WESTERN GREAT PLAINS FOOTHILL AND PIEDMONT GRASSLAND ECOLOGICAL SYSTEM

ECOLOGICAL INTEGRITY ASSESSMENT

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Prepared by: Karin Decker

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

CES303.817 Western Great Plains Foothill and Piedmont Grassland

Classifiers:

Landcover class:	Herbaceous
Spatial Scale & Pattern:	Large Patch
Classification Confidence:	Moderate
Required Classifiers:	Natural/Seminatural, Vegetated (> 10% vascular cover), Upland
Diagnostic Classifiers:	Lowland (Foothill) Toeslope/Valley Bottom Clay Soil Texture Aridic Short Disturbance Interval (Irregular disturbance) Fire: Low intensity, patch-scale Graminoid
Non-Diagnostic Classifiers:	Herbaceous Temperate (Temperate Continental) Short (50-100 yrs) Persistence

U.S. Distribution: CO, NM, OK, SD, TX, WY, potentially occurs in AZ
Global Range: This mixed-grass prairie ecological system occurs in the narrow to broad transition band between the Rocky Mountains and the Shortgrass Steppe where increased soil moisture from orographic lifting and local topography favor tall and mid-height grasses. The band is restricted to the Rocky Mountain foothills and piedmont and adjacent plains, extending farther east on the Palmer Divide, north alongside the Chalk Bluffs near the Colorado-Wyoming border, and south on and below mesas and escarpments in southeastern Colorado, northeastern New Mexico, and the panhandles of Oklahoma and Texas.
Primary Biogeographic Division: 303 – Western Great Plains
TNC Ecoregions:

10	Wyoming Basins	Confident or certain
20	Southern Rocky Mountains	Confident or certain
21	Arizona-New Mexico Mountains	Confident or certain
24	Chihuahuan Desert	Confident or certain
25	Black Hills	Predicted or probable
26	Northern Great Plains Steppe	Predicted or probable
27	Central Shortgrass Prairie	Confident or certain
28	Southern Shortgrass Prairie	Predicted or probable

Concept summary: This system typically occurs between 1600-2200 m in elevation. It is best characterized as a mixed-grass to tallgrass prairie on mostly moderate to gentle slopes, usually at the base of foothill slopes, such as the hogbacks of the Rocky Mountain Front Range where it typically occurs as a relatively narrow elevational band between montane woodlands and shrublands and the shortgrass steppe. This system also extends east on the Front Range piedmont alongside the Chalk Bluffs along the Colorado-Wyoming border, out into the Great Plains on the Palmer Divide, and on piedmont slopes below mesas and foothills in northeastern New Mexico. A combination of increased precipitation from orographic rain, temperature, and soils limits this system to the lower elevation zone with approximately 40 cm of precipitation/year. It is maintained by frequent fire and associated with well-drained clay soils. Usually occurrences of this system have multiple plant associations that may be dominated by *Andropogon gerardii, Schizachyrium scoparium, Muhlenbergia montana, Nassella viridula, Pascopyrum smithii, Sporobolus cryptandrus, Sporobolus heterolepus, Bouteloua gracilis, Hesperostipa comata,* or *Hesperostipa neomexicana.* In Wyoming, typical grasses found in this system include *Pseudoroegneria spicata, Festuca idahoensis, Hesperostipa comata,* and species of *Poa*. Typical adjacent ecological systems include foothill shrublands, ponderosa pine savannas, juniper savannas, as well as shortgrass prairie.

Component Associations

ALLIANCE/Association name	Element code	G rank
ANDROPOGON GERARDII - (SORGHASTRUM NUTANS) HERBACEOUS ALLIANCE (A.1192)		
Andropogon gerardii - Schizachyrium scoparium Western Great Plains Herbaceous Vegetation	CEGL001463	G2?
Andropogon gerardii - Sorghastrum nutans Western Great Plains Herbaceous Vegetation	CEGL001464	G2
Andropogon gerardii - Sporobolus heterolepis Western Foothills Herbaceous Vegetation	CEGL001465	G2
BOUTELOUA GRACILIS HERBACEOUS ALLIANCE (A.1282)		
Bouteloua gracilis - Bouteloua curtipendula Herbaceous Vegetation	CEGL001754	G5
Bouteloua gracilis - Bouteloua hirsuta Herbaceous Vegetation	CEGL001755	G3G4
Bouteloua gracilis - Buchloe dactyloides Herbaceous Vegetation	CEGL001756	G4
Bouteloua gracilis Herbaceous Vegetation	CEGL001760	G4Q
BOUTELOUA HIRSUTA HERBACEOUS ALLIANCE (A.1285)		
Bouteloua hirsuta - Bouteloua curtipendula Herbaceous Vegetation	CEGL001764	G4
Bouteloua hirsuta - Hesperostipa neomexicana Herbaceous Vegetation	CEGL001766	GNRQ
HESPEROSTIPA COMATA - BOUTELOUA GRACILIS HERBACEOUS ALLIANCE (A.1234)		
Hesperostipa comata Colorado Front Range Herbaceous Vegetation	CEGL001702	G1G2
HESPEROSTIPA COMATA BUNCH HERBACEOUS ALLIANCE (A.1270)		
Hesperostipa comata - Achnatherum hymenoides Herbaceous Vegetation	CEGL001703	G2?
HESPEROSTIPA NEOMEXICANA HERBACEOUS ALLIANCE (A.1272)		
Hesperostipa neomexicana Herbaceous Vegetation	CEGL001708	G3
NASSELLA VIRIDULA HERBACEOUS ALLIANCE (A.1261)		
Nassella viridula Herbaceous Vegetation	CEGL001713	GU
PASCOPYRUM SMITHII HERBACEOUS ALLIANCE ???		
Pascopyrum smithii - Bouteloua gracilis Herbaceous Vegetation	CEGL001578	G5
Pascopyrum smithii - Hesperostipa comata Central Mixedgrass Herbaceous Vegetation	CEGL002034	G4
Pascopyrum smithii Herbaceous Vegetation	CEGL001577	G3G5Q
POLIOMINTHA INCANA SHRUBLAND ALLIANCE (A.862)		
Poliomintha incana / Bouteloua gracilis Shrubland	CEGL001339	G2?
PSEUDOROEGNERIA SPICATA HERBACEOUS ALLIANCE (A.1265)		
Pseudoroegneria spicata - Hesperostipa comata Herbaceous Vegetation	CEGL001679	G4
Pseudoroegneria spicata - Pascopyrum smithii Herbaceous Vegetation	CEGL001675	G4
Pseudoroegneria spicata - Poa secunda Herbaceous Vegetation	CEGL001677	G4?

