Rocky Mountain Subalpine-Montane Fen Ecological System

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Ecological Integrity Assessment

Prepared by: Joe Rocchio

Colorado Natural Heritage Program
Colorado State University
254 General Services Building
Fort Collins, CO 80523

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A. INTRODUCTION

A.1 Classification Summary

CECES306.831 Rocky Mountain Subalpine-Montane Fen

<u>Division 306, Herbaceous Wetland</u>
Spatial Scale & Pattern: Small Patch **Classification Confidence**: Medium
Required Classifiers: Natural/Semi-natural, Vegetated (>10% vasc.), Wetland
Diagnostic Classifiers: Moss/Lichen (Non-Vascular), Organic Peat (>40 cm), Graminoid, Bryophyte, Seepage-Fed Sloping [Peaty], Extreme (mineral) rich & iron rich, Saturated Soil

Non-Diagnostic Classifiers: Montane [Upper Montane], Montane [Montane], Montane [Lower Montane], Temperate [Temperate Continental], Depressional [Pond], Shallow (<15 cm) Water

HGM: Slope and Depressional

Concept Summary: This system occurs infrequently throughout the Rocky Mountains from Colorado north into Canada. It is confined to specific environments defined by ground water discharge, soil chemistry, and peat accumulation of at least 40 cm. Most fens in the Rocky Mountains are considered Intermediate to Rich Fens, however this system includes extreme rich and iron fens, both being quite rare. Fens form at low points in the landscape or near slopes where ground water intercepts the soil surface. Ground water inflows maintain a fairly constant water level year-round, with water at or near the surface most of the time. Constant high water levels lead to accumulation of organic material. In addition to peat accumulation and perennially saturated soils, the extreme rich and iron fens have distinct soil and water chemistry, with high levels of one or more minerals such as calcium, magnesium, or iron. Fens usually occur as a mosaic of several plant associations dominated by water sedge (*Carex aquatilis*), beaked sedge (*C. utriculata)*, med sedge (*C. limosa*), wollyfruit sedge (*C. lasiocarpa*), bog birch (*Betula nana*), Bellardi's bog sedge (*Kobresia myosuroides*), simple bog sedge (*K. simpliciuscula*), and Rolland's bulrush (*Trichophorum pumilum*). *Sphagnum* spp. (moss) is indicative of iron fens while calcareous mosses occur in extreme rich fens. The surrounding landscape may be ringed with other wetland systems, e.g., riparian shrublands, or a variety of upland systems from grasslands to forest.

Ecological Divisions (Bailey): 304, 306
TNC Ecoregions: 11:P, 18:C, 19:P, 20:C, 21:P, 68:P, 7:C, 8:P, 9:P
Subnations/Nations: AB:c, AZ:p, BC:c, CO:c, ID:c, MT:c, NV:p, OR:c, UT:c, WA:c, WY:p

A.2 Ecological System Description

A.2.1. Environment

Climate

A continental climate dominates the Southern Rocky Mountains producing warm, dry summers and cold winters and an overall semi-arid climate. Evaporation generally exceeds precipitation, especially at lower elevations and in the intermountain basins; however, increasing precipitation and lower temperatures at higher elevations tends to reverse this trend, although aspect, topography, and intense solar radiation can moderate these effects on the evaporation/precipitation ratio (Laubhan 2004). The ratio between evaporation and precipitation has a strong influence on the hydrology of wetlands throughout the region.

Geomorphology

The Southern Rocky Mountains are composed of various igneous, metamorphic, and sedimentary rocks (Mutel and Emerick 1984; Windell et al. 1986). The mountain valleys are relatively young topographical forms created by the erosional effects of flowing water and glacier movement (Windell et al. 1986). Intermountain basins were formed from tectonic and volcanic events which occurred during mountain-forming processes (Windell et al. 1986). The valleys of these basins are now filled with deep alluvial deposits derived from erosional processes in the nearby mountain ranges (Windell et al. 1986). Glaciation has had a large influence on landforms at high elevations through large-scale erosional and depositional processes and has a large influence on the presence and distribution of fens. Glacial features such as moraines and kettle ponds often result in a geomorphic template conducive for fen formation. Terminal or lateral moraines often create a confined basin where impounded subsurface and/or surface water allow for peat accumulation (Windell et al. 1996; Cooper 1990; and Cooper 2005) whereas kettle ponds have a permanent water body in which fen formation occurs along the fringes. In addition, glaciation has created wide, relatively level mountain valleys where large wetland complexes tend to form. Fens often form in these valleys due to large alluvial aquifers and nearby springs supplied by snowmelt from adjacent hillsides (Cooper 1990).

There are two kinds of peatlands found in the Southern Rocky Mountains: topogeneous and soligeneous.

> **Topogeneous Peatlands**: Develop in topographic depressions that typically have no inlet or outlet. Their water source includes upwelling groundwater or surface runoff from the basin edges (Charman 2002). Topogeneous fens have also been described as *basin fens* and hereafter are referred to as such (Charman 2002; National Wetlands Working Group 1997). Basin fens are found in confined basins which have often been created by impoundment of subsurface and/or surface flow by terminal or lateral moraines or in wide, glacially carved valleys (Cooper 2005). Although many basin fens occur in the Southern Rocky Mountains, only a few have persistent and stable surface/groundwater inflows suitable for the creation of ponds and lakes (Cooper 2005). Many of these sites

develop a unique fen type, a *floating fen* or floating mat, on the margins of the open water.

Soligeneous Peatlands: Develop with regional interflow and surface runoff and are found on slopes and valley bottoms (Charman 2002). Soligenous fens have also been described as *slope fens* and hereafter are referred to as such (Charman 2002; National Wetlands Working Group 1997). Slope fens are probably the most common fen type in the Southern Rocky Mountains. They occur on or at the base of slopes where groundwater discharges due to a break in the topography or a change in geology or in valley bottoms where alluvial groundwater supports peat formation (Cooper 1990; Woods 2001).

Hydrology

The interaction of climate and geomorphology has a strong influence on local hydrological processes in a wetland. For example, snowmelt at high elevations contributes a large proportion of water to most wetland types through its influence on groundwater and surface water dynamics (Laubhan 2004). In mountain valleys, snowmelt and geomorphology are major factors controlling the extent, depth, and duration of saturation resulting from high groundwater levels and also exert controls most aspects of the frequency, timing, duration, and depth of flooding along riparian areas (Laubhan 2004). Wetlands in intermountain basins are also affected by snowmelt via its association with the contributing surface water to the valley aquifers.

Groundwater levels are dependent on the underlying bedrock, watershed topography, soil characteristics, and season (Rink and Kiladis 1986). In areas of thin soils, little surface water is retained as groundwater, however in areas of deep alluvial material surface water collects in alluvial aquifers which support numerous wetlands (Rink and Kiladis 1986). Groundwater discharge also occurs in areas where subsurface flow is forced to the surface due to underlying impermeable bedrock or soils or a break in topography.

Peatlands in the Southern Rocky Mountains are fens that remain saturated primarily as a result of discharging groundwater, seasonal and/or perennial surface water input, or due to their location on the fringes of lakes and ponds (Cooper 1990). Thus, peatlands only occur in confining basins, near persistent groundwater discharge sites, or near permanent water bodies such as lakes, ponds, and streams. Due to the limited amount of precipitation and low humidity in the Southern Rocky Mountains, true bogs do not occur in the region (Cooper1990).

Snowmelt maintains high water tables through June in many wetland types (wet meadows, fens, riparian areas, etc.), however only those areas with soil saturation or a water table within 30 cm of the soil surface through July and August accumulates peat (Cooper 1990; Chimner and Cooper 2003). Thus, a distinguishing characteristic between wet meadows and fens is the depth of the water table in these months. Even in fens, the water table begins to drop in late-July and August. However, late summer precipitation often replenishes local aquifers thereby raising water tables, suggesting summer precipitation may be important to maintaining high water tables in Southern Rocky Mountain fens (Cooper 1990).

Surface water flow is a function of snowmelt, watershed and valley topography and area, late-summer rainfall, and the extent of upstream riparian wetlands (Rink and Kiladis 1986). Upstream wetlands release water throughout the growing season and are an important contribution to streamflow during later-summer and/or drought periods.

A.2.2. Vegetation & Ecosystem

Vegetation

Basin and slope fens share many of the same species and most are dominated by graminoids, especially clonal sedges such as water sedge (*Carex aquatilis*), beaked sedge (*C. utriculata*), woollyfruit sedge (*C. lasiocarpa*), Buxbaum's sedge (*Carex buxbaumii*)and small-winged sedge (*C. simulata*). Graminoid cover may constitute 40-100% of the herbaceous layer. Other common species associated with this system include smallwing sedge (*Carex microptera*), woolly sedge (*C. pellita*), mud sedge (*C. limosa*), Nebraska sedge (*Carex nebrascensis*), clustered field sedge (*Carex praegracilis*), few-flower spikerush (*Eleocharis quinqueflora*), common spikerush (*Eleocharis palustris*), tufted hairgrass (*Deschampsia cespitosa*), mountain rush (*Juncus balticus* var. *montanus*), slimstem reedgrass (*Calamagrostis stricta*), bluejoint reedgrass (*Calamagrostis canadensis*), and marsh bluegrass (*Poa leptocoma*).

Forbs are typically sparse, with occasional dense patches in some areas. Percent cover ranges from nearly absent to over 60% and consists of perennial, terrestrial and aquatic species. Species that my be encountered include elephanthead lousewort (*Pedicularis groenlandica*), marsh marigold (*Caltha leptosepala*), large leaf avens (*Geum macrophyllum*), American speedwell (*Veronica americana*), alpine meadow-rue (*Thalictrum alpinum*), alpine leafy bract aster (*Symphyotrichum foliaceum* var. *foliaceum*), western mountain aster (*Symphyotrichum spathulatum* var. *spathulatum*), willowherb (*Epilobium* spp.), fringed grass of Parnassus (*Parnassia fimbriata*), false gold groundsel (*Packera pseudaurea*), American bistort (*Polygonum bistortoides*), alpine bistort (*P. viviparum*), Queen's crown (*Rhodiola rhodantha*), field horsetail (*Equisetum arvense*), and Jacob's ladder (*Polemonium caeruleum*).

Shrubs such as bog birch (*Betula nana*), planeleaf (*Salix planifolia*) and Wolf willow (*S. wolfii*) are also commonly found in fens. When shrublands dominate the fen or a portion of the fen, these areas may fall within the Rocky Mountain Subalpine-Montane Riparian Shrublands Ecological System type if they occupy an area large enough to be classified as a shrubland. These shrub dominated fens are also often referred to as "carrs;" however, the term is often used to describe shrub dominated wetlands on mineral soil as well (Cooper 1986).

