Scores for the ratings are shown in each cell.

<table>
<tr><th>Measure</th><th>Tier</th><th>A</th><th>B</th><th>C</th><th>D</th><th>Weight*</th><th>Score</th></tr>
<tr><td>Stand Live Basal Area</td><td>2</td><td colspan="2">5</td><td>3</td><td>1</td><td>0.15 (0.25)</td><td></td></tr>
<tr><td>Coarse Woody Debris (volume)</td><td>3</td><td colspan="2">5</td><td>3</td><td>1</td><td>0.15 (0.25)</td><td></td></tr>
<tr><td>Saplings / Seedlings of Native Woody Species</td><td>3</td><td colspan="2">5</td><td>3</td><td>1</td><td>0.15 (0.25)</td><td></td></tr>
<tr><td>Percent of Cover of Native Plant Species</td><td>2</td><td>5</td><td>4</td><td>3</td><td>1</td><td>0.15 (0.25)</td><td></td></tr>
<tr><td>Floristic Quality Assessment (Mean C)</td><td>3</td><td>5</td><td>4</td><td>3</td><td>1</td><td>0.40(N/A)</td><td></td></tr>
</table>

| Measure | Tier | A | B | C | D | Weight* | Score |
|---|---|---|---|---|---|---|---|
| **Biotic Condition Rating**<br>A=4.5 - 5.0<br>B=3.5 - 4.4<br>C=2.5 - 3.4<br>D=1.0 – 2.4 | | | | | | | **Total = sum of N scores** |

* The weight in parentheses is used when metric for FQA is not available.

## A.3.3 Abiotic Condition Rating Protocol

Rate the Abiotic Condition metrics according to their associated protocols (see Table 2 and details in Section B). Use the scoring table below (Table 5) to roll up the metrics into an overall Abiotic Condition rating.

<u>Rationale for Scoring</u>: Quantitative water table data are judged to more reliable than the other metrics for indicating Abiotic Condition (shaded metric in Table 5). However, if such data are lacking then stressor related metrics (Land Use & Hydrological Alterations) are perceived to provide more dependable information concerning Abiotic Condition.

Scoring for Abiotic Condition is a based on two scenarios: (1) one with a Tier 2 Water Table metric or (2) one with a Tier 3 Water Table metric. The Tier 3 metric is shaded to show that only one should be used in the Scorecard. The weights for the former scenario (Tier 2 Water Table Depth included) are shown without parentheses whereas weights for the latter (Tier 3 Water Table Depth included) are in parentheses.

Table 5. Abiotic Condition Rating Calculations. Scores for the ratings are shown in each cell.

| Measure | Tier | A | B | C | D | Weight* | Score (weight x rating) |
|---|---|---|---|---|---|---|---|
| Land Use Within the Wetland | 2 | 5 | 4 | 3 | 1 | 0.25 (0.25) | |
| Water Table Depth (Tier 2) | 2 | 5 | 4 | 3 | 1 | 0.20 (N/A) | |
| Water Table Depth (Tier 3) | 3 | 5 | 4 | 3 | 1 | N/A (0.25) | |
| Hydrological Alterations | 2 | 5 | 4 | 3 | 1 | 0.55 (0.30) | |
| **Abiotic Condition Rating**<br>A=4.5 - 5.0<br>B=3.5 - 4.4<br>C=2.5 - 3.4<br>D=1.0 – 2.4 | | | | | | | **Total = sum of N scores** |

* The weight in parentheses is used when the measure for Water Table Depth (Tier 3) is substituted for the measure for Water Table Depth (Tier 2). The former is a more accurate and reliable measure than the latter.

### A.3.4 Size Rating Protocol

Rate the two measures according to the metrics protocols (see Table 2 and details in Section B). Use the scoring table below (Table 6) to roll up the metrics into an overall Size rating.

Rationale for Scoring: Since the importance of size is contingent on human disturbance both within and adjacent to the wetland, two scenarios are used to calculate size:

(1) When Landscape Context Rating = "A":
Size Rating = Relative Size metric rating (weights w/o parentheses)

(2) When Landscape Context Rating = "B, C, or D".
Size Rating = (weights in parentheses)

Table 6. Size Rating Calculations.

| Measure | Definition | Tier | A | B | C | D | Weight* | Score (weight x rating) |
|---|---|---|---|---|---|---|---|---|
| Absolute Size | The current size of the wetland | 1 | 5 | 4 | 3 | 1 | 0.0 (0.70) | |
| Relative Size | The current size of the wetland divided by the total potential size of the wetland multiplied by 100. | 1 | 5 | 4 | 3 | 1 | 1.0 (0.30) | |
| **Biotic Condition Rating** | A = 4.5 - 5.0<br>B = 3.5 – 4.4<br>C = 2.5 – 3.4<br>D = 1.0 – 2.4 | | | | | | | **Total =** (sum/N) |

* The weight in parentheses is used when Landscape Context Rating = B, C, or D.

# B. DOCUMENTATION FOR METRICS

### *B.1 LANDSCAPE CONDITION METRICS*

## Adjacent Land Use

**Definition:** This metric addresses the intensity of human dominated land uses within 100 m of the wetland. Each land use type occurring in the 100 m buffer is assigned a coefficient ranging from 0.0 to 1.0 indicating its relative impact to the target wetland (Hauer et al. 2002).

**Background:** This metric is one aspect of the landscape context of specific occurrences of wetland or terrestrial ecological systems.

**Rationale for Selection of the Variable:** The intensity of human activity in the landscape has a proportionate impact on the ecological processes of natural systems.

**Measurement Protocol:** This metric is measured by documenting surrounding land use(s) within 100 m of the wetland. This should be completed in the field then verified in the office using aerial photographs or GIS. However with access to current aerial photography and/or GIS data a rough calculation of Land Use can be made in the office. Ideally, both field data as well as remote sensing tools are used to identify an accurate % of each land use within 100 m of the wetland edge. To calculate a Total Land Use Score estimate the % of the adjacent area within 100 m under each Land Use type and then plug the corresponding coefficient (Table 7; the coefficients in this table are derived from Hauer et al. (2002)) with some manipulation to account for regional application) into the following equation:

$$\textit{Sub-land use score} = \sum LU \times PC/100$$

where**:** LU = Land Use Score for Land Use Type; PC = % of adjacent area in Land Use Type.

Do this for each land use within 100 m of the wetland edge, then sum Sub-Land Use Score to arrive at a Total Land Score. For example, if 30% of the adjacent area was under moderate grazing (0.3 * 0.6 = 0.18), 10% composed of unpaved roads (0.1 * 0.1 = 0.01), and 40% was a natural area (e.g. no human land use) (1.0 * 0.4 = 0.4), the Total Land Use Score would = 0.59 (0.18 + 0.01 + 0.40).

