USDA Natural Resources Conservation Service

Ecological site R043AX966MT
Montane Loamy Outwash Terrace Richardson’s needlegrass (Achnatherum richardsonii)

Last updated: 5/06/2024
Accessed: 05/20/2024

General information

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

MLRA notes

Major Land Resource Area (MLRA): 043A–Northern Rocky Mountains

This MLRA is located in Montana (43 percent), Idaho (34 percent), and Washington (23 percent). It makes up about 31,435 square miles (81,460 square kilometers). It has no large cities or towns. It has many national forests, including the Okanogan, Colville, Kootenai, Lolo, Flathead, Coeur d’Alene, St. Joe, Clearwater, and Kaniksu National Forests.

This MLRA is in the Northern Rocky Mountains Province of the Rocky Mountain System. It is characterized by rugged, glaciated mountains; thrust- and block-faulted mountains; and hills and valleys. Steep-gradient rivers have cut deep canyons. Natural and manmade lakes are common.

The major Hydrologic Unit Areas (identified by four-digit numbers) that make up this MLRA are: Kootenai-Pend Oreille-Spokane (1701), 67 percent; Upper Columbia (1702), 18 percent; and Lower Snake (1706), 15 percent. Numerous rivers originate in or flow through this area, including, the Sanpoil, Columbia, Pend Oreille, Kootenai, St. Joe, Thompson, and Flathead Rivers.

This area is underlain primarily by stacked slabs of layered sedimentary or metasedimentary bedrock. The bedrock formations range from Precambrian to Cretaceous in age. The rocks consist of shale, sandstone, siltstone, limestone, argillite, quartzite, gneiss, schist, dolomite, basalt, and granite. The formations have been faulted and stacked into a series of imbricate slabs by regional tectonic activity. Pleistocene glaciers carved a rugged landscape that includes sculpted hills and narrow valleys filled with till and outwash. Continental glaciation over road the landscape in the northern half of the MLRA while glaciation in the southern half was confined to montane settings.

The average annual precipitation is 25 to 60 inches (635 to 1,525 millimeters) in most of this area, but it is as much as 113 inches (2,870 millimeters) in the mountains and is 10 to 15 inches (255 to 380 millimeters) in the western part of the area. Summers are dry. Most of the precipitation during fall, winter, and spring is snow. The average annual temperature is 32 to 51 degrees F (0 to 11 degrees C) in most of the area, decreasing with elevation. In most of the area, the freeze-free period averages 140 days and ranges from 65 to 215 days. It is longest in the low valleys of Washington, and it decreases in length with elevation. Freezing temperatures occur every month of the year on high mountains, and some peaks have a continuous cover of snow and ice.

The dominant soil orders in this MLRA are Andisols, Inceptisols, and Alfisols. Many of the soils are influenced by Mount Mazama ash deposits. The soils in the area have a frigid or cryic soil temperature regime; have an ustic, xeric, or udic soil moisture regime; and dominantly have mixed mineralogy. They are shallow to very deep, are very poorly drained to well drained, and have most of the soil texture classes. The soils at the lower elevations include Udivitrands, Vitrixerands and Haplustalfs. The soils at the higher elevations include Dystrocryepts, Eutrocryepts, Vitricryands , and Haplocryalfs. Cryorthents, Cryepts, and areas of rock outcrop are on ridges and peaks above timberline

This area is in the northern part of the Northern Rocky Mountains. Grand fir, Douglas-fir, western red cedar, western hemlock, western larch, lodgepole pine, subalpine fir, ponderosa pine, whitebark pine, and western white pine are the dominant overstory species, depending on precipitation, temperature, elevation, and landform aspect. The understory vegetation varies, also depending on climatic and landform factors. Some of the major wildlife species in this area are whitetailed deer, mule deer, elk, moose, black bear, grizzly bear, coyote, fox, and grouse. Fish, mostly in the trout and salmon families, are abundant in streams, rivers, and lakes.

More than one-half of this area is federally owned and administered by the U.S. Department of Agriculture, Forest Service. Much of the privately-owned land is controlled by large commercial timber companies. The forested areas are used for wildlife habitat, recreation, watershed, livestock grazing, and timber production. Meadows provide summer grazing for livestock and big game animals. Less than 3 percent of the area is cropland.