Mosses are also an integral floristic as well as functional component to fens. Most fens in the Southern Rocky Mountains are dominated by brown mosses such as *Drepanocladus aduncus, Tomenthypnum nitens,* and *Aulacomnium palustre*.

Sphagnum species are not as common as brown mosses in intermediate and rich fens however *Sphagnum* is an important and conspicuous component of poor and iron fens. Mosses provide a critical role in the accumulation of peat, formation of hummocks, and nutrient cycling within many fens.

Basin fens which have floating mats support many rare wetland plants in the Southern Rocky Mountains, such as roundleaf sundew (*Drosera rotundifolia*), woollyfruit sedge sedge, bog bean (*Menyanthes trifoliata*), marsh cinquefoil (*Comarum palustre*), and numerous uncommon sedges (*Carex buxbaumii*, *C. limosa*, *C. dioica*, etc.). Because these floating mats are often nutrient poor, many species of *Sphagnum* also occur in these areas.

Unique slope fens such as iron fens support Engelmann spruce (*Picea engelmannii*), lodgepole pine (*Pinus contorta*), bog birch, dwarf blueberry (*Vaccinium cespitosum*), creeping wintergreen (*Gaultheria humifusa*), water sedge, and bluejoint reedgrass, with a continuous carpet of mosses mainly dominated by S*phagnum* spp. At the Mount Emmons Iron Fen in Gunnison County, CO, two unusual species of dragonfly (*Leucorhinea hudsonica* and *Sematochlora semicircularis*) are associated with the fen (Colorado Natural Areas Program 2005).

Extreme rich fens are dominated by simple bog sedge (*Kobresia simpliciuscula*), Bellardi's bog sedge (*Kobresia myosuroides*), few-flowered spikerush, and arrowgrass (*Triglochin* sp.) (Cooper and Sanderson 1997). The unusual water chemistry of extreme rich fens supports many rare plants, animals, and plant communities. Porter's feathergrass (*Ptilagrostis mongholica* ssp. *porteri*) and pale blue-eyed grass (*Sisyrinchium pallidum*) are both globally rare plants. Eleven other vascular plant species and one moss that are very rare in Colorado also occur in extreme rich fens including livid sedge (*Carex livida*), Canadian single-spike sedge (*C. scirpoidea*), green sedge (*C. viridula*), slender cottongrass (*Eriophorum gracile*), Greenland primrose (*Primula egaliksensis*), hoary willow (*Salix candida*), low blueberry willow (*S. myrtillifolia*), autumn willow (*S. serissima*), pygmy bulrush (*Trichophorum pumilum*), few-flowered ragwort (*Packer pauciflora*), northern bladderwort (*Utricularia ochroleuca*), and a moss (*Scorpidium scorpioides*) (Sanderson and March 1995).

Biogeochemistry

Soil and water chemistry are among the most important factors in the development and structure of peatland ecosystems. Factors such as pH, mineral concentration, available nutrients, and cation exchange capacity influence the vegetation types and their productivity. In the Southern Rocky Mountains, fens receive much of their nutrients from surface and groundwater inputs (Knud-Hansen 1986). Nitrogen and phosphorus are thought to be the major limiting nutrients in fens (Mitsch & Gosselink 2000; Windell et al. 1986).

Peatlands are often classified along a chemical gradient (pH and concentration of cations such as Ca^{2+}, Na^{+}, K^{+}, and Mg^{2+}) (Cooper and Andrus 1994). The gradient is typically as follows: ombrotrophic bogs and poor fens are characterized by low pH and low cation concentration, whereas rich and extreme rich fens are characterized by high pH and high cation concentration. Most fens in Colorado would be considered "intermediate" or "rich" fens. These terms do not refer to the number of species in the wetland rather refer instead to the levels of nutrients (calcium, magnesium, etc.) in the water. However, the types and concentration of nutrients present have a strong influence over the type of vegetation that grows in a fen.

The chemistry of fens is determined by bedrock associated with the contributing water source. Much of the Southern Rocky Mountains region is dominated by crystalline geology resulting in mostly poor, intermediate, and rich fens on the landscape (Cooper 1990; Johnson and Steingraeber 2003). However, mountain fens can be difficult to classify according to the nutrient gradient, which was developed mostly based on boreal peatlands, due to the discrepancy between the pH and nutrient content of these fens (Johnson 2001). For example, many mountain fens have a pH which is slightly acidic to circumneutral; however, cation concentrations are often very low due to the underlying bedrock (Johnson 2001). Glacial outwash and sedimentary bedrock result in the formation of more nutrient rich fens (Cooper 1993; Johnson and Steingraeber 2003). For example, the levels of calcium, magnesium, and other plant nutrients in the groundwater of extreme rich fens are very high. The groundwater picks up these elements as it percolates through the limestone in the contributing watershed.

Iron fens are unusual peatlands in that surface/groundwater pH and the associated plant species are typical of ombrotrophic bogs and acidic, nutrient poor fens, while the concentration of ions is more typical of rich and extreme rich fens. This occurs due to groundwater draining through rock rich in pyrite. As the pyrite oxidizes, it produces sulfuric acid which leaches cations from nearby bedrock resulting in a nutrient rich yet acidic water supply (Cooper 1999). Iron fens are characterized by limonite ledges, which form when iron precipitates out of solution and then solidifies into hard rock. Organic substrates (e.g., peat and coarse woody debris) often are mixed with the iron precipitate thus limonite often contains large amounts of organic materials.

Productivity
In general, fens are less productive than other wetland types and often less than nearby upland ecosystems as well (Mitsch and Gosselink 2000). Cold temperature, deep snowpacks, and a short growing season lead to lower primary productivity in Southern Rocky Mountain fens compared to other wetland types, especially those at lower elevations (Knud-Hansen 1986). However, Chimner and Cooper (2003) found that fens in the Southern Rocky Mountains have similar plant productivity as northern peatlands.

Animals
Many different wildlife species are know to utilize fens ranging from moose to various waterbirds. Fens provide habitat for the Pigmy Shrew (*Sorex hoyi*), U.S. Forest Service Region 2 Sensitive Species, as well as numerous species of invertebrates (Austin 2003). Two unique dragonflies, Hudsonian Whiteface (*Leucorhinia hudsonica*) and Mountain Emerald (*Sematochlora semicircularis*), are known to utilize the Mt. Emmons Iron Fen in Colorado.

Extreme rich fens support rare aquatic and semi-aquatic macroinvertebrates. In High Creek Fen, the best example of an extreme rich fen in the Southern Rocky Mountains, Durfee and Polonsky (1995) collected nine aquatic beetles that have been found nowhere else in Colorado. As with the plants, these occurrences are far removed from the more typical boreal populations of these species. These researchers also collected a caddisfly (*Ochrotrichia susanae*) that is known from only one other location in the world (also in Colorado). A rare snail, the glass physa (*Physa skinneri*), is also believed to be associated with extreme rich fens (Sanderson and March 2005).

A.2.3. Dynamics

Peatlands are wetlands with at least 40 cm of organic soils that consist of at least 12-18% organic-carbon content (by weight) (USDA 1994). They form where the rate of plant growth exceeds the rate of decomposition of litter. Both saturated soils and cool temperatures slow decomposition to the point that productivity exceeds decomposition, resulting in an accumulation of organic matter (i.e. peat). Peat accumulates slowly in all Southern Rocky Mountain peatlands, anywhere from 11 to 41 cm (4.3 to 16.2 inches) per thousand years (Cooper 1990; Chimner and Cooper 2002). Peat depth varies according to topographic position and nutrient status and ranges from shallow (less than 1 meter) to moderately deep (up to 4 meters).

Two types of peatlands are generally recognized: fens and bogs (Mitch and Gosselink, 2000, Charman 2002). The difference lies in their origins as well as their nutrient status (Charman 2002). Fens are generally more nutrient rich (i.e. minerotrophic) due to their dependence on regional ground and surface water inputs (i.e. geogenous) (Charman 2002). Bogs are nutrient poor (i.e. ombrotrophic) as precipitation is their sole source of hydrological input (i.e. ombrogenous) (Charman 2002). Given that evaporation often exceeds precipitation in the Southern Rocky Mountain region, only peatlands supported by ground or surface water are found in the area. No true bogs occur in the Southern Rocky Mountains.

Moore and Bellamy (1973) (in Charman 2002) describe three types of peat development: primary, secondary, and tertiary. Primary peats develop in confined basins or depressions near open water and are most commonly associated with basin fens in the Southern Rocky Mountains where peat slowly “fills in” small ponds (Moore and Bellamry 1973; Cooper 1990). Secondary peats form when the ground surface becomes inundated or saturated long enough to allow peat formation to initiate and are associated with both basin and slope fens in the Southern Rocky Mountains (Moore and Bellamy 1973; Cooper 1990). Tertiary peat develops above the influence of groundwater and is associated with the process of paludification (Charman 2002). Tertiary peat and paludification are associated with bogs, and thus do not occur in the Southern Rocky Mountains (Cooper 1990).

Cooper (1990) suggests that peatlands in the Southern Rocky Mountains generally do not succeed to upland forests but rather maintain a peatland climax due to dynamic processes associated with the oxidation and accumulation of peat in relation to fluctuating climatic conditions.

A.2.4. Landscape

It is evident from the hydro-geomorphic setting of fens that their integrity is partly determined by processes operating in the surrounding landscape. The quality and quantity of ground and surface water input into fens is almost entirely determined by the condition of the surrounding landscape. Various types of land use can alter recharge of local aquifers, introduce excess nutrients, pollutants, or sediments. Assessments of fens have considered the landscape properties of the local watershed to be a critical factor in assessing fen condition (Bedford 1996, Rondeau 2001Godwin et al. 2002, Hall et al. 2003, Jones 2003).

A.2.5. Size

The size of a wetland, whether very small or very large, is a natural characteristic defined by a site's topography, soils, and hydrological processes. The natural range of sizes found on the landscape varies for each wetland type. As long as a wetland has not been reduced in size by human impacts or isn't surrounded by areas which have experienced human disturbances, then size isn't very important to the assessment of ecological integrity. For example, without human disturbance, a wetland is as large as it will ever be at a given location thus it doesn't make much sense to downgrade a site's integrity simply because it is smaller than other wetlands of the same type. However, if human disturbances have decreased the size of the wetland or if 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. Under such circumstances, size may be an important factor in assessing ecological integrity.

Size is often very important when the conservation or functional value of a wetland is considered. For example, larger wetlands tend to have more diversity, often support larger populations of component species, are more likely to support sparsely distributed species, and may provide more suitable wildlife habitat as well as more ecological services derived from natural ecological processes (e.g. sediment/nutrient retention, floodwater storage, etc.) than smaller wetlands. Thus, when conservation or functional values are of concern, size is almost always an important component to the assessment.

Of course, in the context of regulatory wetland mitigation, size is always important whether mitigation transactions are based on function or integrity "units" and thus should be used to weight such transactions.