Pseudoroegneria spicata Herbaceous Vegetation	CEGL001660	G2
SCHIZACHYRIUM SCOPARIUM - BOUTELOUA CURTIPENDULA HERBACEOUS ALLIANCE (A.1225)		
Schizachyrium scoparium - Bouteloua curtipendula Western Great Plains Herbaceous Vegetation	CEGL001594	G3
SCHIZACHYRIUM SCOPARIUM BUNCH HERBACEOUS ALLIANCE (A.1266)		
Schizachyrium scoparium - Muhlenbergia cuspidata Herbaceous Vegetation	CEGL001683	G3?
YUCCA GLAUCA SHRUB HERBACEOUS ALLIANCE (A.1540)		
Yucca glauca / Pseudoroegneria spicata Shrub Herbaceous Vegetation	CEGL001499	G4Q

A.2 Ecological System Description

A.2.1 Environment

Foothill and Piedmont Grasslands are found at the extreme western edge of the Great Plains, where increasing elevation and precipitation facilitate the development of mixed to tallgrass associations on certain soils. The Great Plains rise gently at the rate of about 10 feet per mile from their eastern edge until, at elevations of 5,000 to 6,000 feet near the mountain front, the plains transition fairly abruptly to foothills and mesas that, in turn, quickly rise to montane elevations. This transition produces a number of climatic changes. These mixed- to tallgrass grasslands are found on moderate to gentle slopes at the mountain front, including hogbacks and outwash mesas. These grasslands share elements with the Central Mixedgrass Prairie system, and are often adjacent to the Ponderosa Pine Savanna and Woodland, Lower Montane-Foothills Shrubland, Pinyon-Juniper Savanna and Woodland, or Shortgrass Prairie ecological systems. In the Central Shortgrass Prairie ecoregion, the system is found as an ecotonal band along the mountain front, as well as at some distance from the mountain front on the Palmer Divide, and along the Chalk Bluffs at the Colorado-Wyoming border.

Climate

The western Great Plains has a continental climate with both east-west and north-south gradients. Over the central plains, precipitation decreases from east to west, while temperatures and day-lengths increase from north to south. Mean summer rainfall decreases very sharply westward from the 100th meridian, especially in the summer months (Borchert 1950). Mean annual precipitation decreases from 40-60 in. east of the Mississippi River to about 10 in. in the western part of the central shortgrass Prairie, with an abrupt increase to around 18-23 inches in the narrow strip just east of the Rocky Mountains (Hansen et al. 1978). Although the number of wet days is essentially the same from west to east at a given latitude, the amount of precipitation from any single storm event is generally higher toward the east (Borchert 1950).

Precipitation on the Western Great Plains generally originates from the Gulf of Mexico. In spring and summer months, warm moist air from the Gulf extends further north, while in fall and winter, cold Arctic air from the polar region dominates. When these contrasting air masses meet, severe weather and precipitation often result. Conditions can change rapidly as air masses shift. Along the western edge of the plains, the Rocky Mountains create a rain shadow and a zone of increasing precipitation in the foothill and piedmont areas. Precipitation rapidly increases with increasing elevation. Grasslands of the foothills piedmont receive 4-6 more inches of precipitation annually (16-18) in comparison with some areas of the plains just to the east where 12 in (30 cm) is the annual average. Severe drought is also a common phenomenon in the Western Great Plains (Borchert 1950, Stockton and Meko 1983, Covitch et al. 1997). Periodic high winds (chinooks) result from the flow of high westerly winds over the mountains, but average wind movement is less here than on the plains to the east (Western Regional Climate Center 2004). Temperature variation is also less than on the plains, with lower summer temperatures and higher winter temperatures producing a climate is more moderate than that for grasslands to the east (Western Regional Climate Center 2004).

Geology and soils
Foothills and Piedmont grasslands are typically found on the comparatively narrow band of hill and mesa landforms dissected by small stream beds at the mountain front, but may extend or occur disjunctly to the east where topography, soils, and precipitation patterns are similar. Soils are typically well-drained alluvial material, often cobbly. In areas where mesa landforms occur, seeps on slopes below the caprock may support more mesic associations. Branson et al. (1961) found xeric tallgrass associations on stony soils of the Rocky Flats alluvium where infiltration rates were significantly higher than for the adjacent mixedgrass system on shale-derived soils. Soil moisture percentages were significantly higher in the stony soil throughout the growing season.