LRU notes

This ecological site resides in MLRA 43A in the Livingston-Lewis-Apgar Mountains which includes the bulk of Glacier National Park (GNP) and the lower western valley portions along the Flathead River. The landscape is mountains and landforms include glaciated mountains with associated features such as U-shaped valleys, mountain slopes, alpine ridges, cirques, valley floors and moraines. Glaciation of this area was in the form of alpine, icecaps and valley outlet glaciers. It also includes associated alluvium and outwash features. This area includes low valleys to tall mountains with elevation ranging 989-2,762 m (3,250-9,050 ft.). The climate is cold and wet with mean annual air temperature of 3 degrees Celsius (37 degrees F)., mean frost free days of 65 days and mean annual precipitation of 1295 mm (51 in.) and relative effective annual precipitation is 169 cm (66 in.). The soil temperature regime is cryic and the soil moisture regime is udic. The geology of this area is dominated by metasedimentary rocks of the Belt Supergroup (Grinnell argillite and Siyeh limestone) with minor Tertiary sediments. Soils are generally weakly developed on mountain slopes within U-shaped valleys. Parent materials are commonly of colluvium, till, and residuum from metasedimentary rocks. Limestone bedrock within this part of the Belt Supergroup is not highly calcareous and due to high precipitation received in this area most carbonates at mid and upper elevations have been leached from the soil profiles. Bedrock depth varies greatly with location, landform and slope position. Volcanic ash is often found in the soil surface with various degrees of mixing. Thicker volcanic ash can be found on more stable positions on mid and upper elevation slopes that are protected from wind erosion. Volcanic ash is not typically found in low elevation areas on stream and outwash terraces associated with streams and rivers. There are numerous large lakes including St. Mary, Bowman, Kintla, Lake Sherburne, Logging, Upper Waterton and numerous creeks (

Classification relationships

NPS Plant Community Name:
Festuca campestris-Festuca idahoensis-Geranium viscosissimum Herbaceous Vegetation (CEGL005870)
Physiognomic Class Herbaceous Vegetation (V)
Physiognomic Subclass Perennial graminoid vegetation (V.A.)
Physiognomic Group Temperate or subpolar grassland (V.A.5.)
Physiognomic Subgroup Natural/Semi-natural temperate or subpolar grassland (V.A.5.N.)
Formation Medium-tall bunch temperate or subpolar grassland (V.A.5.N.d.)
Alliance *Festuca idahoensis* Herbaceous Alliance (A.1251)
Alliance (English name) Idaho Fescue Herbaceous Alliance
Association *Festuca campestris - Festuca idahoensis - Geranium viscosissimum* Herbaceous Vegetation
Association (English name) Prairie Fescue - Idaho Fescue - Sticky Geranium Herbaceous Vegetation
ECOLOGICAL SYSTEM(S): Northern Rocky Mountain Lower Montane, Foothill and Valley Grassland (CES306.040)

Festuca capestris-(*Festuca idahoensis*)-*Achnatherum richardsonii* Herbaceous Vegetation (CEGL005869)
Physiognomic Class Herbaceous Vegetation (V)
Physiognomic Subclass Perennial graminoid vegetation (V.A.)
Physiognomic Group Temperate or subpolar grassland (V.A.5.)
Physiognomic Subgroup Natural/Semi-natural temperate or subpolar grassland (V.A.5.N.)
Formation Medium-tall bunch temperate or subpolar grassland (V.A.5.N.d.)
Alliance *Festuca idahoensis* Herbaceous Alliance (A.1251)

Alliance (English name) Idaho Fescue Herbaceous Alliance
Association *Festuca campestris* - (*Festuca idahoensis*) - *Achnatherum richardsonii* Herbaceous Vegetation
Association (English name) Prairie Fescue - (Idaho Fescue) - Richardson's Needlegrass Herbaceous Vegetation
ECOLOGICAL SYSTEM(S): Northern Rocky Mountain Lower Montane, Foothill and Valley Grassland (CES306.040)