The size of fens can vary greatly depending on their topographic location, underlying soil texture, and driving hydrological processes. Some are very small (< 0.2 hectare) while others can be very large (> 1 hectare).

A.3 ECOLOGICAL INTEGRITY

A.3.1. Threats

Groundwater Alteration

Water diversions and ditches can have a substantial impact on the hydrology as well as biotic integrity of slope fens (Woods 2001; Cooper et al. 1998; Johnson 1996). In a study of calcareous fens, draining did not affect species diversity but did have an effect on community composition by favoring species more typical of mesic meadows (Johnson 1996).

Once the water table is lowered, peat oxidization and subsequent decomposition occurs quickly thereby reducing peat depth, altering hydrological patterns, and resulting in a change of species composition (Cooper 1990; Chimner and Cooper 2003). As peat decomposes, changes in conductivity and bulk density of the peat results.

Since this system is reliant on groundwater any disturbances that impact water quality or quantity are a threat. These threats include groundwater pumping, mining, and improper placement of septic systems, water diversions, dams, roads, etc. (Rondeau 2001).

Peat mining can have a substantial impact on fens. Given the slow accumulation rates of peat, once it is mined (i.e. removed) the fen cannot be restored to historic conditions in a time frame relevant to management activities. The removal of peat alters the subsurface hydrological storage capacity of the fen and tends to channelize surface flow which might result in further degradation of the fen (Johnson 1996). Peat mining has also been shown to significantly decrease species diversity and alter species composition (Johnson 1996).

Land Use

Livestock management can impact peatlands by compacting peat, destroying hummocks and pugging (creation of pedestals by hooves) on the soil surface (Cooper 1993). Cooper et al. (2005) also found that moderate to heavy grazing, and more than 20% bare ground can result in a negative carbon budget and therefore a net loss of peat.

Cooper et al. (2005) noted that excessive trampling by recreational visitation on a floating mat fen may be resulting in an increase in bulk density from compaction which may reduce the ability of the peat mat to float. Recreational use of the area has also resulted in extensive bare areas due to the sensitivity of the *Sphagnum* growing on the mat to trampling. These bare areas could indicate a negative carbon budget and therefore loss of peat (Cooper et al. 2005).

Jones (2003) found that timber management and roads were correlated to a decrease in species richness of vascular plants, an increase in soil nutrient levels, and possibly altered hydrology of peatlands in Montana.

Nutrient enrichment
Increased nutrients can alter species composition by allowing aggressive, invasive species to displace native species. In Montana, beaked sedge was found to be positively correlated to concentrations of ammonium (NH_4^+) and negatively associated with diversity of vascular plants (Jones 2003).

Exotics
Very few exotics occur in Southern Rocky Mountain fens, unless they are severely disturbed by mining or hydrological alterations. Under such conditions, non-native species characteristic of wet or mesic meadows may be present. Such species include pasture grasses such as Kentucky bluegrass (*Poa pratensis*) and timothy (*Phleum pratense*) as well as exotics species common to other wetland types such as Canada thistle (*Cirsium arvense*) and dandelion (*Taraxacum officinale*).

Native increasers such as mountain rush, tufted hairgrass, and shrubby cinquefoil (*Dasiphora floribunda*) often invade after a fen has been artificially drained (Cooper 1990; Johnson 1996). Although these species are native and commonly found in undisturbed fens, they can be indicative of disturbance if they dominate areas previously occupied by sedges.

A.3.2. Justification of Metrics

As reviewed above, the literature suggests that the following attributes are important measures of the ecological integrity of Rocky Mountain Subalpine-Montane Fens:

- Landscape Context: Land use within the contributing watershed has important effects on the connectivity and sustainability of many ecological processes critical to this system.
- Biotic condition: Species composition and diversity, presence of conservative plants, and invasion of exotics are important measures of biological integrity.
- Abiotic Condition: Hydrological integrity is the most important variable to measure, however land use within the wetland can have detrimental impacts on other important abiotic processes such as peat accumulation and nutrient cycling.
- Size: Absolute size is important for consideration of conservation values as well as ecosystem resilience. Relative size is also very important as it provides information regarding historical loss or degradation of wetland size.

A.3.3. Ecological Integrity Metrics

A synopsis of the ecological metrics and ratings is presented in Table 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 metrics are not doable at Tier 1 (i.e., they require a ground visit).

Core and Supplementary Metrics
The Scorecard (see Tables 1 & 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 & 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 & 2.

Table 1. Overall Set of Metrics for the Rocky Mountain Subalpine-Montane Fen System. Tier: 1 = Remote Sensing, 2 = Rapid, 3 =Intensive. (Alpha-numeric codes in parentheses is reference to the metric ID and corresponds to the section in which the metric is described). Shading indicates core metrics.

Category	**Essential Ecological Attribute**	**Indicators /Metrics**	**Tier**	**Field Value**	**Rating (E,G,F,P)**
LANDSCAPE CONTEXT	Landscape Composition	Adjacent Land Use (B.1.1)	1		
		Buffer Width (B.1.2)	1		
		Percentage of unfragmented landscape within 1 km. (B.1.3)	1		
BIOITC CONDITION	Community Composition	Percentage of Native Graminoids (B.2.1)	2		
		Percent of Cover of Native Plant Species (B.2.2)	2		
		Floristic Quality Index (Mean C) (B.2.3)	3		
		Vegetation Index of Biotic Integrity Score (B.2.4)	3		
		Presence of Indicator Species (extreme rich fens only) (B.2.5)	2		
	Patch Diversity	Biotic Patch Richness (B.2.6)	2		
		Interspersion of Biotic Patches (B.2.7)	2		
ABIOITIC CONDITION	Energy/ Material Flow	Land Use Within the Wetland (B.3.1)	2		
		Sediment Loading Index (B.3.2)	1		
	Hydrological Regime	Water Table Depth (B.3.3)	2		
		Water Table Depth (B.3.4)	3		
		Surface Water Runoff Index (B.3.5)	1		
		Hydrological Alterations (B.3.6)	2		
	Chemical /Physical Processes	Litter Cover (B.3.7)	2		
		Nutrient/ Pollutant Loading Index (B.3.8)	1		

Category	**Essential Ecological Attribute**	**Indicators /Metrics**	**Tier**	**Field Value**	**Rating (E,G,F,P)**
		Nitrogen Enrichment (C:N) (B.3.9)	3		
		Phosphorous Enrichment (C:P) (B.3.10)	3		
		pH of Soil Water (B.3.11)	3		
		Organic Soil Horizons (B.3.12)	2		
		Soil Organic Carbon (B.3.12)	3		
		Soil Bulk Density (B.3.14)	3		
SIZE	Size	Absolute Size (B.4.1)	1		
		Relative Size (B.4.2)	1		

Table 2. Metric and Rating Criteria for the Rocky Mountain Subalpine-Montane Fen System. . Tier: 1 = Remote Sensing, 2 = Rapid, 3 =Intensive. (Alpha-numeric codes in parentheses is reference to the metric ID and corresponds to the section in which the metric is described). Confidence column indicates that reasonable logic and/or data support the index. Shading indicates core metrics.

Category	**Essential Ecological Attribute**	**Indicators /Metrics**	**Tier**	**Definition**	**Confidence**	*Metric Rating Criteria*			
						Excellent (A)	**Good (B)**	**Fair (C))**	**Poor (D)**
LANDSCAPE CONTEXT	Landscape Composition	Adjacent Land Use (B.1.1)	1	Addresses the intensity of human dominated land uses within 100 m of the wetland.	Medium	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 (B.1.2)	1	Wetland buffers are vegetated, natural (non-anthropogenic) areas that surround a wetland.	Medium/High	Wide > 100 m	Medium. 50 m to <100 m	Narrow. 25 m to 50 m	Very Narrow. < 25 m
		Percentage of unfragmented landscape within 1 km. (B.1.3)	1	An unfragmented landscape has no barriers to the movement and connectivity of species, water, nutrients, etc. between natural ecological systems.	Medium	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
BIOITC CONDITION	Community Composition	Percentage of Native Graminoids (B.2.1)	2	Estimates the relative abundance of native graminoids as well as native species known to increase with human-disturbance.	Medium/High	Cover of native graminoids 75 - 100%; Abundance of graminoid types: Sedges > Grasses > Rushes. .Native forb cover between 5-15%	Cover of native graminoids 50-75%, Forbs > 15%; Abundance of graminoid types: Sedges > Grasses > Rushes.	Cover of native graminoids < 50%; Forbs dominate. Abundance of graminoid types: Grasses (e.g. Deschampsia cespitosa) and Rushes (e.g. Juncus arcticus) = or > Sedges.	Forbs dominate. Graminoids, when present, are mostly non-native. Grasses (e.g. Deschampsia cespitosa) and Rushes (e.g. Juncus arcticus) > Sedges.

Category	Essential Ecological Attribute	Indicators /Metrics	Tier	Definition	Confidence	*Metric Rating Criteria* Excellent (A)	Good (B)	Fair (C))	Poor (D)
		Percent of Cover of Native Plant Species (B.2.2)	2	Percent of the plant species which are native to the Southern Rocky Mountains.	High	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 Index (Mean C) (B.2.3)	3	The mean conservatism of all the native species growing in the wetland.	High	Mean C > 4.5	Mean C = 3.5-4.5	Mean C = 3.0 – 3.5	Mean C < 3.0
		Vegetation Index of Biotic Integrity Score (B.2.4)	3	A multi-metric index which indicates the floristic integrity of a wetland based on metrics with predictable responses to human-induced disturbance.	High	TBD	TBD	TBD	TBD
		Presence of Indicator Species (extreme rich fens only) (B.2.5)	2	Indicator species are those species which only grow under specific ecological conditions, thereby providing a quick indication of the type or condition of a wetland.	Medium/High	At least 5 of the indicator species present	At least 4 of the indicator species present	At least 3 of the indicator species present	< 3 of the indicator species present
	Patch Diversity	Biotic Patch Richness (B.2.6)	2	The number of biotic/abiotic patches or habitat types present in the wetland.	Medium	> 75-100% of the possible patch types are evident in the wetland	> 50-75% of the possible patch types are evident in the wetland	25-50% of the possible patch types are evident in the wetland	< 25% of the possible patch types are evident in the wetland