A.2.2 Vegetation & Ecosystem

Vegetation
Associations in the Western Great Plains Foothill and Piedmont Grassland are mixed- to tallgrass types that may be dominated by any of the following species: *Andropogon gerardii, Bouteloua gracilis, Muhlenbergia montana, Pascopyrum smithii, Schizachyrium scoparium, Sporobolus cryptandrus, Sporobolus heterolepus, Nassella viridula, Hesperostipa comata,* or *H. neomexicana*. Forbs and subshrubs can be diverse. In the Colorado Front Range typical species include *Artemisia frigida, Dalea purpurea, Eriogonum alatum, Heterotheca vilosa, Liatris punctata, Opuntia polyacantha, Psoralea tenuifolia, Symphyotrichum (Aster) porteri, Yucca glauca,* and the sedge *Carex inops* ssp. *heliophila (=Carex pensylvanica)*. Widely scattered shrubs or trees may occur. Typical adjacent ecological systems include foothill shrublands, ponderosa pine savannas and woodlands, and pinyon-juniper savannas and woodlands as well as shortgrass prairie and periodic foothills riparian corridors. Together, these systems may form a complex mosaic of vegetation in the ecotonal foothill region.

The Foothill and Piedmont Grassland system shares elements with the Western Great Plains Tallgrass, Central Mixedgrass, and Western Great Plains Shortgrass ecological systems. The foothills and piedmont tallgrass associations are distinguished from those of the Western Great Plains tallgrass prairie by their occurrence on well-drained soils, in contrast to the loamy, subirrigated bottomlands characterizing the tallgrass prairie associations. There is considerable overlap between the foothills/piedmont and the shortgrass prairie in associations dominated by *Bouteloua* spp., and the two systems may occasionally intergrade. Again, the well-drained alluvial soils characteristic of the foothill/piedmont type distinguish them from the loamy, silty soils of the shortgrass and mixedgrass systems.

Few rare plant species are associated exclusively or primarily with the Foothills and Piedmont Grassland system, but *Spiranthes diluvialis* (Threatened G2S2), *Carex oreocharis* (G3S1), *Asclepias stenophylla* (G4G5S2), *Viola pedatifida* (G5S2), and *Amorpha nana* (G5S2) are globally or state rare plant found in or near these habitats

Biogeochemistry and productivity
Nutrient cycling in grassland ecosystems is mediated primarily through the assimilation and allocation of carbon and nitrogen by herbaceous plants in relation to precipitation and evapotranspiration rates (Sims and Risser 2000). Water is typically the most limiting factor for plant production; grassland productivity generally increases in a linear fashion with increasing precipitation. Moreover, water availability and use appear to be the fundamental regulators of energy flow in grassland ecosystems (Lauenroth et al. 1979). Productivity in grassland ecosystems of the North American Great Plains is more easily influenced by variation in annual precipitation than in other ecosystems, and these systems can have dramatic increases in production under unusually high precipitation levels (Knapp and Smith 2001).

In the absence of disturbance such as grazing and fire, dead plant material accumulates on the surface. In comparison with wetter regions, decomposition is slow in these semi-arid grasslands and nutrients may accumulate in litter. Wind and water erosion can remove nutrients. Fire quickly returns nutrients to the soil. Herbivory has a much greater influence on energy and nutrient pathways in grasslands than in forests, and a greater proportion of biomass is moving through the grazing pathway in comparison to other ecosystems (Sims and Risser 2000).

Animals
Opler and Krizek (1984) consider the Colorado Front Range the fourth richest butterfly region in the United States, due in part to the ecotonal nature of the foothills. Rare or imperilled species that occur in this system include Ottoe skipper (*Hesperia ottoe*), Cross-line skipper (*Polites origenes rhena*), Arogos skipper (*Atrytone arogos iowa*), Dusted skipper (*Atrytonopsis hianna turneri*), and potentially the Regal fritillary (*Speyeria idalia*). Viable populations of these skippers and butterflies are indicators of a healthy and functioning occurrence of a foothills grasslands system. In addition, the threatened Preble's Meadow Jumping Mouse (*Zapus hudsonius preblei*) is often found in the Colorado Front Range in these grassland habitats when they are associated with riparian areas.

A.2.3 Dynamics

Grasslands are generally believed to be influenced by fire, but little is known about fire dynamics in this system as compared to the larger grassland systems of the Great Plains. Due to the ecotonal nature of these grasslands, fire dynamics may be largely dependent on the adjacent systems, and therefore variable depending on location. Fuel loads in these grasslands are typically higher than in adjacent shortgrass, which may result in more frequent fires. Based on information from ponderosa pine savanna models, fire return intervals for foothills grasslands are estimated to be between 15 and 20+ years, with shorter intervals in the south of the region (Kaufmann et al. 2006). Wieder and Bower (2004) found that grasslands at Aiken canyon, in the foothills south of Colorado Springs, had twice the fire frequency of adjacent woodlands for the period 1872 to 1935.

This system was naturally subject to grazing and browsing by native herbivores including deer, elk, bison, and pronghorn, as well as burrowing and grazing by small mammals such as gophers, prairie dogs, rabbits, and ground squirrels. Activities of these animals can influence both vegetation structure and soil disturbance. Periodic drought is common in the Western Great Plains, but little is known about the importance of drought as a factor in the vegetation dynamics of this system.

A.2.4 Landscape

Foothill and piedmont grasslands are often transitional between other grassland types and savanna or forest ecosystems. These adjacent systems may be characterized by different or conflicting natural processes. An occurrence that is embedded in an intact landscape retains connectivity to adjacent and nearby systems that permits species dispersal and recolonization. A surrounding landscape that is composed of natural vegetation in good condition can buffer a small occurrence, provide migration corridors for important species, and serve as refugia for those species in case of widespread disturbance. Similarly, highly modified surrounding landscapes may facilitate the loss of native species from a patch as well as serve as sources of invasive species. Small, fragmented grasslands are likely to be less resistant to colonization by non-native species.