Ecological site concept

This ecological site is found at low elevations, ranging from 1,100-1,400 meters (3,600-4,600 feet) high, on very low to moderate slopes with all aspects on terraces in valleys. The terraces mainly consist of outwash or stream terraces. This site can also occur on ground moraines. It is dominated by a mixture of native, perennial, cool-season tufted bunch grasses. These grasses include rough fescue (*Festuca campestris*), Idaho fescue (*Festuca idahoensis*), Richardsons needlegrass (*Achnatherum richardsonii*), bluebunch wheatgrass (pseudoroegneria spicata), timber oatgrass (*Danthonia intermedia*), and prairie Junegrass (*Koeleria macrantha*). These grasses can occur in varying amounts of cover, but generally are dominated by rough fescue, Richardsons needlegrass, and Idaho fescue. Associated montane forbs include yarrow (*Achillea millefolium*), sticky purple geranium (*Geranium viscosissimum*), old man's whiskers (*Geum triflorum*), northern bedstraw (*Galium boreale*), and yellow penstemon (*Penstemon confertus*). Shrubs with very low cover occur, including kinnikinnick (*Arctostaphylos uva-ursi*), serviceberry (Amalanchier alnifolia), shrubby cinquefoil (*Dasiphora fruticosa*), sulphur-flower buckwheat (*Eriogonum umbellatum*), common juniper (*Juniperus communis*), creeping barberry (*Mahonia repens*), Woods rose (*Rosa woodsii*), snowberry (*Symphoricarpos albus*), mountain big sagebrush (*Artemisia tridentata* var. vaseyana) and western snowberry (*Symphoricarpos occidentalis*). This ecological site has soils that are very deep, well drained, and formed from alluvial or outwash parent materials. These soils typically have a gravelly loam surface texture and fine-loamy subsurface textures. The deep dark surface horizon with high base saturation, called a mollic epipedon, present in these soils indicate that they have consistently supported grassland vegetation over time. Their dark color is due to the incorporation of organic matter from the roots of grass and forb species. These soils are classified as Mollisols, and the thickness of the dark mollic surface layer averages 38 cm (26-62 cm). Many of these soils have a zone of weak development or cambic diagnostic horizon and are classified as Haplocryolls. Others have an argillic horizon or zone of clay accumulation and are classified as Argicryolls. Surface organic layers when present are usually less than 5 cm thick.

Associated sites

F043AX951MT	**Lower Subalpine Cool Dry Coniferous subalpine fir- Engelmann spruce/ Sitka alder/ thinleaf huckleberry/ common beargrass** The Lower Subalpine Coniferous Cool Moderately Dry (ABLA/CLUN) ecological site is found on lateral moraines, glacial valley walls, ground moraines and mountain slopes. It can be found at higher elevations and steeper slopes than this ecological site. The lower, drier areas in which it is found would interface with this ecological site.The Lower Subalpine Coniferous Cool Moderately Dry ecological site has soils that are very deep and well drained, developed in glacial till or colluvium parent materials that typically have varying amounts of influence of volcanic ash. The surface texture is very gravelly ashy loam and subsurface is loamy-skeletal. The permeability class is moderate to moderately rapid. These are Alfisols and Andisols. The Lower Subalpine Coniferous Cool Moderately Dry has a reference vegetation community of Subalpine fir and Engelmann spruce with an understory of Sitka alder, huckleberry, beargrass and queencup bead lily.
F043AX959MT	**Montane Warm Dry Coniferous Douglas fir/white spirea-common snowberry/pinegrass** The Montane Warm Dry Coniferous (PSME/SYAL) ecological site resides in ground moraines, lateral moraines, outwash terraces and glacial-valley walls. The PSME/SYAL ecological site can be found at higher elevations and steeper slopes than this ecological site. The lower, drier areas in which it is found would interface with this ecological site. There is no flooding or ponding of this site.The Montane Warm Dry Coniferous ecological site has soils that are very deep, well drained and derived from glacial till or outwash. Soil textures typically are loamy, but can have skeletal subsurface horizons that have a high amount of rock fragments (>35% by volume) and relatively lower water-holding capacity. They are typically classified as Inceptisols or Alfisols. The Montane Warm Dry Coniferous ecological site has a reference vegetation community of Douglas fir with an understory of white spirea, common snowberry, pinegrass and heartleaf arnica.

F043AX960MT	**Montane Deciduous Alluvial Flood Plain black cottonwood (paper birch)/redosier dogwood Populus balsamifera ssp. trichocarpa (Betula papyrifera)/Cornus sericea ssp. sericea** The montane deciduous floodplain ecological site occurs on floodplain steps and drainageways, and is often spatially adjacent to the montane loamy ecological site found on outwash terraces. It is also a low elevation and flat ecological site. It is seasonally flooded at the surface (depth 0) during April-July with frequent flooding of long duration during April-July. There is no ponding.The Montane Deciduous Floodplain ecological site also has parent material that is alluvium derived from metasedimentary rock. The surface texture is very gravelly coarse sandy loam and subsurface texture is sandy-skeletal. There can be high cover of gravels on the surface. The permeability class is rapid and the depth class is very deep. These are classified as Oxyaquic Cryofluvents. Montane Deciduous Alluvium Floodplain has a reference community of Black cottonwood with an understory of redosier dogwood, common snowberry, Rocky mountain maple and western meadow-rue.