Category	Essential Ecological Attribute	Indicators /Metrics	Tier	Definition	Confidence	*Metric Rating Criteria* Excellent (A)	Good (B)	Fair (C))	Poor (D)
		Interspersion of Biotic Patches (B.2.7)	2	The spatial arrangement of biotic/abiotic patch types within the wetland, especially the degree to which patch types intermingle with each other (e.g. the amount of edge between patches).	Medium	Horizontal structure consists of a very complex array of nested and/or interspersed, irregular biotic/abiotic patches, with no single dominant patch type	Horizontal structure consists of a moderately complex array of nested or interspersed biotic/abiotic patches, with no single dominant patch type	Horizontal structure consists of a simple array of nested or interspersed biotic/abiotic patches,	Horizontal structure consists of one dominant patch type and thus has relatively no interspersion
ABIOITIC CONDITION	Energy/ Material Flow	Land Use Within the Wetland (B.3.1)	2	Addresses the intensity of human dominated land uses within the wetland.	Medium	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 (B.3.2)	1	Estimates water table depth based on a single site visit in mid-July or August and is a metric of hydrological integrity of the wetland.	Medium/High	Water Table depth during site visit (July through August) = 0-30 cm	Water Table depth during site visit (July through August) = 0-30 cm	Water Table depth during site visit (July through August) = > 30 cm	Water Table depth during site visit (July through August) = > 30 cm
	Hydrological Regime	Water Table Depth (B.3.3)	2	Determines average water table depth based on measurements from shallow groundwater wells.	High	Average water table depth in July and August is between 0-30 cm;	Average water table depth in July and August is between 0-30 cm;	Average water table depth in July and August is between > 30 cm;	Average water table depth in July and August is between > 30 cm;
		Water Table Depth (B.3.4)	3	A measure of the varying degrees to which different land uses contribute excess sediment via surface water runoff and overland flow into a wetland.	Medium	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**	**Indicators /Metrics**	**Tier**	**Definition**	**Confidence**	*Metric Rating Criteria*			
						Excellent (A)	**Good (B)**	**Fair (C))**	**Poor (D)**
		Surface Water Runoff Index (B.3.5)	1	A measure of the varying degrees to which different land uses alters surface water runoff and overland flow into a wetland.	Medium	Average Score = 0.9 – 1.0	Average Score = 0.8 – 0.89	Average Score = 0.75 – 0.79	Average Score = < 0.7
		Hydrological Alterations (B.3.6)	2	The degree to which onsite or adjacent land uses and human activities have altered hydrological processes.	Medium	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
	Chemical /Physical Processes	Litter Cover (B.3.7)	2	The percent cover of plant litter or detritus covering the soil surface.	Low/Medium	Litter cover 75-125% of Reference Standard (Litter > 50% cover)	Litter cover 25-75% of Reference Standard (Litter 10-50% cover)	Litter cover 0-25% of Reference Standard (Litter cover present but sparse < 10%)	No litter present.
		Nutrient/ Pollutant Loading Index (B.3.8)	1	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.	Medium	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	Indicators /Metrics	Tier	Definition	Confidence	*Metric Rating Criteria*			
						Excellent (A)	**Good (B)**	**Fair (C))**	**Poor (D)**
		Nitrogen Enrichment (C:N) (B.3.9)	3	The carbon to nitrogen (C:N) ratio in the aboveground biomass or leaves of plants. .	Medium/High	Leaf tissue C:N is equivalent to natural range of variability	Leaf tissue C:N is slightly less and outside of natural range of variability	Leaf tissue C:N is significantly lower than natural range of variability	Leaf tissue C:N is significantly lower than natural range of variability
		Phosphorous Enrichment (C:P) (B.3.10)	3	The carbon to phosphorous (C:P) ratio in the aboveground biomass or leaves of plants.	Medium/High	Leaf tissue C:P is equivalent to natural range of variability	Leaf tissue C:P is slightly less and outside of natural range of variability	Leaf tissue C:P is significantly lower than natural range of variability	Leaf tissue C:P is significantly lower than natural range of variability
		pH of Soil Water (B.3.11)	3	Changes in pH are associated with changes in nutrient and/or toxicant availability and has a strong effect on plant composition.	Medium/High	Soil pH is equivalent to natural range of variability	Soil pH is equivalent to natural range of variability	Soil pH is outside natural range of variability	Soil pH is outside natural range of variability
		Organic Soil Horizons (B.3.12)	2	Estimates the thickness and integrity of the surface organic soil horizons (e.g., peat; Oi, Oe, and Oa horizons) in the fen.	Medium/High	Within the project assessment area, surface organic horizons are present and undisturbed. Von Post index is within natural range of variability	Within the project assessment area, surface organic horizons are present and undisturbed. Von Post index is within natural range of variability	Surface organic horizons are present. The thickness of the organic horizon has been reduced by > 25 %. The moss layer (when present) has been removed or partially removed. Von Post index is lower (2 categories) than natural range of variability	Surface organic horizons are present. The thickness of the organic horizon has been reduced by > 25 %. The moss layer (when present) has been removed or partially removed. Von Post index is lower (2 categories) than natural range of variability
		Soil Organic Carbon (B.3.12)	3	Measures the amount of soil organic carbon present in the soil.	Medium/High	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

Category	Essential Ecological Attribute	Indicators /Metrics	Tier	Definition	Confidence	*Metric Rating Criteria*			
						Excellent (A)	**Good (B)**	**Fair (C))**	**Poor (D)**
		Soil Bulk Density (B.3.14)	3	A measure of the compaction of the soil horizons.	Medium/High	Bulk density is within natural range of variability	Bulk density is slightly higher than natural range of variability	Bulk density is higher than natural range of variability	Bulk density is much higher than natural range of variability
SIZE	Size	Absolute Size (B.4.1)	1	The current size of the wetland	High	> 1 hectares	0.5 – 1 hectares	0.2 – 0.49 hectares	< 0.2 hectares
		Relative Size (B.4.2)	1	The current size of the wetland divided by the total potential size of the wetland multiplied by 100.	High	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.4 Scorecard Protocols

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

Points are assigned for each rating level (A, B, C, D) within a metric. 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.

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

A.4.1. 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) roll up the metrics into an overall Landscape Context rating.

<u>Rationale for Scoring:</u> Adjacent land use and buffer width 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.

Thus, the following weights apply to the Landscape Context metrics:

Table 3. Landscape Context Rating Calculation.

Measure	**Definition**	**Tier**	**A**	**B**	**C**	**D**	**Weight**	**Score** (weight x rating)
Adjacent Land Use (B.1.1)	Addresses the intensity of human dominated land uses within 100 m of the wetland.	1	5	4	3	1	0.40	
Buffer Width (B.1.2)	Wetland buffers are vegetated, natural (non-anthropogenic) areas that surround a wetland.	1	5	4	3	1	0.40	
Percentage of unfragmented landscape within 1 km. (B.1.3)	An unfragmented landscape has no barriers to the movement and connectivity of species, water, nutrients, etc. between natural ecological systems.	1	5	4	3	1	0.20	
Landscape Context Rating	A = 4.5 - 5.0 B = 3.5 – 4.4 C = 2.5 – 3.4 D = 1.0 – 2.4							**Total = sum of N scores**

A.4.2. 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) roll up the metrics into an overall Biotic Condition rating.

<u>Rationale for Scoring</u>: The Vegetation Index of Biotic Integrity (VIBI) metric is the most reliable indication of Biotic Condition, thus if the VIBI is used no other metrics are needed (VIBI metric is shaded in Table 4). If a VIBI is not a feasible metric to use, then the Floristic Quality Index (FQI) metric is judged to be more important than percentage of native graminoids and species.

If a VIBI is used, then 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 Index (FQI) is used (since it is a Tier 3 metric). If a FQI is included then the weights without parentheses apply to the Biotic Condition metrics. If a FQI is not included then the weight in parentheses is used for the Tier 2 metrics.

Table 4. Biotic Condition Rating Calculation.

Measure	**Definition**	**Tier**	**A**	**B**	**C**	**D**	**Weight***	**Score** (weight x rating)
Percentage of Native Graminoids (B.2.1)	Estimates the relative abundance of native graminoids as well as native species known to increase with human-disturbance.	2	5	4	3	1	0.30 (0.55)	
Percent of Cover of Native Plant Species (B.2.2)	Percent of the plant species which are native to the Southern Rocky Mountains.	2	5	4	3	1	0.20 (0.45)	
Floristic Quality Index (Mean C) (B.2.3)	The mean conservatism of all the native species growing in the wetland.	3	5	4	3	1	0.50 (N/A)	
Vegetation Index of Biotic Integrity Score (B.2.4)	A multi-metric index which indicates the floristic integrity of a wetland based on metrics with predictable responses to human-induced disturbance.	3	5	4	3	1	N/A (N/A) *1.0*	
Biotic Condition Rating	A = 4.5 - 5.0 B = 3.5 – 4.4 C = 2.5 – 3.4 D = 1.0 – 2.4							**Total = sum of N scores**

* The weight in parentheses is used when metric B.2.3 is not used. The weight in italics for metric B.2.4 (e.g. no other metrics are used when B.2.4 is used).

A.4.3 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) roll up the metrics into an overall Abiotic Condition rating.

Rationale for Scoring: 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 version is shaded in Table 4 to indicate that only one should be used in the Scorecard. The weights for the former scenario are shown without parentheses whereas weights for the latter are in parentheses.

Table 5. Abiotic Condition Rating Calculation.

Measure	Definition	Tier	A	B	C	D	Weight*	Score (weight x rating)
Land Use Within the Wetland (B.3.1)	Addresses the intensity of human dominated land uses within the wetland.	2	5	4	3	1	0.25 (0.25)	
Water Table Depth (B.3.3)	Estimates water table depth using hydric soil indicators from a single site visit.	2	5	5	0	0	0.20 (N/A)	
Water Table Depth (B.3.4) (use instead of B.3.3 when available)	Determines average water table depth based on measurements from shallow groundwater wells.	3	5	5	0	0	N/A (0.45)	
Hydrological Alterations (B.3.6)	The degree to which onsite or adjacent land uses and human activities have altered hydrological processes.	2	5	4	3	1	0.55 (0.30)	
Abiotic Condition Rating	A = 4.5 - 5.0 B = 3.5 – 4.4 C = 2.5 – 3.4 D = 1.0 – 2.4							**Total = sum of N scores**

* The weight in parentheses is used when the measure for B.2.10 is substituted for the measure in B.2.9. B.2.10 is a more accurate and reliable measure than B.2.8.

A.4.4 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) 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 Calculation.