**Metric Rating:** Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

| **Metric Rating** |
| --- |

| Excellent | Good | Fair | Poor |
|---|---|---|---|
| Average Land Use Score = 1.0-0.95 | Average Land Use Score = 0.80-0.95 | Average Land Use Score = 0.4-0.80 | Average Land Use Score = < 0.4 |

**Data**: See Table 7. Coefficients should be reworked for northeastern application.

Table 7. Current Land Use and Corresponding Land Use Coefficients (based on Table 21 in Hauer et al. (2002))

| Current Land Use | Coefficient |
|---|---|
| Paved roads/parking lots/domestic or commercially developed buildings/gravel pit operation | 0.0 |
| Unpaved Roads (e.g., driveway, tractor trail) / Mining | 0.1 |
| Agriculture (tilled crop production) | 0.2 |
| Heavy grazing by livestock / intense recreation (ATV use/camping/popular fishing spot, etc.) | 0.3 |
| Logging or tree removal with 50-75% of trees >50 cm dbh removed | 0.4 |
| Hayed | 0.5 |
| Moderate grazing | 0.6 |
| Moderate recreation (high-use trail) | 0.7 |
| Selective logging or tree removal with <50% of trees >50 cm dbh removed | 0.8 |
| Light grazing / light recreation (low-use trail) | 0.9 |
| Fallow with no history of grazing or other human use in past 10 yrs | 0.95 |
| Natural area / land managed for native vegetation | 1.0 |

**Scaling Rationale:** Land uses have differing degrees of potential impact. Some land uses have minimal impact, such as simply altering the integrity of native vegetation (e.g., recreation and grazing), while other activities (e.g., hay production and agriculture) may replace native vegetation with nonnative or cultural vegetation yet still provide potential cover for species movement. Intensive land uses (i.e., urban development, roads, mining, etc.) may completely destroy vegetation and drastically alter hydrological processes. The coefficients were assigned according to best scientific judgment regarding each land use's potential impact (Hauer et al. 2002).

**Confidence that reasonable logic and/or data support the index:** Medium.

## Buffer Width

**Definition:** Wetland buffers are vegetated, natural (non-anthropogenic) areas that surround a wetland. This includes forests, grasslands, shrublands, lakes, ponds, streams, or another wetland. Some land uses such as light grazing and recreation may occur in the buffer, but other land uses should be considered the buffer boundary. Irrigated meadows may be considered a buffer if the area appears to function as a buffer between the wetland and nearby, more intensive land uses such as agricultural row cropping, fenced or unfenced pastures, paved areas, housing developments, golf courses, mowed or highly managed parkland, mining or construction sites, etc. (Mack 2001).

**Background:** This metric is one aspect of the landscape context of specific occurrences of wetland or terrestrial ecological systems.

**Rationale for Selection of the Variable:** The intensity of human activity in the landscape often has a proportionate impact on the ecological processes of natural systems. Buffers reduce potential impacts to wetlands by alleviating the effects of adjacent human activities (Castelle et al. 1992). For example, buffers can moderate stormwater runoff, reduce loading of sediments, nutrients, and pollutants into a wetland as well as provide habitat for wetland-associated species for use in feeding, roosting, breeding and cover (Castelle et al. 1992).

**Measurement Protocol:** This metric is measured by estimating the width of the buffer surrounding the wetland. This should be completed in the field then verified in the office using aerial photographs or GIS. Measure or estimate buffer width on four or more sides of the wetland then take the average of those readings (Mack 2001). This may be difficult for large wetlands or those with complex boundaries. For such cases, the overall buffer width should be estimated using best scientific judgment.

**Metric Rating:** Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

| **Metric Rating** | | | |
|---|---|---|---|
| **Excellent** | **Good** | **Fair** | **Poor** |
| Wide > 100 m | Medium. 50 m to <100 m | Narrow. 25 m to 50 m | Very Narrow. < 25m |

**Data**: N/A

**Scaling Rationale:** Increases in buffer width improve the effectiveness of the buffer in moderating excess inputs of sediments, nutrients, and other pollutants from surface water runoff and provides more potential habitat for wetland dependent species (Castelle et al. 1992). The categorical ratings are based on data from Castelle et al. (1992), Keate (2005), Mack (2001), and best scientific judgment regarding buffer widths. Note that Kennedy et al. (2003) recommend a minimum buffer width of 230 to 300 m.

**Confidence that reasonable logic and/or data support the index:** Medium/High.

## Percentage of Unfragmented Landscape Within One Kilometer

**Definition:** An unfragmented landscape is one in which human activity has not destroyed or severely altered the landscape. In other words, an unfragmented landscape has no barriers to the movement and connectivity of species, water, nutrients, etc. between natural ecological systems. Fragmentation results from human activities such as timber clearcuts, roads, residential and commercial development, agriculture, etc.

**Background:** This metric is one aspect of the landscape context of specific occurrences of wetland or terrestrial ecological systems.

**Rationale for Selection of the Variable:** The intensity of human activity in the landscape often has a proportionate impact on the ecological processes of natural systems. The percentage of fragmentation provides an estimate of connectivity among natural ecological systems. Although related to other landscape metrics, this metric differs by assessing the spatial interspersion of human land use as well as considering a much larger area. Because fragmentation is partly a natural feature, the metric used here measures fragmentation that is likely to be of most concern to managers, i.e., fragmenting features that are caused by anthropogenic processes.

**Measurement Protocol:** This metric is measured by estimating the amount of fragmentation in a one km buffer surrounding the wetland and dividing that by the total area. Calculate from imagery the percent of non-natural cover found in a one kilometer radius around each forest point. If data from remote sensing imagery is based on pixels, a square frame may be preferable (Heinz Center 2002). Summarize the total non-natural cover remaining. Including only non-natural cover allows this metric to focus on fragmentation caused by human activity (development, agriculture) from that of natural patchworks (Heinz Center 2002, pg. 121).

**Metric Rating:** Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

| **Metric Rating** | | | |
|---|---|---|---|
| **Excellent** | **Good** | **Fair** | **Poor** |
| Embedded in 90-100% unfragmented, roadless natural landscape; internal fragmentation absent | Embedded in 60-90% unfragmented natural landscape; internal fragmentation minimal | Embedded in 20-60%% unfragmented natural landscape; Internal fragmentation moderate | Embedded in < 20% unfragmented natural landscape. Internal fragmentation high |

**Data**: The Heinz Center (2002) used <10% nonforest as a measure of unfragmented (core = 100%, interior=90-99%) forest, and between 10-40% as “connected forested. We modify that perspective here to apply it to natural cover around wetlands. The data on which these breakpoints were established needs to be investigated. The Heinz Center is also investigating the use of a fragmentation index that takes into account roads that occur within the neighborhood area. (Cavender-Bares pers. comm. 2005).

**Scaling Rationale:** The Heinz Center (2002) used 100% forest cover as a measure of “core,” and 90-99% as “Interior.” We work with similar cutoffs for wetlands, but use >90% of natural cover as a threshold for Excellent.

**Confidence that reasonable logic and/or data support the index:** Medium.

## Distance to Road or Major Trail

**Definition:** This metric addresses the potential impacts to the forest plot of roads or major trails, which are a specific type of altered habitat effect.

**Background:** This metric is one aspect of the landscape context of specific occurrences of wetland or terrestrial ecological systems.

**Rationale for Selection of the Variable:** The nearness to roads has an impact on the ecological processes of natural systems. Roads may be the source of invasives, affect mortality of amphibians and other animals that migrate to and from the wetland, or cause surface water flow and associated nutrients and sediments to contaminate the wetland.

**Measurement Protocol:** Calculate distance from plot center to road or major trail using GIS.

**Metric Rating:** Assign the metric an Excellent, Good, Fair, or Poor Rating.

| **Measure (Metric) Rating** | | | |
|---|---|---|---|
| **Excellent** | **Good** | **Fair** | **Poor** |
| Very Far > 300 m | Far. 100 m to 300 m | Near. 50 m to 99 m | Very Near. < 50m |

**Data**: Watkins et al. (2003) found that unpaved roads in managed forests caused an increase in exotic plant species and a decrease in native plant species diversity within 150 meters from the road. Edge effects have often been reported between 100 to 300 m (Mladenoff et al. 1994).