Table 1. Dominant plant species

Tree	Not specified
Shrub	Not specified
Herbaceous	(1) *Festuca campestris* (2) *Festuca idahoensis*

Physiographic features

This ecological site is found at low elevations, ranging from 1,100-1,400 meters high, on very low to moderate slopes with all aspects on terraces in valleys. The terraces mainly consist of outwash or stream terraces. This site can also occur on ground moraines.

Figure 1. The Montane loamy outwash terrace ecological site is positioned on a low elevation, flat outwash terrace surrounded by moraine, hill and mountain landforms.

Figure 2. Landscape view of the site.

Figure 3. Landscape photo of site.

Table 2. Representative physiographic features

Landforms	(1) Mountains > Outwash terrace (2) Mountains > Stream terrace (3) Mountains > Ground moraine
Elevation	1,100–1,400 m
Slope	0–15%
Aspect	W, NW, N, NE, E, SE, S, SW

Climatic features

POLEBRIDGE CLIMATE STATION:

Mean Average Precipitation 26-49 inches
Mean Average Annual Temperature 36-43 degrees
Frost free days: 50-70
Relative Effective Annual Precipitation: 20-24 inches

This ecological site is found in the cryic soil temperature regime and in the udic soil moisture regime. Cryic soils have an average annual temperature of less than 8 degrees C, with less than 5 degrees C difference in temperatures from winter to summer. The Udic soil moisture regime denotes that the rooting zone usually is moist throughout the winter and the majority of summer. This site is found on the west side of the Continental Divide and has more maritime weather influences.
INFORMATION IN TABLES BELOW ARE FROM CLIMATE STATIONS LOCATED IN VALLEYS.

Table 3. Representative climatic features

Frost-free period (characteristic range)	17-57 days
Freeze-free period (characteristic range)	76-117 days
Precipitation total (characteristic range)	508-660 mm
Frost-free period (actual range)	6-68 days
Freeze-free period (actual range)	66-127 days
Precipitation total (actual range)	508-711 mm
Frost-free period (average)	37 days
Freeze-free period (average)	97 days
Precipitation total (average)	584 mm