Measure	Definition	Tier	A	B	C	D	Weight*	Score (weight x rating)
Absolute Size (B.4.1)	The current size of the wetland	1	5	4	3	1	0.0 (0.70)	
Relative Size (B.4.2)	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)	
Size Rating	A = 4.5 - 5.0 B = 3.5 – 4.4 C = 2.5 – 3.4 D = 1.0 – 2.4							**Total = sum of N scores**

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

A.4.5 Overall Ecological Integrity Rating Protocol

If an Overall Ecological Integrity Score is desired for a site, then a weighted-point system should be used with the following rules:

1. If Landscape Context = *A* then the Overall Ecological Integrity Rank = **[Abiotic Condition Score *(0.35)] + [Biotic Condition Score *(0.25)] + [Landscape Context Score * (0.25)] + [Size Score * (0.15)]** **Note:** For this calculation ONLY consider Relative Size for Size Score

2. If Landscape Context is *B*, *C*, or *D* AND Size = *A* then the Overall Ecological Integrity Rank = **[Abiotic Condition Score *(0.35)] + [Biotic Condition Score *(0.25)] + [Size Score * (0.25)] + [Landscape Context Score * (0.15)]**

3. If Landscape Context is *B*, *C*, or *D* AND Size = *B* then the Overall Ecological Integrity Rank = **[Abiotic Condition Score *(0.35)] + [Biotic Condition Score *(0.25)] + [Landscape Context Score * (0.20)] + [Size Score * (0.20)]**

4. If Landscape Context is *B*, *C*, or *D* AND Size = *C* or *D* then the Overall Ecological Integrity Rank = **[Abiotic Condition Score *(0.35)] + [Biotic Condition Score *(0.25)] + [Landscape Context Score * (0.25)] + [Size Score * (0.15)]** **Note:** For this calculation use both Absolute and Relative Size for Size Score.

The Overall Ecological Rating is then assigned using the following criteria:

A = 4.5 - 5.0
B = 3.5 – 4.4
C = 2.5 – 3.4
D = 1.0 – 2.4

B. PROTOCOL DOCUMENTATION FOR METRICS

B.1 Landscape Context Metrics

B.1.1. Adjacent Land Use

Definition: This metric addresses the intensity of human dominated land uses within 100 m of the wetland.

Background: This metric is one aspect of the landscape context of specific occurrences of wetland 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. 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 wetland (Hauer et al. 2002).

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 3) with some manipulation to account for regional application) into the following equation:

> *Sub-land use score* = $\sum$ 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 within 100 m of the wetland edge, then sum the Sub-Land Use Score(s) 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.

Measure (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 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.

B.1.2. 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.

Background: This metric is one aspect of the landscape context of specific occurrences of wetland 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. Buffer boundaries extend from the wetland edge to intensive human land uses which result non-natural areas. Some land uses such as light grazing and recreation may occur in the buffer, but other more intense 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).

Measurement 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.

Measure (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 and their effectiveness in the Southern Rocky Mountains.

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

B.1.3. 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, mining, utility lines, railroads, etc.

Background: This metric is one aspect of the landscape context of specific occurrences of wetland 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 (e.g., anthropogenic patches) provides an estimate of connectivity among natural ecological systems. Although related to metric B.1.1 and B.1.2, this metric differs by addressing the spatial interspersion of human land use as well as considering a much larger area.

Measurement Protocol: This metric is measured by estimating the amount of unfragmented area in a one km buffer surrounding the wetland and dividing that by the total area. This can be completed in the office using aerial photographs or GIS.

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

Measure (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: N/A

Scaling Rationale: Less fragmentation increases connectivity between natural ecological systems and thus allow for natural exchange of species, nutrients, and water. The categorical ratings are based on Rondeau (2001).

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

B.2 Biotic Condition Metrics

B.2.1. Percentage of Native Sedges and Grasses

Definition: The percentage of native graminoids is based on the cover of native graminoid species relative to total cover of all species. This metric also accounts for the relative abundance of graminoid types (sedges (*Carex* spp., *Eriophorum* spp., *Eleocharis* spp., *Kobresia* spp., etc.), grasses (*Deschampsia cespitosa*, *Calamagrostis* spp., etc.), and rushes (e.g. *Juncus balticus* var. *montanus*).

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

Rationale for Selection of the Variable: Native graminoids dominate Southern Rocky Mountain fens. Native graminoids, especially clonal sedges such as beaked sedge (*Carex utriculata*), water sedge (*C. aquatilis*), woollyfruit sedge (*C. lasiocarpa*), and short beaked sedge (*C. simulata*), are an important functional component of fens. These species, due to their expansive and rhizomatous root system, are critical for the continued development and stability of the peat substrate (Cooper 2005). With increasing human disturbance, native graminoid cover decreases relative to the cover of forbs. In addition, the abundance of graminoid types changes along the same gradient. For example, tufted hairgrass and mountain rush (*Juncus balticus* var. *montanus*) are known to aggressively invade disturbed portions of fens displacing sedges (Cooper 1990; Johnson 1996; Rondeau 2001). These changes are typically the result of a change in hydrology due to soil compaction, physical disturbance, or upstream alterations.

Measurement Protocol: A qualitative, ocular estimate of cover is used to calculate and score the metric. The entire occurrence of the fen should be walked and a qualitative ocular estimate of the total cover of native graminoid species (e.g. sedges, grasses, and rushes) growing in the wetland should be made. Alternatively, if time and resources allow a more quantitative determination of species presence and cover such methods (i.e. Peet et al. 1998) are encouraged to be used. The metric is calculated by dividing total cover of native graminoids by total cover of all species and multiplying by 100.

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

Metric Rating			
Excellent	**Good**	**Fair**	**Poor**
Cover of native graminoids 75 - 100%; Native forb cover between 5-15%; Abundance of graminoid types: Sedges > Grasses > Rushes.	Cover of native graminoids 50-75%, Forbs > 15%; Abundance of graminoid types: Sedges > Grasses > Rushes.	Cover of native graminoids < 50%; Forbs dominate. Abundance of graminoid types: Grasses (e.g. *Deschampsia cespitosa*) and Rushes (e.g. *Juncus balticus* var. *montanus*) = or > Sedges.	Forbs dominate. Graminoids, when present, are mostly non-native. Grasses (e.g. *Deschampsia cespitosa*) and Rushes (e.g. *Juncus balticus* var. *montanus*) > Sedges.

Data: N/A

Scaling Rationale: The criteria are based on extrapolated thresholds from ecological site descriptions from Utah, Wyoming, and Montana (NRCS 2005), data and descriptions in Cooper (1990), Windell et al. (1996), CNHP (2005), and best scientific judgment. These are tentative hypotheses as they have not been validated with quantitative data. The Colorado Natural Heritage Program is currently developing a Vegetation Index of Biotic Integrity. Data from this project will likely provide the necessary information to confirm the validity of these criteria and inform as to what changes should be made.

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

B.2.2. Percent of Cover of Native Plant Species

Definition: Percent of the plant species which are native to the Southern Rocky Mountains.

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

Rationale for Selection of the Variable: Native species dominate Southern Rocky Mountain wetlands 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: A qualitative, ocular estimate of cover is used to calculate and score the metric. The entire occurrence of the fen should be walked and a qualitative ocular estimate of the total cover of native species growing in the wetland should be made. Alternatively, if time and resources allow a more quantitative determination of species presence and cover such methods (i.e. Peet et al. 1998) are encouraged to be used. The metric is calculated by dividing the total cover of native species by the total cover of all species and multiplying by 100.

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

Measure (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 Utah, Wyoming, and Montana (NRCS 2005), data and descriptions in Cooper (1990), Windell et al. (1996), CNHP (2005), and best scientific judgment. These are tentative hypotheses as they have not been validated with quantitative data. The Colorado Natural Heritage Program is currently developing a Vegetation Index of Biotic Integrity. Data from this project will likely provide the necessary information to confirm, validate, and improve the criteria.

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

B.2.3. Floristic Quality Index (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 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 personal communication, 2005).

The Floristic Quality Index (FQI), originally developed for the Chicago region (Swink and Wilhelm 1979, 1994) is a vegetative 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). FQI 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).

The Colorado Floristic Quality Assessment Panel is currently assigning coefficients of conservatism to the Colorado flora. Initial testing of the Colorado FQI should begin in 2006 and available for use shortly thereafter. However, calibration of the FQI will likely occur over many years of use and thus this metric will need to be updated accordingly.

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 wetland 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 (Mack 2004; Peet et al. 1998).

The metric is calculated by referencing only native species C value from the Colorado FQI Database (*in development*; *expected to be completed in 2006*), summing the C values, and dividing by the total number of native species (Mean C).

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

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
> 4.5	3.5-4.5	3.0 – 3.5	< 3.0

Data: Colorado FQI Database (*in development*; *expected to be completed in 2006*)

Scaling Rationale: In the Midwest, field studies using FQI 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). 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 (Wilhelm and Masters 1995). 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 FQI literature. Although it is not know if these same thresholds are true for the Southern Rocky Mountains, they have been used to construct the scaling for this metric. As the FQI is applied in this region, the thresholds may change.

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

B.2.4. Vegetation Index of Biotic Integrity Score

Definition: A vegetation index of biotic integrity is a multi-metric index which indicates the floristic integrity of a wetland based on metrics with predictable responses to human-induced disturbance.

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

Rationale for Selection of the Variable: Vegetation is known to be a sensitive measure of human impacts to wetlands and because vegetation provides habitat for numerous taxa, exhibits correlations to water chemistry, are conspicuous component of wetlands, and is associated with most wetland ecological processes, the taxa is an ideal metric group for use in bioassessment methods (U.S. EPA 2002b). Vegetation Index of Biotic Integrity (VIBI) models are typically developed by sampling various attributes of vegetation in wetlands subjected various levels of human-induced disturbance. Those attributes that show a predictable response to increasing human disturbance are chosen as metrics to be incorporated into the VIBI (U.S. EPA 2002a).

Numerous states (e.g. Ohio (Mack 2004a), Michigan (Kost 2001), Minnesota (Gernes and Helgen 1999), North Dakota (Dekeyser et al. 2003), Indiana (Simon et al. 2001), Wisconsin (Lillie et al. 2002), Massachusetts (Carlisle et al. 1999), and Montana (Jones 2004)) have developed VIBIs for wetlands to improve their ability to assess wetland biotic integrity. All of these efforts have found various vegetation metrics which successfully predict wetland condition.

Measurement Protocol: Quantitative species presence/absence and cover data need to be collected from the wetland. 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 (Mack 2004b; Peet et al. 1998).

The Colorado Natural Heritage Program is currently developing a Vegetation Index of Biotic Integrity for wetlands in the Southern Rocky Mountains. The VIBI is expected to be completed in 2007. Once complete, users will only need to enter their plot data into an automated calculator (MS Excel) which will provide metric scores and an overall VIBI score for the site.

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

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
TBD	TBD	TBD	TBD

Data: Vegetation Index of Biotic Integrity model for Rocky Mountain Subalpine-Montane Fens, Wet Meadows, and Riparian Shrublands (*in development*; *expected to be completed in 2007*)

Scaling Rationale: The scaling criteria will be developed from calibrated and tested VIBI scores from wetlands subjected various levels of human-induced disturbance. These scores will be used to assign the metric ratings, similar to the process in which VIBI scores have been used to assign Tiered Aquatic Life Use categories (Mack 2004a). This process identifies the natural range of VIBI scores for each wetland type (e.g. wet meadows, fens, riparian shrublands, etc.) and partitions them into performance categories (Mack 2004a). These categories will be defined by a particular range of VIBI scores, allowing the user to place the wetland's VIBI score into the scaling criteria in the scorecard. Criteria have yet to be determined, but will be identified following completion of the VIBI model.