Grasslands are also in part maintained by natural processes such as fire and grazing by large herbivores. If an occurrence is not large enough by itself to support a natural fire and grazing regime where disturbance is patchy and cyclical, a surrounding natural landscape can provide additional area for the operation of these processes.

A.2.5 Size

Throughout its range, this system is found as a large patch type. Large patch communities, although sometimes covering extensive areas, usually have fairly distinct boundaries, require specific environmental conditions, and are strongly linked to and dependent upon the landscape around them. Like matrix communities, large-patch communities are influenced by large-scale processes, but these tend to be modified by specific site features that influence the community (Anderson et al. 1999).

Evaluation of the size of an occurrence should consider its current extent in relation to what would be ecologically possible given the precipitation and soils of the area. The natural size of an occurrence of foothills and piedmont grassland will be determined largely by a site's topography, soils, and ecosystem processes. If an occurrence has not been reduced in size by human impacts or is surrounded by natural landscape that has not been affected by human disturbances, then size is less important to the assessment of ecological integrity. If, however, human disturbances have decreased the size of the occurrence, or if the surrounding landscape is impacted and has the potential to affect the site, bigger occurrences are able to buffer against these impacts better than smaller sized occurrences 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 more important in assessing ecological integrity. Larger occurrences (e.g. >5000 acres) can provide refuge for edge sensitive species, and would likely contain sufficient internal variability to capture characteristic biophysical gradients and retain natural geomorphic disturbance. Under such circumstances, size may be an important factor in assessing ecological integrity.

A.3 Ecological Integrity

A.3.1 Threats

This system is one of the most severely altered ecological systems in the Southern Rocky Mountains and Central Shortgrass Prairie ecoregions.

Alteration of historic disturbance regime

During its evolutionary history, the Western Great Plains region experienced heavy grazing pressure, first from the herbivores of the Pleistocene, and then from presettlement herds of bison and pronghorn antelope, as well as numerous prairie dogs and rabbits (Collins and Glenn 1991, Knight 1994). Before the advent of cattle ranching, grazing pressure from native herbivores was variable in intensity and seasonality from year to year. Grazing pressure from domestic cattle is typically more homogeneous in timing and intensity (The Nature Conservancy 1998). Historically, soil disturbance was largely the result of occasional concentrations of large native herbivores, or the digging action of fossorial mammals. Prairie dog populations have undergone a decline since settlement, so much of this type could be in various states of secondary succession, returning from a somewhat denuded state and altered composition created by the prairie dogs. Changes in patterns of grazing disturbance have the potential to alter environmental factors such as species composition, soil compaction, nutrient levels, and vegetation structure.

Fire, both aboriginal and lightening-caused, was a regular part of this association. Fire-return intervals have been considerably lengthened since settlement by European-Americans. Fire suppression has allowed the invasion of woody species, especially in combination with heavy grazing (Mast et al. 1997, 1998). Although woodlands and savannas are expected to occur naturally on the landscape, alteration of fire intensity and frequency, grazing, and changes in climate has resulted in various densities of younger trees occurring on sites that were once shrublands or grasslands (West 1999). Ecotonal areas between grassland and ponderosa or juniper savanna may be especially vulnerable to successional changes.

Habitat conversion

Land use within the foothills and piedmont grassland as well as in adjacent areas can fragment the landscape and reduce connectivity between patches and between grasslands and the surrounding landscape. This fragmentation can adversely affect the movement of surface/groundwater, nutrients, and dispersal of plants and animals. In the Colorado Front Range, many of these habitats are in areas that are highly desirable for suburban or exurban development, roads, or recreational infrastructure.

Non consumptive biological resource use
Many of the occurrences of this system along the mountain are found on public (open space) lands where recreational use can be a major source of disturbance.

Invasive species
Increasing small-acreage exurban development with livestock ("ranchettes") appears to be increasing the incidence of weedy exotic species in these habitats. Exotics include *Linaria dalmatica, Centaurea spp., Bromus inermis, B. tectorum, Melilotus officinalis*, and others.

A.3.2 Justification of Metrics

Landscape Context: Land use in the adjacent land as well as in the larger surrounding landscape has important effects on the connectivity and sustainability of many ecological processes critical to this system. The amount and configuration of natural landscape will determine the degree to which natural processes such as fire and species dispersal can function or be simulated by management.

Biotic condition: Species composition and diversity, presence and regeneration of characteristic native plants, invasion of exotics, and structural diversity are important measures of biological integrity.

Abiotic Condition: Ecological processes including the water cycle, energy flow, and nutrient cycling support characteristic plant and animal comunities. Measures of physical components are used as indicators of the integrity of these functions.

Size: Because it is difficult to characterize the potential size of an occurrence of this system due to its ecotonal nature, size is addressed by evaluating the total area of the occurrence and the area that is in A-ranked biotic and abiotic condition classes.

A.3.3 Ecological Integrity Metrics

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

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 Western Great Plains Foothills and Piedmont Grassland System.

Tier: 1 = Remote Sensing, 2 = Rapid, 3 =Intensive. Shading indicates core metrics.