**Scaling Rationale:** Scaling is approximately logarithmic, presuming that edge effects become increasingly pronounced as distance to road or major trail decreases. A minimum threshold of 50 m was established, based on the many edge effects demonstrated to occur within the 50 m range (Kennedy et al. 2003, Harper et al. 2005). Edge effects seem to decline rapidly after 100m, and few edge effects are reported at over 500 m (Kennedy et al. 2003, Harper et al. 2005). Kennedy et al. (2003) recommend a road distance of 300 m as a precautionary threshold, which we use here as the A/B threshold.

**Confidence that reasonable logic and/or data support the index:** Medium/High

## *B.2. BIOTIC CONDITION METRICS*

## Stand Live Basal Area

**Definition:** This measure assesses the overall stand structure based on basal area of live trees.

**Background**: Stand live basal area is a simple measure of the overall structure and maturity of the canopy.

**Rationale for Selection of the Variable:**

**Measurement Protocol:** All standing live trees that are at least 10 cm (4 inches) diameter-at-breast-height (DBH) within each plot, typically between 400 – 1000 $m^2$, are measured for species and dbh. Sum the basal area of trees in plot and convert to $m^2$ per hectare.

**Metrics Rating:** Assign the metric a Good, Fair, or Poor rating on the scorecard.

| **Measure (Metric) Rating** | | | |
|---|---|---|---|
| **Excellent** | **Good** | **Fair** | **Poor** |
| N/A | >20 | 10-20 | <10 |

**Data**: Keddy and Drummond (1996) summarize basal area of primary forest stands in the northeast and central U.S., and suggest three preliminary categories Control/normal (>29$m^2$/ha), Intermediate (20-29$m^2$/ha), and low (<20$m^2$/ha); Mean = 29, SD = 4). Tyrrell et al. (1998) reported live tree basal area, based on trees $\geq$ 10 cm dbh, for old growth hardwood wetlands and those values correspond reasonably well to those of Keddy and Dummond.

Live Tree Basal Area (based on trees $\geq$ 10 cm dbh) from Tyrrell et al. (1998).

| **Type** | **Range ($m^2$/ha)** | **Outlier ($m^2$/ha)** |
|---|---|---|
| Hardwood Wetlands | 22.0 – 44.4 | 57.0 |
| | | |

**Scaling Rationale:** Not all stands may be expected to be in an old growth condition (though many or most will, depending on the System); therefore, lower values of basal area, i.e. in the 20 – 29 $m^2$/ha are within an acceptable range of variation. Given that the range of basal area values greatly exceeds 29 $m^2$/h, it seems appropriate to give some weight to stands that have higher values.

**Confidence that reasonable logic and/or data support the index:** Medium

## Coarse Woody Debris (Volume)

**Definition:** This measure assesses the overall coarse woody debris based on volume of down stems (fallen logs and large branches).

**Background**: The amount of coarse woody debris reflects the degree to which overall stand dynamics are functioning well. As the stand matures and old individual stems die, they contribute to the structural features of the ground layer.

**Rationale for Selection of the Variable:**

**Measurement Protocol:** All dead, fallen trees that are at least 10.5 cm diameter (dbh) and 1 m in length within each plot, typically between 400 – 1000 $m^2$, are measured for species, dbh, length, and decay class. Standing dead snags are excluded. Sum the volume and convert to $m^3$ per hectare.

**Metrics Rating:** Assign the metric a Good, Fair, or Poor rating on the scorecard.

| **Measure (Metric) Rating** | | | |
|---|---|---|---|
| **Excellent** | **Good** | **Fair** | **Poor** |
| N/A | >100 | 30-100 | <30 |

**Data**:
Volume: Tyrrell et al. (1998) reported fallen dead tree volume, based on trees $\geq$ 10 cm dbh for hardwood wetland forests (see Table below). But data are limited.
CWD volume (based on various tree size cutoffs)

| **Type** | **Range (m3/ha)** | **Outlier (m3/ha)** |
|---|---|---|
| Hardwood wetland stands (>10 cm dbh) | 34.5-200.9 | |

**Scaling Rationale:** Given the lack of data and different size classes used to assess CWD, it is difficult to establish a scale with confidence and the greatest range in variation. In addition, variability among different forest swamp types may be high.

**Confidence that reasonable logic and/or data support the index:** Low

## Tree Regeneration

**Definition:** This measure assesses the degree to which native tree seedlings are successfully establishing in the regeneration layer.

**Background:** This metric is one aspect of the condition of specific occurrences of wetland or terrestrial ecological systems.

**Rationale for Selection of the Variable:** Native tree species dominate the canopy of swamps with excellent ecological integrity, and depend on regeneration for replacement of current canopy individuals. This metric is a measure of the degree to which that regeneration is being reduced by threats.

**Measurement Protocol:** Seedlings are counted on a 2-m radius microplot (= 12.56 $m^2$ area). Seedlings are defined as live, established seedlings of native tree species that are at

least 15 cm tall and less than 2.5 cm DBH, with at least two true leaves and no cotyledons present. Count the number of seedlings in a single microplot. Sum of points per seedling of **high canopy tree species** in each size class; points awarded for each seedling based on seedling height as follows:
<=30 cm seedling = 1 point;
30-100 cm seedlings = 2 points;
100-150 cm seedling = 20 points;
> 150 cm seedling = 50 points;

**Metrics Rating:** Assign the metric a Good, Fair, or Poor rating on the scorecard. See Scaling Rationale section; there's insufficient info for an break between Excellent and Good.

| **Measure (Metric) Rating** | | | |
|---|---|---|---|
| **Excellent** | **Good** | **Fair** | **Poor** |
| N/A | ≥ 100 points | 25-99 points | >25 points |

**Data**: See FIA study in Pennsylvania (McWilliams et al. 2005).FIA study in Pennsylvania

**Scaling Rationale:** FIA suggested threshold at 25 points, 100 points. There is insufficient information to establish a threshold between Excellent and Good

**Confidence that reasonable logic and/or data support the index:** Low/Medium. This metric may benefit from some fine-tuning, e.g., 1) define 'high canopy tree species," 2) exclude exotic tree seedlings, and 3) fine-tune points based on forest ecosystem type.

## Percent of Cover of Native Plant Species

**Definition:** Percent of the plant species which are native.

**Background:** This metric is one aspect of the condition of specific occurrences of wetland or terrestrial ecological systems.

**Rationale for Selection of the Variable:** Native species dominate swamps that have excellent ecological integrity. This metric is a measure of the degree to which native plant communities have been altered by human disturbance. With increasing human disturbance, non-native species invade and can dominate the wetland.

**Measurement Protocol:** Although, quantitative measurements are preferred, depending on time and financial constraints, this metric can be measured with qualitative or quantitative data. The two methods are described as follows: (1) Site Survey (semi-quantitative): walk the entire occurrence of the wetland system and make a qualitative ocular estimate of the total cover of each species growing in the wetland. The 10 point cover classes identified in Peet et al. (1998) are recommended, but any cover class system can be used as long as they same system remains consistent when comparing data with time or different site. (2) Quantitative Plot Data: The plot method described by Peet et al. (1998) is recommended for collecting quantitative data for this metric. This method uses a 20 x 50 m plot which is typically established in a 2 x 5 arrangement of 10 x 10 m modules. However, the array of modules can be rearranged or reduced to meet site conditions (e.g. 1 x 5 for linear areas or 2 x 2 for small, circular sites). The method is suitable for most types of vegetation, provides information on species composition across spatial scales, is flexible in intensity and effort, and compatible with data from other sampling methods (Peet et al. 1998, Mack 2004).

The metric is calculated by dividing the total cover of native species by the total cover of all species and multiplying by 100.

Once qualitative or quantitative cover data are collected, these values are then used to determine the metric status in the scorecard.