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

B.2.5. Presence of Indicator Species

Definition: Indicator species are those species which only grow under specific ecological conditions, thereby providing a quick indication of the type or condition of a wetland.

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

Rationale for Selection of the Variable: Plants grow in habitats in which they are adapted. Some plants have a wide tolerance of ecological conditions, while others require specific edaphic conditions. Thus, indicator species are useful for unique wetlands such as extreme rich fens.

Plant indicators were found to definitively and accurately identify unimpacted and undegraded calcareous fens in Minnesota (Leete et al. 2004). Numerous indicator species have been identified for extreme rich fens in the Southern Rocky Mountains and are expected to accurately indicate the presence of unimpacted unique wetland types in the region (Cooper 1996; Sanderson and March (1996); Johnson 2001).

Measurement Protocol: The total number of indicator species present (see list below) is used to rate this metric. The entire occurrence of the fen should be walked and the presence of any of the indicator species listed below should be noted. Alternatively, if time and resources allow a more quantitative determination of species presence such methods (i.e. Peet et al. 1998) are encouraged to be used.

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

Metric Rating			
Excellent	**Good**	**Fair**	**Poor**
At least 5 of the indicator species present	At least 4 of the indicator species present	At least 3 of the indicator species present	< 3 of the indicator species present

Data:
Extreme rich fen indicator species: *Trichophorum pumilum, Salix candida, S. myrtillifolia, Carex microglochin, C. livida, C. viridula, Eriophorum gracile*, and the following mosses: *Scorpidium scorpioides, S. turgescens*, and *Calliergon trifarium*. In addition, these species, when found in fens, are also indicator species: *Triglochin maritimum, T. palustris, Carex scirpoidea, Kobresia myosuroides,* and *K. simpliciuscula*.

Scaling Rationale: The scaling criteria are based on Cooper (1996), Sanderson and March (1996), Johnson (2001), and best scientific judgment.

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

B.2.6. Biotic/Abiotic Patch Richness

Definition: The number of biotic/abiotic patches or habitat types present in the wetland. The metric is not a measure of the spatial arrangement of each patch.

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

Rationale for Selection of the Variable: Ecological diversity of a site is correlated with biotic/abiotic patch richness (Collins et al. 2004). Unimpacted sites have an expected range of biotic/abiotic patches. Human-induced alterations can decrease patch richness.

Measurement Protocol: This metric is measured by determining the number of biotic/abiotic patches present at a site and dividing by the total number of possible patches for the specific wetland (see Table 4). This percentage is then used to rate the metric in the scorecard.

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

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
> 75-100% of the possible patch types are evident in the AA	> 50-75% of the possible patch types are evident in the AA	25-50% of the possible patch types are evident in the AA	< 25% of the possible patch types are evident in the AA

Data:

Table 8. Biotic/Abiotic Patch Types in Fens

Patch Type	Description
Hummock/tussock	A mound composed of organic materials (peat) and either created by *Sphagnum* or other moss or formed by sedges and grasses which have tussock habit as they raise themselves upon a pedestal or short trunk of persistent rhizomes and roots.
Water Tracks/Hollows	A depression found between hummocks or mounds which remains permanently saturated or is inundated with slow moving surface water.
Lawns	A flat expanse of fen typically dominated by sedges or moss. Compare to hummock/tussock
Open Water - Pools	These areas hold stagnant or slow moving pools of water from groundwater discharge but are not associated with hummocks or a defined channel.
Open Water – Rivulets/Streams	These are areas that have flowing water associated with a defined channel
Floating Mat	This is a mat of peat held together by roots and rhizomes of sedges. Floating mats are found along the edges of ponds and lakes and are slowing encroaching into open water. The mats are underlain by water and/or very loose peat.
Spring fen	These are areas where local peat has built up due to upwelling groundwater forming an elevated surface above the surrounding soil. Areas which “quack” but are not associated with open water (i.e., floating mats) would also be considered spring fens.
Shrubs	Areas of peat with abundant cover of shrubs (don’t count as patch type if the patch meets the minimum size criteria for the Riparian Shrublands Ecological System (1 hectare or 2.47 acres).
Treed	Areas of peat with abundant cover of coniferous trees
Moss bed	Not all fens in the Southern Rocky Mountains have a dominant moss subcanopy. However, when present, they are an important component to the fen.
Marl/Limonite beds	(Extreme rich/iron fens only) Marl, a calcium carbonate precipitate, is often found in calcareous fens. Limonite forms in iron fens when iron precipitates from the groundwater incorporating organic matter (Cooper 1999).

Scaling Rationale: The scaling criteria are based on Collins et al. (2004), however best scientific judgment was used to modify patch types to correspond with Southern Rocky Mountainwetlands.

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

B.2.7. Interspersion of Biotic/Abiotic Patches

Definition: Interspersion is the spatial arrangement of biotic/abiotic patch types within the wetland, especially the degree to which patch types intermingle with each other (e.g. the amount of edge between patches).

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

Rationale for Selection of the Variable: Spatial complexity of biotic/abiotic patches is indicative of intact ecological processes (Collins et al. 2004). Unimpacted sites have an expected spatial pattern of biotic/abiotic patches. Human-induced alterations can decrease this complexity and homogenize patch distribution.

Measurement Protocol: This metric is measured by determining the degree of interspersion of biotic/abiotic patches present in the wetland. This can be completed in the field for most wetlands, however aerial photography may be beneficial for larger sites (Collin et al. 2004). The metric is rated by matching site interspersion with the categorical ratings in the scorecard.

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

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Horizontal structure consists of a very complex array of nested and/or interspersed, irregular biotic/abiotic patches, with no single dominant patch type	Horizontal structure consists of a moderately complex array of nested or interspersed biotic/abiotic patches, with no single dominant patch type	Horizontal structure consists of a simple array of nested or interspersed biotic/abiotic patches,	Horizontal structure consists of one dominant patch type and thus has relatively no interspersion

Data: See B.2.6 for list and definitions of Biotic Patches.

Scaling Rationale: The scaling criteria are based on Collin et al. (2004), however best scientific judgment was used to modify criteria to correspond with Southern Rocky Mountain wetlands.

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

B.3 Abiotic Condition Metrics

B.3.1. Land Use Within the Wetland

Definition: This metric addresses the intensity of human dominated land uses within the wetland.

Background: This metric is one aspect of the condition of specific occurrences of wetland 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. 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).

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 6) 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 the Sub-Land Use Score(s) 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).

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

Measure (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 9. Current Land Use and Corresponding Land Use Coefficients (based on Table 21 in Hauer ete 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.

B.3.2. 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 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.

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 (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 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.

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.

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 restoreable (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.3.3. Water Table Depth

Definition: This metric estimates water table depth based on a single site visit in mid-July or August.

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

Rationale for Selection of the Variable: Only those areas with soil saturation or a water table within 30 cm of the soil surface through July and August accumulates peat in the Southern Rocky Mountains (Cooper 1990; Chimner and Cooper 2003). Thus, a distinguishing characteristic between wet meadows and fens is the depth of the water table in these months. However, even in fens, sometimes the water table begins to drop in late-July and August so careful interpretation of this metric needs to be implemented (Cooper 1990).

If metric B.3.4 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. 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.

This metric should only be used during site visits made in mid-July through August. Consideration of annual precipitation (or more specifically, annual snowpack) 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 (e.g. average snowpack) this metric is a reliable rapid metric of the integrity of groundwater levels in the wetland.

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

Metric Rating			
Excellent	**Good**	**Fair**	**Poor**
Water Table depth during site visit (July through August) = 0-30 cm	Water Table depth during site visit (July through August) = 0-30 cm	Water Table depth during site visit (July through August) = > 30 cm	Water Table depth during site visit (July through August) = > 30 cm

Data: Cooper (1990), Woods (2001; and Chimner Cooper (2003).

Scaling Rationale: The metric criteria are based on Cooper (1990), Woods (2001; and Chimner Cooper (2003), and best scientific judgment. Water tables within or near 30 cm of the soil surface have been shown to sustain peat integrity, while water tables below 30 cm begin to decompose resulting in a loss of peat integrity and subsequent change in biotic composition.

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

B.3.4. Water Table Depth

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

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

Rationale for Selection of the Variable: Only those areas with soil saturation or a water table within 30 cm of the soil surface through July and August accumulates peat in the Southern Rocky Mountains (Cooper 1990; Chimner and Cooper 2003). Thus, a distinguishing characteristic between wet meadows and fens is the depth of the water table in these months. However, even in fens, sometimes the water table begins to drop in late-July and August so careful interpretation of this metric needs to be implemented (Cooper 1990).

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

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.

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 2002). 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 which 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 2002). 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 2002).

Consideration of annual precipitation (or more specifically, annual snowpack) 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 (e.g. average snowpack) this metric is a reliable rapid metric of the integrity of groundwater levels in the fen. Long-term monitoring of ground water in the wetland coupled with an analysis of climatic variation during that time-frame will provide the most reliable information.

Median water table levels 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**
Average water table depth in July and August is between 0-30 cm;	Average water table depth in July and August is between 0-30 cm;	Average water table depth in July and August is between > 30 cm;	Average water table depth in July and August is between > 30 cm;

Data: Cooper (1990), Woods (2001; and Chimner Cooper (2003).

Scaling Rationale: The metric criteria are based on Cooper (1990), Woods (2001; and Chimner Cooper (2003), and best scientific judgment. Water tables within or near 30 cm of the soil surface have been shown to sustain peat integrity, while water tables below 30 cm begin to decompose resulting in a loss of peat integrity and subsequent change in biotic composition.

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

B.3.5. 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 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 physical 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 (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 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.

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.

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 are considered to not be restoreable (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.

B.3.6. 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 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.

B.3.7. Litter Cover

Definition: The percent cover of plant litter or detritus covering the soil surface.

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

Rationale for Selection of the Variable: Litter cover provides an indication of the amount of organic matter produced and recycled in the wetland. Disturbed wetlands often have different amounts of litter cover than reference sites due to a change in species composition, productivity, and decomposition.

Measurement Protocol: Litter cover is measured using the same protocols as vegetation. A qualitative, ocular estimate of litter cover is used to calculate and score the metric. The entire occurrence of the fen should be walked and a qualitative ocular estimate of the total cover of litter in the wetland should be made. Alternatively, if time and resources allow a more quantitative determination of species presence and cover such methods (i.e. Peet et al. 1998) are encouraged to be used. The metric is scored by comparing current litter cover values to those of reference or baseline conditions.

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

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
No significant change from Reference Amount	Slight change from Reference Amount	Moderate change from Reference Amount	Large change from Reference Amount

Data: The Colorado Vegetation Index of Biotic Integrity project will likely provide the necessary data to establish the range of litter cover found in undisturbed examples.