Category	**Essential Ecological Attribute**	**Indicators / Metrics**	**Tier**
LANDSCAPE CONTEXT	Landscape Composition	Adjacent land use	1
		Buffer width	1
		Percentage of unfragmented landscape within 1 km	1
BIOTIC CONDITION	Community Composition	Percent cover of native plant species	2
		Floristic quality index	3
		Presence and abundance of invasive spp.	2, 3
	Patch Diversity	Patch structure - variety	2
		Patch structure - interspersion	2
	Indicator species	Status of Lepidopteran community	3
ABIOTIC CONDITION	Energy/Material Flow	Soil erosion & compaction	2, 3
		Disturbance & Fragmentation – land use within occurrence	1, 2
SIZE	Size	Total area of system occurrence	1
		Area of system occurrence in best Biotic and Abiotic Condition class	1

Table 2. Metrics and Rating Criteria for the Western Great Plains Foothills and Piedmont Grassland 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 Attributes**	**Indicators/ Metics**	**Tier**	**Metric Ranking Criteria**			
				Excellent (A)	Good (B)	Fair (C)	Poor (D)
LANDSCAPE CONTEXT	Landscape Compostion	Adjacent land use (B.1.1)	1	Average land use score = 1.0 – 0.95	Average land use score = 0.80 – 0.95	Average land use score = 0.40 – 0.80	Average land use score = <0.40
		Buffer width (B.1.2)	1	Wide >1000m	Medium 500 – 1000m	Narrow 100 – 500m	Very narrow < 100 m
	Landscape Pattern and Process	Percentage of unfragmented landscape within 1 km. (B.1.3)	1	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
BIOTIC CONDITION	Community composition	Percent cover of native plant species (B.2.1)	2	100% cover of native plant specis	85-100% cover of native plant specis	50-85% cover of native plant specis	<50% cover of native plant specis
		Floristic quality index (Mean C) (B.2.2)	3	>4.5	3.5 – 4.5	3.0 – 3.5	<3.0
		Presence and abundance of noxious species (B.2.3)		Invasive exotics with major potential to alter structure and composition are absent	Invasive exotics with major potential to alter structure and composition occupy less than 1% of occurrence.	Invasive exotics with major potential to alter structure and composition occupy less than 3% of occurrence.	Invasive exotics with major potential to alter structure and composition occupy more than 5% of occurrence.

Category	**Essential Ecological Attributes**	**Indicators/ Metics**	**Tier**	**Metric Ranking Criteria**			
				Excellent (A)	Good (B)	Fair (C)	Poor (D)
	Community Extent	Patch structure – variety (B.2.4)	2	> 75-100% of possible patch types are present in the occurrence	> 50-75% of possible patch types are present in the occurrence	25-50% of possible patch types are present in the occurrence	< 25% of possible patch types are present in the occurrence
		Patch structure – interspersion (B.2.5)	2	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
		Status of Lepidopteran community (B.2.6)	3	Characteristic butterfly and moth species present at close to natural levels of abundance and species richness	Characteristic butterfly and moth species present but at somewhat reduced levels of abundance and species richness	Some characteristic butterfly and moth species present but at significantly reduced levels of abundance and species richness.	Only habitat generalist or weedy species abundant. Few or no butterflies and moths present.
ABIOTIC CONDITION	Energy/ Material Flow	Soil erosion & compaction (B.3.1)	2,3	Score = 4.5-5.0	Score = 3.5-4.4	Score = 2.5-3.4	Score = 1.0-2.4
		Land use within the occurrence (B.3.2)	1, 2	Average land use score = 1.0 – 0.95	Average land use score = 0.80 – 0.95	Average land use score = 0.40 – 0.80	Average land use score = <0.40
SIZE	Size	Total area of occurrence (B.4.1)	1	> 10,000acres	5,000-10,000 acres	1000-5000 acres	< 1000 acres
		Area of system occurrence in best Biotic and Abiotic Condition	1	> 10,000acre	5,000-10,000 acres	1000-5000 acres	< 1000 acres

Category	**Essential Ecological Attributes**	**Indicators/ Metics**	**Tier**	**Metric Ranking Criteria**			
				Excellent (A)	Good (B)	Fair (C)	Poor (D)
		class (B.4.2)					

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

Rationale for Scoring: Adjacent land use, buffer width, and connectivity of the occurrence are judged to be more important than the amount of fragmentation within 1 km of the occurrence since an occurrence with no other natural communities bordering it is very unlikely to have a strong biological connection to other natural lands at a further distance.

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 occurrence.	1	5	4	3	1	0.40	
Buffer Width (B.1.2)	Buffers are vegetated, natural (non-anthropogenic) areas that surround an occurrence.	1	5	4	3	1	0.30	

Measure	Definition	Tier	A	B	C	D	Weight	Score (weight x rating)
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	0.30	
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) to roll up the metrics into an overall Biotic Condition rating.

Rationale for Scoring: The Floristic Quality Index (FQI) metric is judged to be more important than the other metrics as the FQI provides a more reliable indicator of biotic condition.

Scoring for Biotic Condition is a bit more complex. For example, the Floristic Quality Index (FQI) may or may not be assessed, depending on resources (since it is a Tier 3 metric). If it is included then the weights without parentheses apply to the Biotic Condition metrics. If 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)
Percent of Cover of Native Plant Species (B.2.1)	Percent of the plant species which are native to the Southern Rocky Mountains.	2	5	4	3	1	0.20 (0.70)	
Floristic Quality Index (Mean C) (B.2.2)	The mean conservatism of all the native species growing in the occurrence.	3	5	4	3	1	0.60 (N/A)	
Presence and abundance of noxious species (B.2.3)	Presence/abundance of invasive exotics with major potential to alter structure and composition of system.	2	5	4	3	1	0.20 (0.30)	
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.2.2 is not 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.

Table 5. Abiotic Condition Rating Calculation.

Measure	Definition	Tier	A	B	C	D	Weight*	Score (weight x rating)
Soil erosion & compaction		2,3	5	5	0	0	0.50	
Disturbance & Fragmentation – land use within occurrence	Addresses the intensity of human dominated land uses within the occurrence.	1, 2	5	4	3	1	0.50	
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**

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) to roll up the metrics into an overall Size rating.