**Metric Rating:** Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

| **Metric Rating** | | | |
|---|---|---|---|
| **Excellent** | **Good** | **Fair** | **Poor** |
| 100% cover of native plant species | 85-< 100% cover of native plant species | 50-85% cover of native plant species | <50% cover of native plant species |

**Data**: N/A

**Scaling Rationale:** The criteria are based on extrapolated thresholds from ecological site descriptions from a variety of sources, including (NRCS 2005), Cooper (1990), Windell et al. (1986), CNHP (2005), and best scientific judgment. These thresholds need further validation.

**Confidence that reasonable logic and/or data support the index:** High

## Floristic Quality Assessment (Mean C)

**Definition:** The mean conservatism of all the native species growing in the wetland.

**Background:** This metric is one aspect of the condition of specific occurrences of wetland or terrestrial ecological systems.

**Rationale for Selection of the Variable:** Plants grow in habitats in which they are adapted to, including biotic and abiotic fluctuations associated with that habitat (Wilhelm and Masters 1995). However, when disturbances to that habitat exceed the natural range of variation (e.g. many human-induced disturbances), only those plants with wide ecological tolerance will survive and conservative species (e.g. those species with strong fidelity to habitat integrity) will decline or disappear according to the degree of human disturbance (Wilhelm and Master 1995; Wilhelm pers. comm. 2005).

These observations can be combined into a "conservatism" (or C) index, whereby species with strong fidelity to habitat integrity are scored 10 and those with a very low integrity are scored 1. Exotics are either scored 0 or excluded. The average C value (xC) is then multiplied by the square root of site or total plot (or native) richness (√S) to produce the Floristic Quality Assessment Index (FQA) index, (also called the Floristic Quality Index, or FQI). The FQA index, originally developed for the Chicago region (Swink and Wilhelm 1979, 1994) is a plant community index designed to assess the degree of "naturalness" of an area based on the presence of species whose ecological tolerance are limited (U.S. EPA 2002). FQA methods have been developed and successfully tested in Illinois (Swink and Wilhelm 1979), Missouri (Ladd 1993), Ohio (Andreas and Lichvar 1995), southern Ontario (Oldham et al. 1995), Michigan (Herman et al. 1996), Indiana (Coffee Creek Watershed Conservancy 2001), and North Dakota (Northern Great Plains Floristic Quality Assessment Panel 2001), but the exact form of the equation is still debated. Various authors have criticized the approach of combining the C value with the square root of richness (Bowles and Jones 2006), and recommend treating each separately, as done here.

**Measurement Protocol:** Species presence/absence data need to be collected from the wetland. Although, quantitative measurements are preferred, depending on time and financial constraints, this metric can be measured with qualitative or quantitative data. The two methods are described as follows: (1) Site Survey (semi-quantitative): walk the entire occurrence of the wetland system and make notes of each species encountered. A thorough search of each macro- and micro-habitat is required. (2) Quantitative Plot Data: The plot method described by Peet et al. (1998) is recommended for collecting quantitative data for this metric. This method uses a 20 x 50 m plot which is typically established in a 2 x 5 arrangement of 10 x 10 m modules. However, the array of modules can be rearranged or reduced to meet site conditions (e.g. 1 x 5 for linear areas or 2 x 2 for small, circular sites). The method is suitable for most types of vegetation, provides information on species composition across spatial scales, is flexible in intensity and effort, and compatible with data from other sampling methods (Peet et al. 1998, Mack 2004). See section A.2.2 for further information regarding plot establishment.

The metric is calculated by referencing only native species C value from a given state FQA Database, summing the C value, and dividing by the total number of native species (Mean C).

The Mean C is then used to determine the metric status in the scorecard.

**Metric Rating:** Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

| Metric Rating | | | |
|---|---|---|---|
| **Excellent** | **Good** | **Fair** | **Poor** |
| > 4.5 | 3.5-4.5 | 3.0 – 3.5 | < 3.0 |

**Data**: Various state and provincial FQA Databases (*in development*)

**Scaling Rationale:** In the Midwest, field studies using FQA have determined that a site with a Mean C of 3.0 or less is unlikely to achieve higher C values thus this value was used as the Restoration Threshold (between Fair and Poor) (Wilhelm and Masters 1995). In other words, those sites have been disturbed to the degree that conservative species are no longer able to survive and or compete with the less conservative species as a result of the changes to the soil and or hydrological processes on site. Sites with a Mean C of 3.5 or higher are considered to have at least marginal quality or integrity thus this value was used as the Minimum Integrity Threshold (between Good and Fair) (Wilhelm and Masters 1995). The threshold between Excellent and Good was assigned based on best scientific judgment upon reviewing the FQA literature. As the FQA is applied in this region, the thresholds may change.

**Confidence that reasonable logic and/or data support the index:** High

## *B.3 ABIOTIC CONDITION METRICS*

### Land Use Within the Wetland

**Definition:** This metric addresses the intensity of human dominated land uses within the wetland. Each land use type is assigned a coefficient ranging from 0.0 to 1.0 indicating its relative impact to the wetland (Hauer et al. 2002).

**Background:** This metric is one aspect of the condition of specific occurrences of wetland or terrestrial ecological systems.

**Rationale for Selection of the Variable:** The intensity of human activity in the wetland often has a proportionate impact on the ecological processes occurring onsite.

**Measurement Protocol:** This metric is measured by documenting land use(s) within the wetland. This should be completed in the field then verified in the office using aerial photographs or GIS. However with access to current aerial photography and/or GIS data a rough calculation of Land Use can be made in the office. Ideally, both field data as well as remote sensing tools are used to identify an accurate % of each land use within 100 m of the wetland edge. To calculate a Total Land Use Score estimate the % of the wetland area under each Land Use type and then plug the corresponding coefficient (Table 8; the coefficients in this table are derived from Hauer et al. (2002)) with some manipulation to account for regional application) into the following equation:

*Sub-land use score* = ∑ LU x PC⁄100

where**:** LU = Land Use Score for Land Use Type;  PC = % of adjacent area in Land Use Type.

Do this for each land use, then sum Sub-Land Use Score to arrive at a Total Land Score. For example, if 30% of the wetland was under moderate grazing (0.3 * 0.6 = 0.18), 10% composed of unpaved roads (0.1 * 0.1 =  0.01), and 40% was a natural area (e.g. no human land use) (1.0 * 0.4 = 0.4), the Total Land Use Score would = 0.59 (0.18 + 0.01 + 0.40).

Based on the Total Land Use Score, assign the Metric an Excellent, Good, Fair, or Poor rating on the scorecard.

**Metric Rating:**  Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

| **Metric Rating** | | | |
|---|---|---|---|
| **Excellent** | **Good** | **Fair** | **Poor** |
| Average Land Use Score = 1.0-0.95 | Average Land Use Score = 0.80-0.95 | Average Land Use Score = 0.4-0.80 | Average Land Use Score = < 0.4 |

**Data**:

Table 8.  Current Land Use and Corresponding Land Use Coefficients (based on Table 21 in Hauer et al. (2002))

| **Current Land Use** | **Coefficient** |
|---|---|
| Paved roads/parking lots/domestic or commercially developed buildings/gravel pit operation | 0.0 |
| Unpaved Roads (e.g., driveway, tractor trail) / Mining | 0.1 |
| Agriculture (tilled crop production) | 0.2 |
| Heavy grazing by livestock / intense recreation (ATV use/camping/popular fishing spot, etc.) | 0.3 |
| Logging or tree removal with 50-75% of trees >50 cm dbh removed | 0.4 |
| Hayed | 0.5 |
| Moderate grazing | 0.6 |
| Moderate recreation (high-use trail) | 0.7 |
| Selective logging or tree removal with <50% of trees >50 cm dbh removed | 0.8 |
| Light grazing / light recreation (low-use trail) | 0.9 |
| Fallow with no history of grazing or other human use in past 10 yrs | 0.95 |
| Natural area / land managed for native vegetation | 1.0 |

**Scaling Rationale:**  The coefficients were assigned according to best scientific judgment regarding each land use’s potential impact (Hauer et al. 2002). Land uses have differing degrees of potential impact.  Some land uses have minimal impact, such as simply altering the integrity of native vegetation (e.g., recreation and grazing), while other activities (e.g., hay production and agriculture) may replace native vegetation with nonnative or cultural vegetation yet still provide potential cover for species movement.