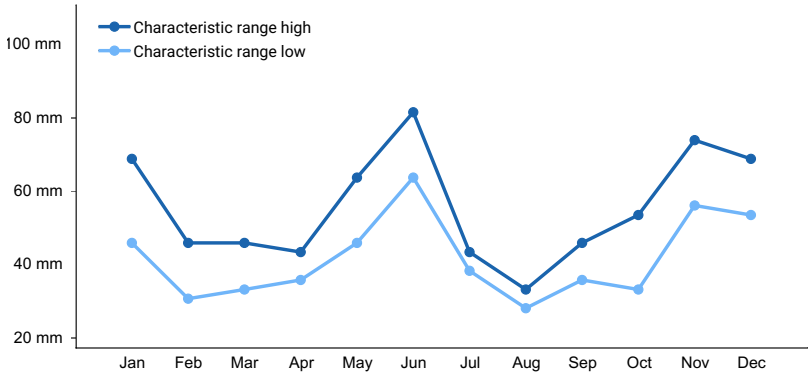


Figure 4. Monthly precipitation range

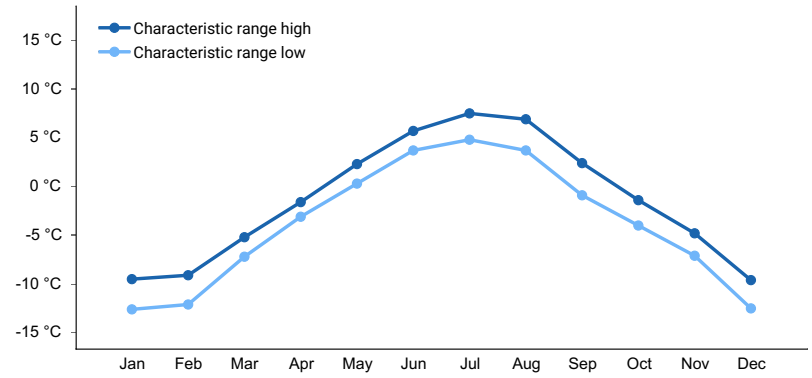


Figure 5. Monthly minimum temperature range

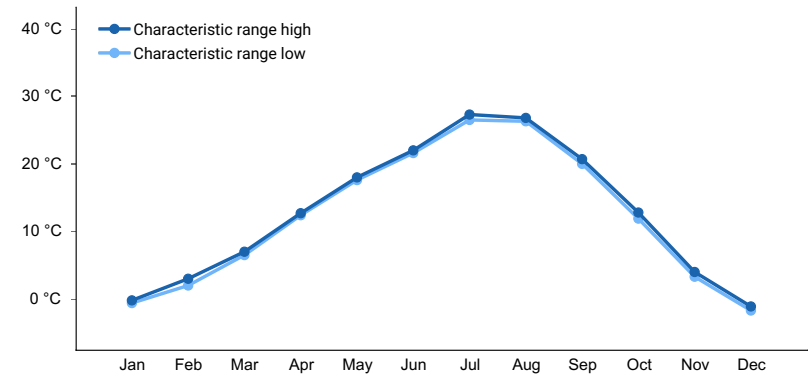


Figure 6. Monthly maximum temperature range

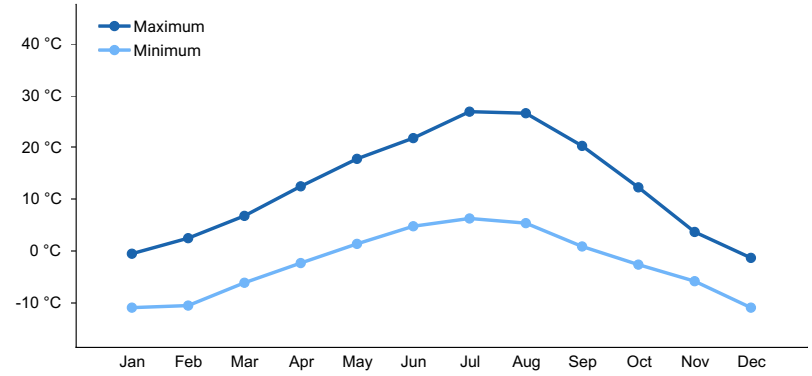


Figure 7. Monthly average minimum and maximum temperature

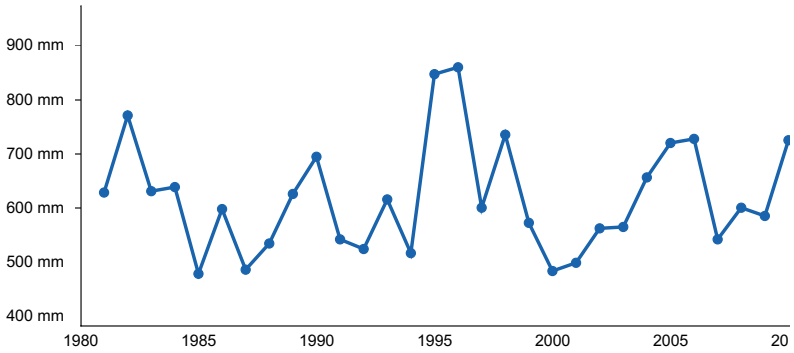


Figure 8. Annual precipitation pattern

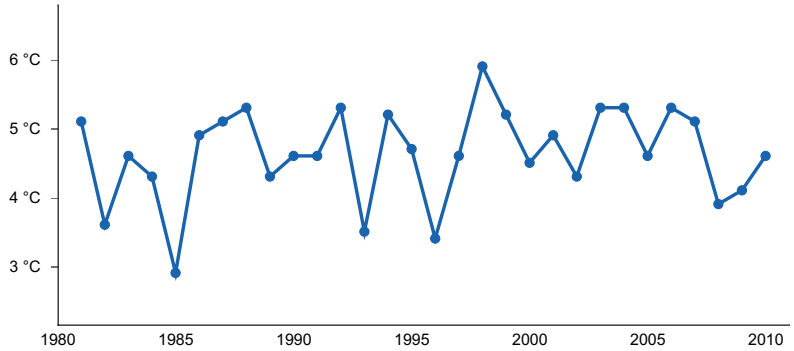


Figure 9. Annual average temperature pattern

Climate stations used

- (1) POLEBRIDGE 1 N [USC00246618], Essex, MT
- (2) POLEBRIDGE [USC00246615], Essex, MT
- (3) WEST GLACIER [USC00248809], Kalispell, MT