Rationale for Scoring: Since the importance of size is contingent on human disturbance both within and adjacent to the occurrence, 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)
Total size (B.4.1)	The current size of the occurrence	1	5	4	3	1	0.0 (0.40)	

Measure	Definition	Tier	A	B	C	D	Weight*	Score (weight x rating)
Size of area in best condition (B.4.2)	Area of system occurrence in best Biotic and Abiotic Condition class	1	5	4	3	1	1.0 (0.60)	
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)]**

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)]**

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

Note: Much of the following discussion is adapted from Rocchio (2006).

B.1 Landscape Context Metrics

B.1.1 Adjacent Land Use

Definition: This metric addresses the intensity of human dominated land uses within 1000 m of the occurrence.

Background: This metric evaluates one aspect of the landscape context of an individual occurrrance of the ecological system.

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 1000 m buffer is assigned a coefficient ranging from 0.0 to 1.0 indicating its relative impact to the occurrence (Hauer et al. 2002).

Measurement Protocol: This metric is measured by documenting surrounding land use(s) within 1000 m of the occurrence. This should be completed in the field if possible, 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 without a field visit. Ideally, both field data as well as remote sensing tools are used to identify an accurate % of each land use within 1000 m of the occurrence.

To calculate a Total Land Use Score estimate the % of the adjacent area within 1000 m under each Land Use type and then plug the corresponding coefficient (Table 7) with some manipulation to account for regional application) into the following equation:

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

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

Do this for each land use within 500 m of the occurrence, 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

Current Land Use	Coefficient
Paved roads/parking lots/residential or commercially developed buildings/gravel pit operation/ Energy development (pumping station/ wind machine farm / strip mine)	0.0
Unpaved Roads (e.g., driveway, tractor trail) / Mining / Energy development (well pad, pipeline, exploration)	0.1
Agriculture (tilled crop production)	0.2
Heavy grazing by livestock / intense recreation (ATV use/camping/popular fishing spot, etc.)	0.3
Logging, chaining, 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

based on Table 21 in Hauer et al. (2002)

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: Buffers are vegetated, natural (non-anthropogenic) areas that surround an occurrence. This includes forests, grasslands, shrublands, wetlands, riparian areas, natural lakes and ponds, or streams.

Background: This metric evaluates one aspect of the landscape context of an individual occurrrance of the ecological system.

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 intensity of human activity in the landscape often has a proportionate impact on the ecological processes of natural systems. Buffers are known to reduce potential impacts to wetlands and riparian areas, but their effects on terrestrial ecological systems are less well studied. Although the term “buffer” is retained for this metric, there is insufficient data to confirm that an adjacent natural landscape acts to mitigate the effects of stressors on an occurrence. The relative extent of adjacent natural landscape, however, is potentially important, and is retained until further information is available. This metric may be adequately addressed by the previous metric, or may need to be replaced with some measure of fragmentation.

Measurement Protocol: This metric is measured by estimating the width of the buffer surrounding the occurrence. Buffer boundaries extend from the occurrence edge to intensive human land uses which result in 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.

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 occurrence then take the average of those readings. This may be difficult for large occurrences 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 > 1000 m	Medium. 500 m to <1000 m	Narrow. 100 m to 500 m	Very Narrow. < 100 m

Data: N/A

Scaling Rationale: Scaling is based on minimum separation distance for an occurrence.

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

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. 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 evaluates one aspect of the landscape context of an individual occurrrance of the ecological system.

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 occurrence 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.

<u>B.2 Biotic Condition Metrics</u>

B.2.1 Percent of Cover of Native Plant Species

Definition: Percent of the plant species which are native to the Western Great Plains or adjacent Southern Rocky Mountains.

Background: This metric is one aspect of the condition of an individual occurrrance of the ecological system.

Rationale for Selection of the Variable: Occurrences dominated by native species typically 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 occurrence.

Measurement Protocol: A qualitative, ocular estimate of cover is used to calculate and score the metric. The entire occurrence of the system should be walked and a qualitative ocular estimate of the total cover of native species growing in the area 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 recommended. 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 thresholds from similar systems in Rondeau (2001), and best scientific judgment. These are tentative hypotheses as they have not been validated with quantitative data.

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

B.2.2 Floristic Quality Index (Mean C)

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

Background: This metric is one aspect of the condition of an individual occurrrance of the ecological system.

Rationale for Selection of the Variable: Plants are generally adapted to biotic and abiotic fluctuations associated with the habitat where they grow (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. In contrast, 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).

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). See discussion in Rocchio (2007) for additonal information on this method.

A preliminary FQI for Colorado has been developed (Rocchio 2007). However, calibration of the FQI will likely occur over many years of use and this metric should be updated accordingly.

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

The metric is calculated by referencing only native species C value from the Colorado FQI Database, 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 (Rocchio 2007).

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 Western Great Plains, 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.2.3 Presence and abundance of invasive species.

Definition: This metric estimates the presence and abundance of invasive species with the potential to alter system functioning.

Background: This metric evaluates one aspect of the biotic condition of an individual occurrence of the ecological system.

Rationale for Selection of the Variable: Invasives are introduced species that can thrive in areas beyond their natural range of dispersal. These species are generally adaptable, aggressive, and have a high reproductive capacity, so that in the absence of natural enemies they can increase dramatically and displace native species. The worst invasives can change the character of an entire habitat by affecting ecosystem processes like fire, nutrient flow, flooding, etc

Measurement Protocol: This metric is measured by determining the presence and rough abundance of system altering invasive species in the occurrence. This is completed in the field and ocular estimates are used to match 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**
System altering invasive species, such as leafy spurge, Russian knapweed, diffuse knapweed, spotted knapweed, or yellow toadflax are either not present or occupy less than 1 percent of the occurrence, with no patches larger than 1 acre.	System altering invasive species, such as leafy spurge, knapweed species, or yellow toadflax occupy no more than 1-3% of the occurrence with no patches larger than 1 acre.	System altering invasive species, such as leafy spurge, knapweed species, or yellow toadflax occupy 3-5% of the occurrence, with some patches larger than 1 acre	System altering invasive species, such as leafy spurge, knapweed species, or yellow toadflax occupy >5% of the occurrence.