Intensive land uses (i.e., urban development, roads, mining, etc.) may completely destroy vegetation and drastically alter hydrological processes.

**Confidence that reasonable logic and/or data support the index:** Medium.

## Sediment Loading Index

**Definition:** The sediment loading index is a measure of the varying degrees to which different land uses contribute excess sediment via surface water runoff and overland flow into a wetland.

**Background:** This metric is one aspect of the condition of specific occurrences of wetland or terrestrial ecological systems.

**Rationale for Selection of the Variable:** The type and amount of each land use in the wetland and contributing watershed affects the amount of sediment that enters into a wetland. Excess sediment can change nutrient cycling, bury vegetation, suppress regeneration of plants, and carry pollutants into the wetland.

**Measurement Protocol:** Identify and estimate the percentage of each land use within the wetland and the contributing watershed (within 100 m of the wetland). This is best completed in the field, however with access to current aerial photography a rough calculation of Land Use can be made in the office. Ideally, both field data as well as remote sensing tools are used to identify an accurate % of each land use. Once the percentage of each land use is identified, multiply it by the corresponding Sediment Loading coefficient found for each land use in Appendix B, then sum for the Sediment Loading Index Score.

For example, if 50% of the wetland and contributing watershed (within 100 m of the wetland) was multi-family residential, 20% had a dirt/local roads, and 30% natural vegetation the calculation would be (0.5 * 0.61) + (0.2 * 0.97) + (0.3* 1.0) = 0.79 (Sediment Loading Index Score). Referring to the scorecard, this would give the metric a "Fair" rating.

The contributing watershed can be calculated or digitized using Digital Elevation Models in a GIS. Surface water divides are determined using topography and although groundwater divides do not always coincide with these same hydrological divides, groundwater movement is assumed to do so, unless other data for the site is available.

**Metric Rating:** Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

| Metric Rating | | | |
|---|---|---|---|
| **Excellent** | **Good** | **Fair** | **Poor** |
| | | | |

| Metric Rating | | | |
|---|---|---|---|
| **Excellent** | **Good** | **Fair** | **Poor** |
| Average Score = 0.9 – 1.0 | Average Score = 0.8 – 0.89 | Average Score = 0.75 – 0.79 | Average Score = < 0.7 |

**Data**: Appendix B (from Keate 2005).

**Scaling Rationale:** The scaling is based on best scientific judgment. Scores below 0.7 are assumed to have crossed a threshold in which loading impacts were considered to not be restorable (based on the land uses that have coefficients below 0.7). Additional research may suggest changes to the scaling criteria.

**Confidence that reasonable logic and/or data support the index:** Low/medium.

## Water Table Depth (Tier 2)

**Definition:** This metric estimates water table depth using hydric soil indicators from a single site visit.

**Background:** This metric is one aspect of the condition of specific occurrences of wetland or terrestrial ecological systems.

**Rationale for Selection of the Variable:** Hydric soils exhibit morphological characteristics which result from extended (more than a few days) periods of saturation and/or inundation (USDA 2002). These indicators are often used to indicate soil saturation and water table depth for wetland assessment procedures (Environmental Laboratory 1987, USDA 2002).

If Water Table Depth (Tier 3) cannot be used due to time/financial constraints, this metric provides an alternative, rapid, qualitative estimate of water table depth.

**Measurement Protocol:** This metric is measured by digging multiple soil pits in the wetland, ensuring that soil pit locations represent the edge as well as interior of the wetland. If quantitative vegetation data are being collected, soil pits should be located within these plots to allow correlations with vegetation data. For example, if using the 20 x 50 m plots described by Peet et al. (1998), soil pits would be located within each of the intensive modules (See section A.2.2 for further information regarding plot establishment). Allow at least 30 minutes to pass before measuring the water level in the soil pits. The distance between the soil surface and water level equals depth to water table.

Each horizon should be described and hydric soil indicators should be noted as to their depth, abundance, size, and contrasts (soil color). Soil and mottle colors (chroma/value) should be estimated from a Munsell Soil Chart. The USDA (2002) document, Field

Indicators of Hydric Soils (see below) should be consulted for additional information about hydric soil indicators.

Consideration of annual precipitation and its deviation from long-term averages from the closest weather station are needed to assess the reliability of this metric. Also, special attention should be placed on identifying any mottling or other soil profile features which may be indicative of remnant hydrological conditions.

**Metric Rating:** Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

| **Metric Rating** | | | |
|---|---|---|---|
| **Excellent** | **Good** | **Fair** | **Poor** |
| Seasonal high water table and/or soils saturated for long durations; Hydric Soils present; Water table is within 0.5 m of soil surface.<br><br>Surface soil horizons are gleyed or have a chroma value of 2 or less in mottled soils, or 1 less in unmottled soils; Depth to mottles is within 40 cm | Seasonal high water table and/or soils saturated for long durations; Hydric Soils present; Water table is within 0.5 m of soil surface.<br><br>Surface soil horizons are gleyed or have a chroma value of 2 or less in mottled soils, or 1 less in unmottled soils; Depth to mottles is within 40 cm | Seasonal high water table may be present; mottling is present but > 40 cm deep soil chroma values are >2<br><br>Hydric Soils NOT present<br><br>Indicators of remnant hydric conditions may be present (e.g., distinct boundaries between mottles and matrix) | No redoximorphic features present.<br><br>Hydric Soils NOT present<br><br>Indicators of remnant hydric conditions may be present (e.g., distinct boundaries between mottles and matrix) |

**Data**: See

**Scaling Rationale:** The metric criteria are based on Environmental Laboratory (1987), USDA (2002), and best scientific judgment.

**Confidence that reasonable logic and/or data support the index:** Medium/High.

## Water Table Depth (Tier 3)

**Definition:** This metric estimates average water table depth based on measurement from shallow groundwater wells.

**Background:** This metric is one aspect of the condition of specific occurrences of wetland or terrestrial ecological systems.

**Rationale for Selection of the Variable:** Seasonally high water tables are critical for the maintenance of ecological integrity in swamps.

This metric uses weekly measurements of the water table through June, July, and August to indicate the hydrological integrity.

**Measurement Protocol:** If quantitative vegetation data are being collected, monitoring wells should be located within these plots to allow correlations with vegetation data. For example, if using the 20 x 50 m plots described by Peet et al. (1998), wells would be located within each of the intensive modules (See section A.2.2 for further information regarding plot establishment).

Monitoring wells are set vertically in the ground to intercept the groundwater passively. Shallow monitoring wells should be installed according the protocol identified in the technical note, *Installing Monitoring Wells/Piezometers in Wetlands* (U.S. Army Corps of Engineers 2000). To summarize, 3.8 cm PVC pipe is perforated from just below the ground surface to the bottom of the pipe. Using a soil auger, a hole is dug to at least 40 cm. Sand is placed in the bottom of the well, the pipe is placed in the hole which is then backfilled with the excavated soil. Bentonite clay is then used to seal the opening of the hole and to ensure surface water does not infiltrated freely into the hole. Water levels inside the pipe result from the integrated water pressures along the entire length of perforations.