Influencing water features

Soil features

This ecological site has soils that are very deep, well drained, and formed from alluvial or outwash parent materials. These soils typically have a gravelly loam surface texture and fine-loamy subsurface textures. The deep dark surface horizon with high base saturation, called a mollic epipedon, present in these soils indicate that they have consistently supported grassland vegetation over time. Their dark color is due to the incorporation of organic matter from the roots of grass and forb species. These soils are classified as Mollisols, and the thickness of the dark mollic surface layer averages 38 cm (26-62 cm). Many of these soils have a zone of weak development or cambic diagnostic horizon and are classified as Haplocryolls. Others have an argillic horizon or zone of clay accumulation and are classified as Argicryolls. Surface organic layers when present are usually less than 5 cm thick. Diagnostic features include a mollic epipedon and either a cambic or argillic subsurface horizon. (Soil Survey Staff, 2015). For more information on soil taxonomy, please follow this link: http://http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/class/?cid=nrcs142p2_053580

CORRELATED SOIL SERIES & TAXONOMIC CLASS NAME
Parkcity Loamy-skeletal, mixed, superactive Pachic Haplocryolls
Vulture Fine-loamy, mixed, superactive Typic Argicryolls

Figure 10. Soil photo of site.

Figure 11. Soils at site noting loamy soils in upper horizon and skeletal soil in lower horizons.

Figure 12. Typical soil profile for this ecological site.

Table 4. Representative soil features

Parent material	(1) Alluvium–metasedimentary rock (2) Outwash–metasedimentary rock (3) Till–metasedimentary rock
Surface texture	(1) Gravelly loam
Family particle size	(1) Fine-loamy (2) Loamy-skeletal
Drainage class	Well drained
Permeability class	Moderately slow to moderate

Soil depth	152–254 cm
Surface fragment cover <=3"	0%
Surface fragment cover >3"	0%
Available water capacity (8.4-14.2cm)	Not specified
Soil reaction (1:1 water) (14.7-17.8cm)	Not specified

Ecological dynamics

Ecological Dynamics of the Site
This ecological site is found at low elevations, ranging from 1,100-1,400 meters (3,600-4,600 feet) high, on very low to moderate slopes with all aspects on terraces in valleys. The terraces mainly consist of outwash or stream terraces. This site can also occur on ground moraines. This ecological site is at lower elevations than the warmest coniferous zone dominated by ponderosa pine.

State 1.0: Historic Reference state with no weedy species present.
Richardson's needlegrass (*Achnatherum richardsonii*)-rough fescue (*Festuca campestris*)-Idaho fescue (*Festuca idahoensis*)/old man's whiskers (*Geum triflorum*)-sticky purple geranium (*Geranium viscosissimum*)

The Montane Loamy Outwash Terrace ecological site is dominated by a mixture of native, perennial, cool-season tufted bunch grasses. These grasses include rough fescue (*Festuca campestris*), Idaho fescue (*Festuca idahoensis*), Richardson's needlegrass (*Achnatherum richardsonii*), bluebunch wheatgrass (pseudoroegneria spicata), timber oatgrass (*Danthonia intermedia*), and prairie Junegrass (*Koeleria macrantha*). These grasses can occur in varying amounts of cover, but generally are dominated by rough fescue, Richardson's needlegrass, and Idaho fescue. The grasslands in western Montana, in general, are considered unique in that they have similar species to both grasslands of eastern Washington and northern Idaho (Palouse Region grasslands) as well as northern grasslands in Canada (Alberta fescue grasslands). Associated montane forbs include yarrow (*Achillea millefolium*), sticky purple geranium (*Geranium viscosissimum*), old man's whiskers (*Geum triflorum*), northern bedstraw (*Galium boreale*), and yellow penstemon (*Penstemon confertus*). Shrubs with very low cover occur, including kinnikinnick (*Arctostaphylos uva-ursi*), serviceberry (Amalanchier alnifolia), shrubby cinquefoil (*Dasiphora fruticosa*), sulphur-flower buckwheat (*Eriogonum umbellatum*), common juniper (*Juniperus communis*), creeping barberry (*Mahonia repens*), Woods' rose (*Rosa woodsii*), snowberry (*Symphoricarpos albus*), mountain big sagebrush (*Artemisia tridentata* var. vaseyana) and western snowberry (*Symphoricarpos occidentalis*). Only kinnikinnick occurs in any abundance, forming low-growing clumps. Some tree species occur in very low cover (1 percent canopy cover at 18 percent of the 22 sites visited). Conifer encroachment by lodgepole pine (*Pinus contorta*) usually occurs along the edges of the prairie.