Data: N/A

Scaling Rationale: The criteria are based on extrapolated thresholds from similar systems in Rondeau (2001), and best scientific judgment. These are tentative hypotheses as they have not been validated with quantitative data.

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

B.2.4 Biotic/Abiotic Patch Richness

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

Background: This metric evaluates one aspect of the condition of an individual occurrence of the ecological system.

Rationale for Selection of the Variable: Spatial heterogeneity (i.e., the types and arrangement of habitat patches within a landscape) can strongly influence the abundance and distribution of species that use a particular habitat (Pulliam et al. 1992) 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 system type (Table 8). 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 possible patch types are present in the occurrence	> 50-75% of possible patch types are present in the occurrence	25-50% of possible patch types are present in the occurrence	< 25% of possible patch types are present in the occurrence

Data:

Table 8. Biotic/Abiotic Patch Types in Foothills and Piedmont Grasslands

Patch Type
Sparse tree canopy
Shrub canopy
Herbaceous canopy – mid-tall height graminoid
Herbaceous canopy – short graminoid
Herbaceous canopy - forb
Litter cover
Bare soil
Rock outcrop

TOTAL = 8

Scaling Rationale: Simple quartiles were used. Need additional information about appropriate breaks.

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

B.2.5 Interspersion of Biotic/Abiotic Patches

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

Background: This metric evaluates one aspect of the condition of an individual occurrence of the ecological system.

Rationale for Selection of the Variable: Spatial heterogeneity (i.e., the types and arrangement of habitat patches within a landscape) can strongly influence the abundance and distribution of species that use a particular habitat (Pulliam et al. 1992)

Measurement Protocol: This metric is measured by determining the degree of interspersion of biotic/abiotic patches present in the occurrence. This can be completed in the field for most sites, however aerial photography may be beneficial for larger sites. 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.2.3 for list and definitions of Biotic Patches.

Scaling Rationale: In the absence of quantitative data, the scale is based on guidelines for professional judgment.

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

B.2.6 Status of Lepidopteran community

Definition: This metric assesses the status of butterflies and moths, a group that is known to be diverse in foothills grasslands and to be particularly sensitive to management as well as to community condition.

Background: These foothills and piedmont grasslands typically support a rich Lepidopteran community that is considered to be an indicator of a healthy, functioning system.

Rationale for Selection of the Variable: The status of Lepidoptera is not well reflected by any of the other metrics. Lepidoptera are believed to reflect the status of the larger invertebrate community, which is an important part of the biota and ecosystem of foothills grasslands. This metric is designated as non-core solely because of the difficulty of obtaining data.

Measurement Protocol: Lepidoptera species present and rough abundances (catch per unit effort) are determined by black-light trapping and netting of day-flying species. Species data are compared to expected or previously measured data to determine rating. Appropriate means of comparison need to be developed. With additonal research, this metric may be replaced by a more targeted measurement of selected indicator species.

Measure (Metric) Rating

Excellent	**Good**	**Fair**	**Poor**
Characteristic butterfly and moth species present at close to natural levels of abundance and species richness	Characteristic butterfly and moth species present but at somewhat reduced levels of abundance and species richness	Some characteristic butterfly and moth species present but at significantly reduced levels of abundance and species richness.	Only habitat generalist or weedy species abundant. Few or no butterflies and moths present.

Data:

Scaling Rationale: In the absence of quantitative data, the scale is based on guidelines for professional judgment.

Confidence that reasonable logic and/or data support the index: High for inclusion of the index. Medium to low for the specific measures and thresholds.

B.3 Abiotic Condition Metrics

B.3.1 Soil erosion & compaction

Definition: An index measure of the degree to which erosion and soil compaction are out of the range of natural variation.

Background: This metric evaluates one aspect of the abiotic condition of an individual occurrence of the ecological system.

Rationale for Selection of the Variable: The functional integrity of this ecological system type is dependent in part on the the integrity of the soil (National Research Council 1994, Smith et al. 1995). The selected variables are part of a more comprehensive assessment of rangeland health that is focused on soil condition (Pellant et al. 1995).

Measurement Protocol: This metric is estimated in the field by observing overland water flow patterns, signs of rill formation and wind scour, the presence of pedestals and terrecettes, drainage patterns, bare ground, and soil compaction.

Metric Rating: Assign each of the six metrics in Table 9 an Excellent, Good, Fair, or Poor rating on the scorecard. Use the scores and weights shown to compile a final score.

Table 9. Soil erosion and compaction scoring.