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

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

B.3.8. 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 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 (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.

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 restoreable (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.3.9. Nutrient Enrichment (C:N)

Definition: The carbon to nitrogen (C:N) ratio in the aboveground biomass or leaves of plants is used to determine whether there is excess N in the system (compared to reference standard). Increasing leaf N decreases the C:N ratio and indicates nitrogen enrichment.

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

Rationale for Selection of the Variable: Nitrogen enrichment causes vegetation to increase uptake and storage of nitrogen in plant tissue and generally results in increased productivity (Craft et al. 1995, Bridgham et al. 1996 *in* U.S. EPA 2002). These changes affect ecosystem processes including decomposition (Valiela et al. 1982, Davis 1991, Rybczyk et al. 1996 *in* U.S. EPA 2002) and accumulation of soil organic matter (Craft and Richardson 1993, 1998, Morris and Bradley 1999 *in* U.S. EPA 2002). Floristic composition may change as aggressive, competitive species take advantage of increased nutrients and displace less competitive species. All of these changes degrade the ecological integrity of the wetland by altering energy flow, nutrient cycling, and potential habitat for fauna assemblages (U.S. EPA 2002).

Measurement Protocol: Herbaceous plants are preferentially sampled because they respond to nutrient enrichment quicker than woody species (U.S. EPA 2002). Two or three dominant species should be selected for sampling. Samples should be collected from plants of a similar age and clipped from nodes a similar distance below the terminal bud (U.S. EPA 2002). The plants should be growing in similar habitats. If habitat is heterogeneous, then it is best to sample from each dominant habitat type. Multiple samples should be collected from several individual plants (5-10) to capture variability within the population. It is important to make collections from the same species at each site so that variation in leaf tissue nutrient concentrations is minimized (U.S. EPA 2002). See U.S. EPA (2002) for additional information.

Nitrogen is typically measured by dry combustion using a CHN analyzer. Each clipped sample should be placed in their own individual paper bag and sent to a laboratory for analysis of soil organic carbon (e.g., CHN Analyzer). Do not put the sample in a plastic bag as this could induce decomposition of the sample.

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

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Leaf tissue C:N is equivalent to natural range of variability	Leaf tissue C:N is slightly less and outside of natural range of variability	Leaf tissue C:N is significantly lower than natural range of variability	Leaf tissue C:N is significantly lower than natural range of variability

Data: N/A

Scaling Rationale: Reference C:N ratios need to be established in undisturbed wetlands. 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 nutrient enrichment. If data are collected from wetlands across a disturbance gradient, quantitative criteria could be established.

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

B.3.10. Nutrient Enrichment (C:P)

Definition: The carbon to phosphorous (C:P) ratio in the aboveground biomass or leaves of plants is used to determine whether there is excess P in the system (compared to reference standard). Increasing leaf P decreases the C:P ratio and indicates phosphorous enrichment.

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

Rationale for Selection of the Variable: Phosphorous enrichment causes vegetation to increase uptake and storage of phosphorous in plant tissue and generally results in increased productivity (Craft et al. 1995, Bridgham et al. 1996 *in* U.S. EPA 2002). These changes affect ecosystem processes including decomposition (Valiela et al. 1982, Davis 1991, Rybczyk et al. 1996 *in* U.S. EPA 2002) and accumulation of soil organic matter (Craft and Richardson 1993, 1998, Morris and Bradley 1999 *in* U.S. EPA 2002). Floristic composition may change as aggressive, competitive species take advantage of increased nutrients and displace less competitive species. All of these changes degrade the ecological integrity of the wetland by altering energy flow, nutrient cycling, and potential habitat for fauna assemblages (U.S. EPA 2002).

Measurement Protocol: Herbaceous plants are preferentially sampled because they respond to nutrient enrichment quicker than woody species (U.S. EPA 2002). Two or three dominant species should be selected for sampling. Samples should be collected from plants of a similar age and clipped from nodes a similar distance below the terminal bud (U.S. EPA 2002). The plants should be growing in similar habitats. If habitat is heterogeneous, then it is best to sample from each dominant habitat type. Multiple samples should be collected from several individual plants (5-10) to capture variability within the population. It is important to make collections from the same species at each site so that variation in leaf tissue nutrient concentrations is minimized (U.S. EPA 2002). See U.S. EPA (2002) for additional information.

Phosphorous is typically measured by spectrophotometry in acid (H_2SO_4-H_2O_2) digests. Each clipped sample should be placed in their own individual paper bag and sent to a laboratory for analysis of soil organic carbon (e.g., CHN Analyzer). Do not put the sample in a plastic bag as this could induce decomposition of the sample.

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

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Leaf tissue C:P is equivalent to natural range of variability	Leaf tissue C:P is slightly less and outside of natural range of variability	Leaf tissue C:P is significantly lower than natural range of variability	Leaf tissue C:P is significantly lower than natural range of variability

Data: N/A

Scaling Rationale: Reference C:P ratios need to be established in undisturbed wetlands. 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 nutrient enrichment. If data are collected from wetlands across a disturbance gradient, quantitative criteria could be established.

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

B.3.11. pH of Soil Water

Definition: The pH of soil water is an indication of the amount of hydrogen ions in the water which indicates the level of acidity in the water.

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

Rationale for Selection of the Variable: The pH of soil water is a result of the type of peat and bedrock associated with contributing groundwater. Land use within or near the wetland can change pH levels with a resulting degradation in ecosystem integrity. Changes in pH are typically associated with changes in nutrient and/or toxicant availability and has a strong effect on plant composition.

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.

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 each pit. 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**
Soil pH is equivalent to natural range of variability	Soil pH is equivalent to natural range of variability	Soil pH is outside natural range of variability	Soil pH is outside natural range of variability

Data: N/A

Scaling Rationale: Due to the diversity of geological substrates in the Southern Rocky Mountains, it is difficult to set sensitive pH criteria for most fen types. Although broad ranges of pH are known for some bedrock types (Bedford and Godwin 2003; see below) their ranges often overlap making it difficult to set criteria. Standards are more easily set for extreme rich and iron fens since they have unique geochemical characteristics. Thus, for “typical” fens, this metric may be best used within a monitoring context to document changes over time at the same wetland. Until the natural variability of soil water pH associated with various bedrock types is established, this metric is less useful to determine, from a one time measurement, whether the pH of the wetland is deviating from the reference standard.

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 alteration of pH. If data are collected from wetlands across a disturbance gradient, quantitative criteria could be established.

Published data (Cooper 1996; Johnson 1998; Beford and Godwin 2003;) suggest the following ranges of pH for fens in the Southern Rocky Mountains:

Intermediate/Rich Fen: 5.6 – 6.7
Extreme Rich Fen: 6.7 – 8.1
Iron Fen: 3.1 - 4.4

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

B.3.12. Organic Soil Horizons

Definition: This metric estimates the thickness and integrity of the surface organic soil horizons (e.g., peat; Oi, Oe, and Oa horizons) in the fen.

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

Rationale for Selection of the Variable: The presence of at least 40 cm of organic soils separate fens from other wetlands (USDA 1994). Surface organic horizons contribute to critical hydrologic, biogeochemical, and physical processes such as surface/sub-surface water storage, elemental cycling, carbon storage, and maintenance of fen plant communities (Hall et al. 2003). The amount of decomposition of organic matter relative to reference standards is an indication of disturbance or oxidation of the organic soils (Chimner and Cooper 2003).

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 within each of the intensive modules.

The reduction in soil organic horizons is determined by comparing the assessment area with adjacent unaltered areas or by visually estimating reduction (i.e., organic soil horizons near a drainage ditch may be a few inches lower than surrounding, unimpacted peat).

The von Post index measures the amount of decomposition of organic soils in the field by assessing the distinctness of the structure of plant remains and color of soil water, determined by squeezing wet peat in the hand. A small handful of peat is squeezed in the hand. Three characteristics are then observed: the color of the solution extracted from the peat, the distinctness of the remaining peat fibers, and the proportion of the original sample that remains in the hand (MacKenzie 1999). The amount of peat water can have a significant effect on the results. For example, a dry and dense peat may only result in a 4 or 5 on the scale, whereas a wet mesic peat may be easily squeezed out of the hand (MacKenzie 1999). Thus, it is important that residue fibers be closely examined (by rubbing between fingers) to assist in concluding on the final von Post index score (MacKenzie 1999).

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

Metric Rating			
Excellent	**Good**	**Fair**	**Poor**
Within the project assessment area, surface organic horizons are present and undisturbed. Von Post index is within natural range of variability	Within the project assessment area, surface organic horizons are present and undisturbed. Von Post index is within natural range of variability	Surface organic horizons are present. The thickness of the organic horizon has been reduced by > 25 %. The moss layer (when present) has been removed or partially removed. Von Post index is lower (2 categories) than natural range of variability	Surface organic horizons are present. The thickness of the organic horizon has been reduced by > 25 %. The moss layer (when present) has been removed or partially removed. Von Post index is lower (2 categories) than natural range of variability

Data:

Table 10. von Post Index

Index Value	Description
1	**Undecomposed:** Plant structure unaltered. Yields only clear colorless water.
2	**Almost undecomposed:** Plant structure distinct. Yields only clear water colored light yellow-brown.
3	**Very weakly decomposed:** Plant structure distinct. Yields distinctly turbid brown water; no peat substance passes between fingers, residue not mushy.
4	**Weakly decomposed:** plant structure distinct. Yields strongly turbid water; no peat substance passes between fingers, residue rather mushy
5	**Moderately decomposed:** Plant structure still clear but becoming indistinct. Yields much turbid brown water; some peat escapes between the fingers; residue very mushy.
6	**Strongly decomposed**: Plant structure somewhat indistinct but clearer in the squeezed residue than in the undisturbed peat. About half the peat escapes between the fingers; residue strongly mushy.
7	**Strongly decomposed:** Plant structure indistinct but still recognizable. About half the peat escapes between the fingers.
8	**Very strongly decomposed:** Plant structures very indistinct. About two-thirds of the peat escapes between the fingers; residue consists almost entirely of resistant remnants such as root fibers and wood.
9	**Almost completely decomposed:** Plant structure almost unrecognizable. Almost all the peat escapes between the fingers.
10	**Completely decomposed:** Plant structure unrecognizable. All the peat escapes between the fingers.

Scaling Rationale: The metric criteria for organic soil reduction are based on empirical field data from 37 reference sites and best scientific judgment from Alaska slope wetlands (Hall et al. 2003). Due to widely variable thickness of organic soil horizons in reference wetlands and to account for reference standard differences in the Southern Rocky Mountain, the criteria are based on based on the percent reduction of organic soil horizon thickness from reference standard conditions, which should be determined from adjacent unaltered sites.

The scaling for the von Post index is based on best scientific judgment with the assumption that an increase in decomposition from “baseline” conditions is indicative of disturbance and loss of integrity of organic soil horizons. Baseline conditions are derived from “pre-impact” conditions or from adjacent unaltered sites.