Water levels can be read with a steel measuring tape marked with a water-soluble marker. The only equipment needed is the tape, marker, and a rag to wipe the tape dry after each reading. The height of the well above the ground surface should be noted every time the instrument is read because pipes are known to move (U.S. Army Corps of Engineers 2000). Another simple measuring tool is that described in Henszey (1991). This instrument is attached to a meter tape, lowered into the well, and beeps when it contacts water at which point a measurement is taken from the tape and subtracted from the height of the well above the soil surface to give the depth of the water table.

Water levels should be checked weekly during the summer months. Automatic recording devices record water levels with down-well transducers or capacitance-based sensors are efficient for season-long monitoring but these cost much more than manually read instruments (U.S. Army Corps of Engineers 2000). However, automatic recorders may be less expensive than total travel costs and salaries. In addition, the credibility of monitoring data is enhanced by automatic wells (U.S. Army Corps of Engineers 2000). Automatic water-level recorders should be periodically checked and recalibrated as necessary (U.S. Army Corps of Engineers 2000).

Consideration of annual precipitation and its deviation from long-term averages from the closest weather station are needed to assess the reliability of this metric. During years of average precipitation this metric is a reliable rapid metric of the integrity of groundwater levels in the wetland. Long-term monitoring of groundwater in the wetland coupled with an analysis of climatic variation during that time-frame will provide the most reliable information.

Water table averages should be calculated for each month and hydrographs should be constructed to visually inspect trends.

**Metric Rating:** Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

| **Metric Rating** | | | |
|---|---|---|---|
| **Excellent** | **Good** | **Fair** | **Poor** |
| Water table depth in June-early July is < 40 cm | Water table depth in June-early July is 40-60 cm | Water table depth in June-early July is < 60 cm OR water table is above soil surface through July and August (indicates increased hydrological input) | Water table depth in June-early July is < 60 cm OR water table is above soil surface through July and August (indicates increased hydrological input) |

**Data**:

**Scaling Rationale:** The metric criteria are based on best scientific judgment, but current only a single threshold is possible, namely Excellent/Good versus Fair/Poor. Better scaling requires long term water depth data.

**Confidence that reasonable logic and/or data support the index:** High.

## Hydrological Alterations

**Definition:** The degree to which onsite or adjacent land uses and human activities have altered hydrological processes.

**Background:** This metric is one aspect of the condition of specific occurrences of wetland or terrestrial ecological systems.

**Rationale for Selection of the Variable:** Land uses within or near a wetland can reduce soil permeability, affect surface water inflows, impede subsurface flow, and lower water tables.

**Measurement Protocol:** This metric is measured by evaluating land use(s) and human activity within or near the wetland which appear to be altering the hydrological regime of the site. Data collected in the field as well as from aerial photograph and GIS should be used. The ratings in the scorecard reflect various degrees of hydrological alteration.

**Metric Rating:** Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

| **Metric Rating** |
|---|

| Excellent | Good | Fair | Poor |
|---|---|---|---|
| No alterations. No dikes, diversions, ditches, flow additions, or fill present in wetland that restricts or redirects flow | Low intensity alteration such as roads at/near grade, small diversion or ditches (< 1 ft. deep) or small amount of flow additions | Moderate intensity alteration such as 2-lane road, low dikes, roads w/culverts adequate for stream flow, medium diversion or ditches (1-3 ft. deep) or moderate flow additions. | High intensity alteration such as 4-lane Hwy., large dikes, diversions, or ditches (>3 ft. deep) capable to lowering water table, large amount of fill, or artificial groundwater pumping or high amounts of flow additions |

**Data**: N/A

**Scaling Rationale:** The criteria are based on Keate (2005) and best scientific judgment.

**Confidence that reasonable logic and/or data support the index:** Medium.

## Surface Water Runoff Index

**Definition:** The surface water runoff index is a measure of the varying degrees to which different land uses alters surface water runoff and overland flow into a wetland.

**Background:** This metric is one aspect of the condition of specific occurrences of wetland or terrestrial ecological systems.

**Rationale for Selection of the Variable:** The type and amount of each land use in the wetland and contributing watershed affects the timing, duration, and frequency of surface water runoff and overland flow into a wetland. These flows alter the hydrological regime of the wetland and can result in degradation of biotic integrity, change nutrient cycling, and potentially affect peat integrity.

**Measurement Protocol:** Identify and estimate the percentage of each land use within the wetland and the contributing watershed (within 100 m of the wetland). This is best completed in the field, however with access to current aerial photography a rough calculation of Land Use can be made in the office. Ideally, both field data as well as remote sensing tools are used to identify an accurate % of each land use. Once the percentage of each land use is identified, multiply it by the corresponding Surface Water Runoff coefficient found for each land use in Appendix B, then sum for the Surface Water Index Score.

For example, if 50% of the wetland and contributing watershed (within 100 m of the wetland) was under heaving grazing, 10% had a dirt road, and 40% natural vegetation the calculation would be (0.5 * 0.76) + (0.1 * 0.71) + (0.4* 1.0) = 0.85 (Surface Water Index Score). Referring to the scorecard, this would give the metric a “Fair” rating.

The contributing watershed can be calculated or digitized using Digital Elevation Models in a GIS. Surface water divides are determined using topography and although groundwater divides do not always coincide with these same hydrological divides, groundwater movement is assumed to do so, unless other data for the site is available

**Metric Rating:** Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

| Metric Rating | | | |
|---|---|---|---|
| **Excellent** | **Good** | **Fair** | **Poor** |
| Average Score = 0.9 – 1.0 | Average Score = 0.8 – 0.89 | Average Score = 0.75 – 0.79 | Average Score = < 0.7 |

**Data**: Appendix B (from Keate 2005).

**Scaling Rationale:** The scaling is based on best scientific judgment. Scores below 0.7 are assumed to have crossed a threshold in which runoff impacts were considered to not be restorable (based on the land uses that have coefficients below 0.7). Additional research may suggest changes to the scaling criteria.

**Confidence that reasonable logic and/or data support the index:** Medium.

## Soil Organic Carbon

**Definition:** This metric measures the amount of soil organic carbon present in the soil.

**Background:** This metric is one aspect of the condition of specific occurrences of wetland or terrestrial ecological systems.

**Rationale for Selection of the Variable:** Soil organic matter or carbon generally refers to the organic fraction of the soil, including plant and animal residues at various stages of decomposition, as well as substances synthesized by the soil organisms (Neue 1984). Organic matter plays an extremely important role in the soil environment, including increases water holding capacity, encouraging soil structure, has a high cation exchange capacity, and supplies essential nutrients (Brady 1990).

Soil organic carbon is strong metric of soil quality due to its sensitivity to environmental disturbance (NRC 2000 *in* Fennessy et al. 2004). Given that soil organic carbon contributes to critical hydrologic, biogeochemical, and physical processes (Hall et al. 2003), a reduction in soil organic carbon from reference conditions serves as a strong metric of loss of soil quality.

**Measurement Protocol:** Multiple soil pits should be dug in the wetland to a depth of at least 40 cm (deeper pits are suggested…up to 120 cm). If quantitative vegetation data are being collected, soil pits should be located within these plots to allow correlations with vegetation data. For example, if using the 20 x 50 m plots described by Peet et al. (1998), soil pits would be located within each of the intensive modules. At least five replicate soil samples should be taken within the top 10 cm of the soil surface in each pit. The replicates are mixed together as "one" sample from the site. Each soil sample should be placed in their own individual plastic bag, packed on ice, and sent to a laboratory for analysis of soil organic carbon (e.g., CHN Analyzer).