Big Prairie along the North Fork of the Flathead River in Glacier National Park is an excellent example of this site. This prairie has the highest number of microhabitat types for a grassland in this area, due to differential accumulation of glacio-alluvial material and the mix of subtle river swales and depressions on this former glacial outwash floodplain (Koterba and Habeck, 1971). Koterba and Habeck found in their ordination study of North Fork grasslands that species distribution was grouped by available soil moisture and soil attributes. Drier sites with available soil moisture of 17.7 percent and 60-70 percent sand and 5-10 percent clay had more bluebunch wheatgrass. Bluebunch wheatgrass usually is associated with drier areas and south facing aspects, but has very broad range of osmoregulation and can grow in a variety of sites.
Areas with higher available soil moisture of 31.3 percent and less sandy soils (40-50 percent) had a higher proportion of rough fescue. Idaho fescue, timber oatgrass, and prairie Junegrass were found throughout. They surmised that the development and maintenance of the North Fork grasslands are attributed to the local climate (the "rain shadow effect" of the Whitefish Range), soil texture (coarse subsoil materials), and a long history of fire. The U.S. Forest Service (USFS) Fire Effects Information System (FEIS) evaluates the fire regime for northwestern montane and foothill grasslands with a fire interval of 9-66 years, with 43-100 percent of the fires occurring as replacement severity and 0-57 percent of fires as mixed severity, and 0-35 percent of the fires as low severity. The National Park Service (NPS) generally states that the historic mean fire return interval for the Big Prairie specifically is 9-26 years (Barrett, 1983). The policy of full fire suppression resulted in an absence of fire for 77 years, with a concomitant increase in the encroachment of lodgepole pine (*Pinus contorta*) upon the prairies during this period.

The NPS fire management process is to actively try to return the area to close to the historic fire return interval through the prescribed fire program (NPS Fire Ecology Annual Report (2014) and Prescribed fire in the North fork Grasslands of Big Prairie poster (Fire Effects Program, Glacier NPS,). In October of 1996, a prescribed fire was conducted. The NPS objectives are to maintain existing native species without introducing an inordinate number of non-native species, and to reduce overstory and pole sized trees by 30-70 percent within five years postburn. Post fire analysis showed there was minimal change in relative cover of native and nonnative species, the overstory and pole-sized density was reduced, but the seedling establishment increased and requires further prescribed burning.

Species Descriptions of Dominant Grasses
Rough fescue is a native, cool-season, perennial bunchgrass that produces thick mats of persistent sheath and stem bases and culms that grow to 3.5 feet, and leaf tufts that grow to 16 inches in height (Cronquist, 1977). It has extensive fibrous roots to a depth of 4 feet, 73 percent of which are concentrated in the top 6 inches of soil (Coupland, 1953). Rough fescue regenerates from seed, tillers, and sometimes creeping rhizomes (Pavlick, 1984). It is well adapted to a short growing season by initiating growth following snowmelt, and completes growth before the onset of summer drought. It is very productive and highly palatable to livestock and wildlife. Rough fescue is used by bighorn sheep, mule deer, elk, and bison. It is resistant to moderate grazing, but heavy grazing can result in severely decreased root depth and biomass (Aiken, 1990). Grazing can cause a general decline in rough fescue coverage, and it is one of the first species to decline with a concomitant increase of common increaser species, such as Idaho fescue, needlegrass species, prairie Junegrass, and Parry's oatgrass.
Rough fescue and elk sedge are considered very resistant to human trampling due to its tough core of the tuft, according to D. Cole of the USFS in his study of recreational human trampling effects on habitat types in western Montana. The majority of the loss of cover, a reduction of 50percent, occurred in the first 400 passes. Thereafter, cover loss was stabilized from 400-800 passes. The community of rough fescue-timber oatgrass is considered very resistant to both light and heavy trampling (Cole, 1987).
Rough fescue is well adapted to periodic burning and resistant to light fire because of their dense, tufted habit. It sprouts from surviving residual plants and colonizes from off-site wind-dispersed seed. Fire may top-kill plants, but normal cover and production usually is attained in 2-3 years post-fire. Severe damage can occur by hot, mid-summer wildfires (Wright, 1982).