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

B.3.13. 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 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, a reduction in soil organic carbon from reference conditions serves as a strong indicator of loss of soil quality.

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 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.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
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

Data: N/A

Scaling Rationale: Reference soil organic carbon levels need to be established in undisturbed wetlands. 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.

B.3.14. 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 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 an indication of the level of compaction. Compaction can result from any activity which compresses soil particles thereby increasing the weight to volume ratio. This can reduce the soil's water holding capacity, infiltration rate, 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 soil profile, extracted, then shaved to eliminate any soil 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 be 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 wetland 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**
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.

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 areas) 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.

B.4 Size Metrics

B.4.1. 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 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. Regardless, absolute size 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 for delineating the boundaries of the wetland ecological system type.

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

Metric Rating			
Excellent	**Good**	**Fair**	**Poor**
> 1 hectares	0.5 – 1 hectares	0.2 – 0.49 hectares	< 0.2 hectares

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.

B.4.2. 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 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 the abiotic potential of the wetland from remote sensing data. However, the reverse may also be true since old or historic aerial photographs may indicate a larger wetland than observed in the field. 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 for delineating the boundaries of the wetland ecological system type.

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

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Wetland area = onsite Abiotic Potential	Wetland area < Abiotic Potential; < 10% of wetland has been reduced (destroyed or severely disturbed e.g change in hydrology) due to roads, impoundments, development, human-induced drainage, etc.	Wetland area < Abiotic Potential; 10-25% of wetland has been reduced (destroyed or severely disturbed e.g change in hydrology) due to roads, impoundments, development, human-induced drainage, etc.	Wetland area < Abiotic Potential; > 25% of wetland has been reduced (destroyed or severely disturbed e.g change in hydrology) 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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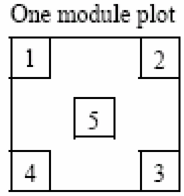
APPENIDX A: FIELD FORMS

Scorecard Field Form, pg 1 of 5

General Information	Location		Site Characteristics	
Project	General:		Elevation (m/ft):	
Team:	County:		Slope (deg):	
Plot:	USGS quad:		Aspect (deg):	
Date (Start): / /	Ownership:		Compass: magnetic /corrected	
Date (End): / /	GPS location in plot: x= y=		Buffer width:	
	UTM Zone: 13		% unfragmented area of wetland:	
Plot Documentation	Uncorrected	UTM-E:		
Cover method:		UTM-N:	**Land use w/in 100m of wetland**	
		Coord. Accuracy (m radius):	Types:	Relative %:
Photos				
Film roll: /Frame(s)	GPS File Name:			
Focal length:	T: R: S:			

Map: Fill in the template below (2 modules or more) or right (1 module plot), using the guide at far right. Also note actual arrangement of modules, which corners were sampled, and location of any witness trees.

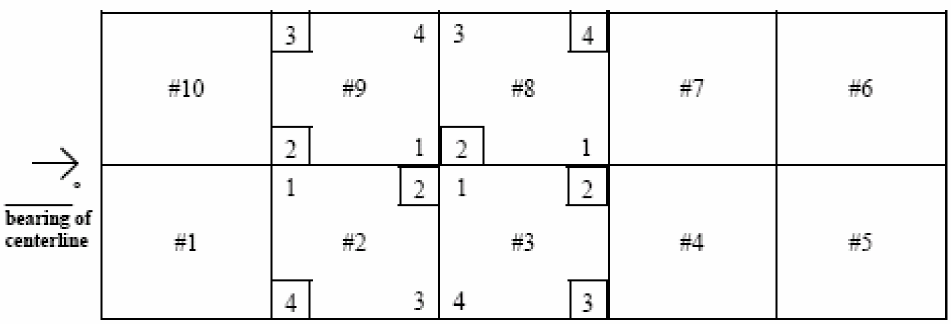
One module plot



⊗ GPS location point

○→ photo taken, with direction

● location of permanent posts



Land use in contributing watershed	
Ground watershed	
Surface watershed	

Physiognomic Class*	Leaf Type*	Leaf Phenology*
__ I Forest __ II Woodland __ III Shrubland __ IV Dwarf Shrubland __ V Herbaceous __ VI Nonvascular __ VII Sparsely vegetated	__ B Broad-leaved __ N Needle-leaved __ M Microphyllous __ G Graminoid __ F Forb __ P Pteridophyte	__ EG Evergreen __ CD Cold-deciduous __ DD Drought- deciduous __ MC Mixed evergreen- cold deciduous __ MD Mixed evergreen- drought deciduous

Soil Chemistry*	Cowardin System*	Community Classification*
____ pH __ __ Conductivity __ __ Temperature	__ UPL Upland __ EST Estuarine __ RIP Riparian __ PAL Palustrine __ LAC Lacustrine	CNHP Type ___________________ Cowardin ___________________ HGM___________________ Classifier ___________________ Date ___________________

** Definitions and/or values are in the Reference section of the Pulse Field Guide

Scorecard Field Form, pg 2 of 5

Present?	Biotic/abiotic patch type	√ one	Interspersion of patches
	Open water –stream		**Excellent:** Horizontal structure consists of a very complex array of nested and/or interspersed, irregular biotic/abiotic patches, with no single dominant patch type.
	Open Water - Pools		
	Open Water – Rivulets/Streams –fen		
	Open water – beaver pond		**Good:** Horizontal structure consists of a moderately complex array of nested or interspersed biotic/abiotic patches, with no single dominant patch type.
	Oxbow/backwater channels		
	Tributary or secondary channels		
	Streams – pool/riffle complex		**Fair:** Horizontal structure consists of a simple array of nested or interspersed biotic/abiotic patches.
	Active beaver dams		
	Wet meadows		**Poor:** Horizontal structure consists of one dominant patch type and thus has relatively no interspersion.
	Occasional trees		
	Point bars		**Abundance of willows/cottonwoods**
	Adjacent hillside seeps/springs		**Excellent:** Saplings/seedlings present in expected amount; obvious regeneration
	Beaver canals		
	Interfluves on floodplain		**Good:** Saplings/seedlings present but less than expected; some seedling/saplings present
	Debris jams (woody debris) in stream		
	Mudflats		**Fair:** Saplings/seedlings present but in low abundance; Little regeneration by native species
	Saltflats		
	Submerged/floating vegetation		**Poor:** No reproduction of native woody species
	Emergent vegetation		**Beaver Activity**
	Moss bed		**Excellent:** New, recent, and/or old beaver dams present. Beaver currently active in the area.
	Occasional shrubs		
	Emergent vegetation		**Good:** Recent and old beaver dams present. Beaver may not be currently active but evidence suggests that have been with past 10 years.
	Hummock/tussock - fen		
	Water Tracks/Hollows - fen		
	Lawns - fen		**Fair:** Only old beaver dams present. No evidence of recent or new beaver activity despite available food resources and habitat.
	Floating Mat - fen		
	Spring fen		**Poor:** No beaver dams present when expected (in unconfined valleys).
	Shrubs - fen		
	Marl/Limonite beds - fen		**Relative Size**

Ground Cover (%)		√ one	Relative Size
			Excellent: Wetland area = outside abiotic potential
Bryo/lichen:	Sand/soil:		**Good:** Wetland area < abiotic potential; Relative size = 90 – 100%; (<10% of wetland has been reduced, destroyed or severly disturbed due to roads, impoundments, development, human-induced drainage, etc.
Decaying wood:	Water:		
Bedrock/boulder:	Litter/OM:		
Gravel/cobble:	Other		

Cover by Strata

Canopy height (m):

Abr.	Stratum	Height range (m)	Total Cover (%)
S	Shrub		
F	Forb		
G	Graminoid		
T	Tree		
FL	Floating		
A	Aquatic submerged		

Landform type*: ______________________________

Fair: Wetland area < abiotic potential; Relative size = 75 – 90%; (10-25% of wetland has been reduced, destroyed or severly disturbed due to roads, impoundments, development, human-induced drainage, etc.

Poor: Wetland area < abiotic potential; Relative size = <75 – > 25 %; of wetland has been reduced, destroyed or severly disturbed due to roads, impoundments, development, human-induced drainage, etc.

** Definitions and/or values are in the Reference section of the Pulse Field Guide

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<table>
<tr><td colspan="1" rowspan="5">Diversions in/near wetland?</td><td colspan="2">Water Source (√ one)</td></tr>
<tr><td>Ground water</td><td></td></tr>
<tr><td>Seasonal surface water</td><td></td></tr>
<tr><td>Permanent surface</td><td></td></tr>
<tr><td>Precipitation</td><td></td></tr>
<tr><td>Layout Notes: (anything unusual about plot layout and shape)</td><td colspan="2" rowspan="2">Hydro Regime*
__ SP Semipermanently flooded
__ SE Seasonally flooded
__ ST Saturated
__ TM Temporarily flooded
__ IN Intermittently flooded
__ PR Permanently flooded
__ TD Tidally flooded
__ IR Irregularly flooded
__ IE Irregularly exposed
__ UN Unknown
__ RD Rapidly drained
__ WD Well drained
__ MW Moderately well drained
__ SP somewhat poorly drained
__ PD Poorly drained
__ VP Very poorly drained</td></tr>
<tr><td>Location Notes: (include why location was chosen and a small map, more space on reverse)</td></tr>
<tr><td>Vegetation Notes: (characterization of community, dominants, and principle strata)</td><td colspan="2" rowspan="2">Topographic Position *
__ H interfluve (crest,summit,ridge)
__ E High slope (shoulder, upper, convex)
__ M High level
__ D Mid slope
__ F Back slope (cliff)
__ C Low slope (lower, foot, colluvial)
__ B Toeslope
__ G Low level (terrace)
__ J Channel wall (bank)
__ K Channel bed (valley bottom)
__ I Basin floor (depression)</td></tr>
<tr><td>Additional Notes:</td></tr>
</table>

** Definitions and/or values are in the Reference section of the Pulse Field Guide

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Soils Data

Horizon	Range (depth cm)	Texture	Soil & Mottle Color	Depth to water table (cm)	Depth to Saturated Soils (cm)	Depth of Peat (cm)	Structure	% Coarse (Est.% per horizon by type- gravel, cobble, boulder)	Comments (90% root depth, charcoal, etc.) Mottle Abundance(few <2%, common 2-20%, many >20%), Size (fine <5 mm dia., medium 5-15 mm, large >15 mm) and Contrast (faint-similar to matrix, distinct-contrast slightly, prominent-mottles vary by several units of hue, value or chroma)

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Vegetation Plot data (see Carolina Vegetation Survey for digital versions of their data forms: http://www.bio.unc.edu/faculty/peet/lab/CVS/)

Species Code	2	2	2	4	3	2	3	3	8	2	8	4	9	2	9	3	R	R

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