**Metric Rating:** Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

| **Metric Rating** | | | |
|---|---|---|---|
| **Excellent** | **Good** | **Fair** | **Poor** |
| N/A | Soil C is nearly equivalent to natural range of variability | Soil C is significantly lower than natural range of variability | Soil C is significantly lower than natural range of variability |

**Data**: N/A

**Scaling Rationale:** Reference soil organic carbon levels need to be established in undisturbed examples. Thereafter, the scaling is based on best scientific judgment and an assumed linear relationship of the amount of deviation from the reference standard to level of disturbance. If data are collected from wetlands across a disturbance gradient, quantitative criteria could be established. Alternatively, if "baseline" soil organic carbon levels are known (from "pre-impact" conditions or from adjacent unaltered sites) then this metric can be used to determine change of soil organic carbon with time.

**Confidence that reasonable logic and/or data support the index:** Medium/High.

## Soil Bulk Density

**Definition:** Soil bulk density is a ratio of the mass/volume of the soil. This metric is a measure of the compaction of the soil horizons.

**Background:** This metric is one aspect of the condition of specific occurrences of wetland or terrestrial ecological systems.

**Rationale for Selection of the Variable:** Bulk density is a measure of the weight of the soil divided by its volume and provides and indication of the level of compaction. Compaction can results from any activity which compresses soil particles thereby increasing the weight to volume ratio. This can reduce the soil's water holding capacity, infiltration, water movement through the soil, and limit plant growth by physically restricting root growth (NRCS 2001). Bulk density of organic soils are typically much less than those of mineral soils, however as decomposition increases and/or organic soils are compacted from human activity, bulk density of organic soils will increase. This has corresponding negative impacts on ecological processes such as water movement through the peat body, decomposition, and nutrient cycling.

**Measurement Protocol:** Multiple soil pits should be dug in the wetland to a depth of at least 40 cm. If quantitative vegetation data are being collected, soil pits should be located within these plots to allow correlations with vegetation data. For example, if using the 20 x 50 m plots described by Peet et al. (1998), soil pits would be located and samples collected within each of the intensive modules.

The samples are collected by taking a core sample within the top 15 cm of the soil. A cylinder of known volume should be used to collect samples. A PVC pipe of known dimensions will suffice. The cylinder is simply inserted into the peat profile, extracted, then shaved to eliminate any peat which is not contained within the cylinder. The soil remaining in the cylinder can then be placed into a plastic bag and then sent to a laboratory for analysis. Bulk density and soil texture (e.g., particle distribution) should analyzed. Alternatively, texture can be determined in the field using the "field hand method", however lab analysis is preferable.

Once texture and bulk density are determined, use the information below to determine whether the soil's bulk density is less than, equal to, or greater then the minimum root-restricting bulk density values listed for the corresponding texture of the soil and assign the metric rating accordingly in the scorecard.

There are no root restricting values given for organic soils, thus if the swamp is dominated by organic soil, reference bulk density measurements need to be established in undisturbed areas.

**Metric Rating**: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

| **Measure (Metric) Rating** | | | |
|---|---|---|---|
| **Excellent** | **Good** | **Fair** | **Poor** |
| N/A | Bulk density value for wetland is at least 0.2 (g/cm3) less than Root Restricting Bulk Density value for the soil texture found in the wetland. ( | Bulk density for wetland is between 0.2 to 0.1 (g/cm3) less than Root Restricting Bulk Density value for the soil texture found in the wetland. | Bulk density for wetland is = or > than Root Restricting Bulk Density value for the soil texture found in the wetland. |

**Data**: The data below are derived from a Natural Resource Conservation Service, Soil Quality Information Sheet — Compaction which can be found online at: http://soils.usda.gov/sqi/publications/sqis.html

Theses texture classes have the following Root Restricting Bulk Density values (g/cm3):

1. Coarse, medium, and fine sand AND loamy sand other than loamy very fine sand = 1.8 g/cm3
2. Very fine sand, loamy very find sand = 1.77 g/cm3
3. Sandy loam = 1.75 g/cm3
4. Loam, sandy clay loam = 1.7 g/cm3
5. Clay loam = 1.65 g/cm3
6. Sandy clay = 1.6 g/cm3
7. Silt, silt loam = 1.55 g/cm3
8. Silty clay loam = 1.5 g/cm3
9. Silty clay = 1.45 g/cm3
10. Clay = 1.4 g/cm3

**Scaling Rationale:** The scaling is based on best scientific judgment and an assumed linear relationship of the amount of deviation from the reference standard to level of disturbance. However, no distinction was made between Excellent and Good as there is no information to suggest that threshold. Alternatively if "baseline" bulk density levels are known (from "pre-impact" conditions or from adjacent unaltered sites) then this metric can be used to determine change of bulk density with time.

**Confidence that reasonable logic and/or data support the index:** Medium/High.

## Nutrient/Pollutant Loading Index

**Definition:** The nutrient/pollutant loading index is a measure of the varying degrees to which different land uses contributed excess nutrients and pollutants via surface water runoff and overland flow into a wetland.

**Background:** This metric is one aspect of the condition of specific occurrences of wetland or terrestrial ecological systems.

**Rationale for Selection of the Variable:** The type and amount of each land use in the wetland and contributing watershed affects the amounts and types of nutrients and pollutants that enter into a wetland. Excess nutrients can result in degradation of biotic integrity, change nutrient cycling, and potentially affect peat integrity.

In a functional assessment of slope and depressional wetlands associated with the Great Salt Lake, Keate (2005) developed a HGM assessment model primarily based on land use as a surrogate for human impacts on wetland functions. Coefficients from Nnadi and Bounvilay (1997) were used to represent the sediment, nutrient loading, runoff, and wildlife impacts associated with various land uses. The functions considered included hydrologic, geochemical and habitat characteristics. The same coefficients used in the Keate (2005) method are used for this metric.

**Measurement Protocol:** Identify and estimate the percentage of each land use within the wetland and the contributing watershed (within 100 m of the wetland). This is best completed in the field, however with access to current aerial photography a rough calculation of Land Use can be made in the office. Ideally, both field data as well as remote sensing tools are used to identify an accurate % of each land use. Once the percentage of each land use is identified, multiply it by the corresponding Nutrient/Pollutant Loading coefficient found for each land use in Appendix B, then sum for the Nutrient/Pollutant Loading Index Score.

For example, if 50% of the wetland and contributing watershed (within 100 m of the wetland) was under heaving grazing, 10% had a dirt road, and 40% natural vegetation the calculation would be (0.5 * 0.87) + (0.1 * 0.92) + (0.4* 1.0) = 0.93 (Surface Water Index Score). Referring to the scorecard, this would give the metric a "Good" rating.

The contributing watershed can be calculated or digitized using Digital Elevation Models in a GIS. Surface water divides are determined using topography and although groundwater divides do not always coincide with these same hydrological divides, groundwater movement is assumed to do so, unless other data for the site is available

**Metric Rating**: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

| Measure (Metric) Rating | | | |
|---|---|---|---|
| **Excellent** | **Good** | **Fair** | **Poor** |
| Average Score = 0.9 – 1.0 | Average Score = 0.8 – 0.89 | Average Score = 0.75 – 0.79 | Average Score = < 0.7 |

**Data**: Appendix B (from Keate 2005).

**Scaling Rationale:** The scaling is based on best scientific judgment. Scores below 0.7 are assumed to have crossed a threshold in which loading impacts are considered to not be restorable (based on the land uses that have coefficients below 0.7). Additional research may suggest changes to the scaling criteria.