Metric (weight)	**Excellent** **Score = 5**	**Good** **Score =4**	**Fair** **Score = 3**	**Poor** **Score = 5**	**Score** (weight x rating)
Water patterns (0.10)	Minimal evidence of past or current soil deposition or erosion.	Matches what is expected for the site; erosion is minor with some instability and deposition	More numerous than expected; deposition and cut areas common; occasionally connected.	Water flow patterns may be extensive and numerous; unstable with active erosion; usually connected.	
Rills, wind scour (0.10)	Slight to no evidence	Some evidence of rill formation or accelerated wind scour	Rill formation or accelerated wind scour may be moderately active and well defined throughout most of the occurrence.	Rill formation or accelerated wind scour may be severe and well defined throughout most of the occurrence	
Pedestals and/or Terracets (0.10)	Absent or uncommon.	Occasionally present	Common	Abundant	
Drainages (0.10)	Represented as natural stable channels with no signs of unnatural erosion.	Represented as natural stable channels with only slight signs of unnatural erosion.	Gullies may be present with indications of active erosion; vegetation is intermittent on slopes. Headcuts are active; downcutting is apparent	Gullies common, with indications of active erosion and downcutting; vegetation is infrequent on slopes or bed of gully.	
Bare Ground (0.10)	Bare areas are no higher than expected for the substrate.	Bare areas are moderately larger than expected size and only sporadically connected.	Bare ground is moderate to much higher than expected for the site. Bare areas are large and may be connected.	Much higher than expected for the site. Bare areas are large and generally connected.	
Soil compaction (0.50)	Soils are not compacted and are not restrictive to water movement and root penetration.	Soil compaction moderately widespread and moderately restricts water movement and root penetration.	Soil compaction widespread and greatly restricts water movement and root penetration.	Soil compaction is extensive throughout the occurrence, severely restricting water movement and root penetration	
Final rating:	A = 4.5 - 5.0				**Total =**

	B = 3.5 – 4.4 C = 2.5 – 3.4 D = 1.0 – 2.4				**sum of N scores**

Data: Based on Pellant et al. 2005. There is some evidence that soil aggregate stability (AS) could be used as a composite index for this metric (Bestelmeyer et al. 2006), but data collection may be more labor intensive.

Scaling Rationale: In the absence of quantitative data, the scale is based on guidelines for professional judgment.

Confidence that reasonable logic and/or data support the index: High for inclusion of the index. Medium to low for the specific measures and thresholds.

B.3.2 Disturbance and Fragmentation – land use within occurrence

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

Background: This metric is one aspect of the abiotic condition of an individual occurrence of the ecological system.

Rationale for Selection of the Variable: Fragmentation and disturbance are important factors on the ecological processes of natural systems. Due to the difficulties of applying measures of fragmentation (Hargis et al. 1998, Tischendorf and Fahrig 2000) this variable is measured using the same technique as in Section B.1.1.

Measurement Protocol: This metric is measured by documenting land use(s) withinthe boundaries of the occurrence. 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.

To calculate a Total Land Use Score estimate the % of the adjacent area within the occurrence under each Land Use type and then plug the corresponding coefficient (Table 7, section B.1.1) into the following equation:

Sub-land use score = ∑ LU x PC/100

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

Do this for each land use within the occurrence, then sum the Sub-Land Use Score(s) to arrive at a Total Land Score. For example, if 30% of the 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: See table in section B.1.1.

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.4 Size Metrics

B.4.1 Total size of system occurrence

Definition: This metric assesses the total size of all areas included in the occurrence or stand, i.e., all stands or patches that are close enough together to fall within the same occurrence.

Background: Size (area) of the occurrence has a large effect on the internal heterogeneity and diversity of an occurrence. To define the area, rules are needed to specify when two or more patches or stands are close enough together to belong to the same occurrence.

Rationale for Selection of the Variable: Most ecological function is proportional to size of occurrences, and some is disproportionately related to large occurrences. Some ecological functions occur only, or at much greater levels, in areas in good condition, while other ecological functions may occur even in relatively poor or degraded areas. Some species are specific to habitat in the best condition while others are more tolerant of degraded examples. Other ecological functions may occur in poorer quality areas, but only at a much reduced frequency/intensity, and some species may occur there but only at low density. Poorer areas thus contribute to the ecological significance of occurrences, but to a lesser degree than areas in better condition.

Measurement Protocol: This metric is evaluated by measuring or estimating the total area of the occurrence.

Measure	Definition Tier	A Excellent	B Good	C Fair	D Poor
Total system size	Total area of system within separation distance	>5000 acres	2000-5000 acres	1000-2000 acres	< 1000 acres

Data:

Scaling Rationale: The present scale is based on the range of sizes of occurrences in eastern Colorado and professional judgment about thresholds (Rondeau 2001). The range of sizes is expected to be similar throughout the range of the system. The scale could be improved by basing it on the correlation of species presence/richness with size values.

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

B.4.2 Size of high quality area

Definition: This metric assesses the size of the area to which the highest condition rating applies.

Background: For occurrences that are heterogeneous with regard to condition, this metric indicates the size of area which is in the best condition class. For homogeneous occurrences, this will be the same as the total system size, but for heterogeneous occurrences it may be smaller.

Rationale for Selection of the Variable: Most ecological function is proportional to size of occurrences, and some is disproportionately related to large occurrences. Some ecological functions occur only, or at much greater levels, in areas in good condition, while other ecological functions may occur even in relatively poor or degraded areas. Some species are specific to habitat in the best condition while others are more tolerant of degraded examples. Other ecological functions may occur in poorer quality areas, but only at a much reduced frequency/intensity, and some species may occur there but only at low density. Because the combined rating for the occurrence is based on a combination of size and condition, the size of the high quality area, the area corresponding to the condition rating, is the most important size measure. However, having large additional areas in poorer condition may compensate to some degree.

Measurement Protocol: This metric is evaluated by measuring or estimating the total area within the occurrence that meets the criteria for the best condition rating score given to the occurrence, the most intact area within the overall occurrence.

Measure	Definition - Tier	A Excellent	B Good	C Fair	D Poor
Size of high quality area	Area of system in best condition	>5000	2000-5000	1000-2000	< 1000

	class (see rollup of condition metrics) 2, 3	acres	acres	acres	acres

Data:

Scaling Rationale: The present scale is based on the range of sizes of occurrences in eastern Colorado and professional judgment about thresholds (Rondeau 2001). The range of sizes is expected to be similar throughout the range of the system. The scale could be improved by basing it on the correlation of species presence/richness with size values.

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

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