**Confidence that reasonable logic and/or data support the index:** Low/medium.

## *B.4 SIZE*

### Absolute Size

**Definition:** Absolute size is the current size of the wetland

**Background:** This metric is one aspect of the size of specific occurrences of wetland or terrestrial ecological systems.

**Rationale for Selection of the Variable:** Absolute size is pertinent to ecological integrity if the surrounding landscape is impacted by human-induced disturbances. When the surrounding landscape is impacted and has the potential to affect the wetland, larger sized wetlands are able to buffer against these impacts better than smaller sized wetlands due to the fact they generally possess a higher diversity of abiotic and biotic processes allowing them to recover and remain more resilient. However, when the landscape is unimpacted (i.e. has an "Excellent" rating), then absolute size has little impact on ecological integrity since there are no adjacent impacts to buffer. Of course, larger wetlands tend to have more diversity (MacArthur and Wilson 1967), however this is a metric more pertinent to functional or conservation value than ecological integrity. Thus, absolute size is included as a metric but is only considered in the overall ecological integrity rank if the landscape is impacted (See Section A.3.3). Regardless if absolute size is considered in the overall ecological integrity rank, it provides important information to conservation planners and land managers.

**Measurement Protocol:** Absolute size can be measured easily in GIS using aerial photographs, orthophoto quads, National Wetland Inventory maps, etc. Absolute size can also be estimated in the field using 7.5 minute topographic quads, National Wetland Inventory maps, or a global positioning system. Wetland boundaries aren't delineated using jurisdictional methods (U.S. Army Corps of Engineers 1987) rather by the guidelines identified elsewhere [need to specify where] for delineating the boundaries of this system. Size is then calculated in hectares.

**Metric Rating:** Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

| **Metric Rating** | | | |
|---|---|---|---|
| **Excellent** | **Good** | **Fair** | **Poor** |
| > 25 acres (10 ha) | 10 to 25 acres (4-10 ha) | 1 to 10 acres (0.5-4 ha) | < 1 acre (<0.5 ha) |

**Data**: In Vermont, Sorenson et al. (2004) report that the mean size of hardwood swamps types ranged from 2.9 acres (range 0.1-9.0) to 70 acres (range of 1 – 708). Alkaline swamps tended to be larger than acid swamps. Overall the mean size of hardwood swamps and floodplains in Vermont was 11.0 (S.D. of 72.0).

**Scaling Rationale:** Scaling criteria are based on best scientific judgment.

**Confidence that reasonable logic and/or data support the index:** Medium/High.

## Relative Size

**Definition:** Relative size is the current size of the wetland divided by the total potential size of the wetland multiplied by 100.

**Background:** This metric is one aspect of the size of specific occurrences of wetland or terrestrial ecological systems.

**Rationale for Selection of the Variable:** Relative size is an indication of the amount of the wetland lost due to human-induced disturbances. It provides information allowing the user to calibrate the Absolute Size metric to the abiotic potential of the wetland onsite. For example, if a wetland has an Absolute Size of 2 hectares but the Relative Size is 50% (1 hectare), this indicates that half of the original wetland has been lost or severely degraded. Unlike Absolute Size, the Relative Size metric is always considered in the ecological integrity rank.

**Measurement Protocol:** Relative size can be measured in GIS using aerial photographs, orthophoto quads, National Wetland Inventory maps, etc. However, field calibration of size is required since it can be difficult to discern potential wetland boundaries with current potential boundaries. Relative size can also be estimated in the field using 7.5 minute topographic quads, National Wetland Inventory maps, or a global positioning system. Wetland boundaries aren't delineated using jurisdictional methods (U.S. Army Corps of Engineers 1987) rather by the guidelines identified elsewhere [need to specify where] for delineating the boundaries of this system. Relative size is then calculated in hectares.

**Metric Rating:** Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

| **Metric Rating** | | | |
|---|---|---|---|
| **Excellent** | **Good** | **Fair** | **Poor** |
| Wetland area = onsite Abiotic Potential | Wetland area < Abiotic Potential; Relative Size < 10% of wetland has been reduced, destroyed or severely disturbed due to roads, impoundments, development, human-induced drainage, etc. | Wetland area < Abiotic Potential; 10-25% of wetland has been reduced, destroyed or severely disturbed due to roads, impoundments, development, human-induced drainage, etc | Wetland area < Abiotic Potential; > 25% of wetland has been reduced, destroyed or severely disturbed due to roads, impoundments, development, human-induced drainage, etc |

**Data**: N/A

**Scaling Rationale:** Scaling criteria are based on Rondeau (2001) and best scientific judgment.

**Confidence that reasonable logic and/or data support the index:** Medium/High.

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# APPENDIX A:  FIELD FORM REQUIREMENTS

# APPENDIX B: SUPPLEMENTARY DATA:

Coefficient Table (coefficients were calculated from numerous studies throughout the U.S. (Keate 2005)

| Land Use | Surface Water Runoff | Nutrient/ Pollutant Loading | Suspended Solids |
|---|---|---|---|
| Natural area | 1.00 | 1.00 | 1.00 |
| Dirt Road (dirt or crushed or loose gravel, unpaved roads, local traffic) | 0.71 | 0.92 | 0.90* |
| Field Crop (actively plowed field) | 0.95 | 0.94 | 0.85** |
| Clearcut forest | 0.83 | 0.93 | 0.98 |
| Golf Course (area manipulated for golf, manicured grass) | 0.75 | 0.86 | 0.94 |
| High Intensity Commercial (area is entirely of commercial use and paved - shopping malls, construction yards) | 0.13 | 0 | 0 |
| High Traffic Highway (4 lanes or larger, railroads) | 0.26 | 0.43 | 0.48 |
| Industrial (intense production activity occurs on a daily basis - oil refineries, auto body and mechanic shops, welding yards, airports) | 0.25 | 0.54 | 0 |
| Feedlot, Dairy | 0.62 | 0 | 0.81 |
| Heavy grazing - Non-rotational grazing (year-round or mostly year-round grazing, vegetation is sparse and area trampled) | 0.76 | 0.87 | 0.85*** |
| Rotational Grazing (grazing is for short periods during the year, vegetation is allowed to recover) | 0.96 | 0.95 | 0.98 |
| Light Intensity Commercial (businesses have large warehouses and showrooms - large patches of vegetation occur between buildings) | 0.19 | 0.64 | 0.02 |
| Low Density Rural Development (areas of small structures in a farm or ranch setting - silos, barns) | 0.87 | 0.92 | 0.98 |
| Low Traffic Highway (2-3 lane paved highways) | 0.26 | 0.69 | 0.16 |
| Multi-family Residential (subdivisions with lots ½ acre or less) | 0.38 | 0.55 | 0.61 |
| Nursery (business where the production of nursery grade vegetation occurs including greenhouses, outbuildings and sales lots) | 0.86 | 0.94 | 1.00 |
| Orchards | 0.86 | 0.93 | 0.99 |
| Waterfowl Management Areas | 0.86 | 0.91 | 0.98 |
| Single Family Residential (residential lots are greater than ½ acre with vegetation between houses) | 0.75 | 0.86 | 0.94 |
| Surface Solid Waste (landfills and waste collection facilities) | 0.71 | 0.87 | 0.61 |
| Sewage Treatment Plants and Lagoons | 0.60 | 0.61 | 0.71 |
| Mining | 0.76 | 0.94 | 0.80 |

* changed value from 0.97; ** changed value from 1.00; *** changed value from 0.98