Idaho fescue is a long-lived native perennial cool-season bunchgrass. It is densely tufted with fine leaves. The root system is strong and can extend 16 inches deep (Hanson, 1959). In well drained soils, the root biomass is greatest at depths of 2-4 cm. Reproduction is from seeds and tillers, although seed production is variable (Stubbendieck, 1992). Idaho fescue is found in more mesic grasslands and is considered a climax species. It can survive fires of light severity, but usually is harmed by more severe fires (Smith, 1981). Fire return intervals of 10-25 years have neutral to negative effects. Rapid tillering of Idaho fescue occurs where root crowns are not suppressed and soil moisture is favorable. Plants may re-establish from seed after fire if the burn temperatures are low enough to allow for survival of seed in the soil. Idaho fescue can decrease with heavy grazing or severe fire and be succeeded by native and non-native increaser species including poa and needlegrass grass species, sagebrush, lupine, phlox, and the invasive timothy (*Phleum pratense*) (Eckert, 1987). Idaho fescue is an important forage species for livestock (cattle, sheep, and horses) and wildlife species including elk and mule deer (Mueggler, 1980). It is particularly important in elk diets throughout the Rocky Mountain region.

Richardson's needlegrass is a native perennial cool-season bunchgrass with fine stems. It is shallow-rooted and clay accumulation can restrict roots (Lackschewitz, 1991). Richardson's needlegrass becomes dormant following the depletion of surface soil moisture during the latter part of the growing season (Nimlos, 1968). It reproduces by seed and is wind- and animal-dispersed (Tyser, 1990). Richardson's needlegrass is considered an obligate climax species, meaning it is co-dominant with another grass (Koterba, 1971). In general, perennial needlegrasses are among the least fire-resistant of the bunchgrasses, especially with midsummer burns: the accumulated dead culm and leaves makes them more susceptible to burning. Perennial needlegrasses often survive low-intensity fires as the heat is not transferred below the soil surface, only top-killing plants (Wright, 1965). Richardson's needlegrass is an important forage species for livestock and wildlife especially deer, bighorn sheep, and elk.

Hansen et al. (1995) found that Idaho fescue is good for cattle, horse, and sheep forage: it has high energy value and medium protein values in the fall and winter. Sticky geranium is good sheep forage, but only fair for cattle and horses: it has low energy and protein values in fall and winter. Sticky geranium also is considered good food value for elk and whitetail and mule deer, but poor for antelope and for bird species. Old man's whiskers (*Geum triflorum*) is considered fair to poor forage for cattle, sheep, and horses. It contains low energy and protein values in fall and winter. It has fair to poor food value for elk, whitetail and mule deer, and antelope, and also for bird species.

The NPS fire effects crew has established monitoring plots pre- and post-prescribed fire burns. These also are located within Big Prairie, which is where the reference sites are for this ecological site. The NPS established thirteen plots with the same dominant bunchgrass species found within this ecological site, and it is assumed that these plots occur within this ecological site. The composition of each site varies, with some dominated by rough fescue with a lower canopy cover of associated grasses including Idaho fescue, Richardson's needlegrass, timber oatgrass, prairie Junegrass, and bluebunch wheatgrass. There are weedy species recorded at these sites including redtop (*Agrostis stolonifera*), smooth brome (*Bromus inermis*), Canada thistle (*Cirsium arvense*), butter and eggs (*Linaria vulgaris*), hop clover (*Medicago lupulina*), common timothy (*Phleum pratense*), Kentucky bluegrass (*Poa pratensis*), sheep sorrel (*Rumex acetosella*), common dandelion (*Taraxacum officinale*), yellow clover (*Trifolium aureum*), red clover (*Trifolium pratense*), and common speedwell (*Veronica arvensis*). Of these weedy species, the only ones with cover over 10 percent were butter and eggs, hop clover, and yellow clover.

Effects of Land Management Practices On Ecological Dynamics And Invasive Species

Invasion Theory

Invasion of weedy species into native vegetation communities requires an understanding of the processes and mechanisms by which an invasion occurs. Resistance and resilience of the native community are essential elements in predicting the success of the invasion. There are two counter point theories on invasive species. The driver theory considers the invasive species to be driving species decline while the passenger model sees the invading species as filling in empty niches left by habitat alteration (Didham, 2005). The passenger model suggests that disturbance is the cause and if stopped, invasion can be reversed. Potential mechanisms of invasion include theories such as novel weapons, enemy release, competitive superiority, and manipulation of environment. Novel weapons include biological weapons or associations with micro-organisms that allow the invader species to either access new resources or steal them from indigenous plants (Tannas, 2011). Specifically, arbuscular mycorrhizal fungi may provide a substantial competitive advantage to spotted knapweed by carbon parasitism (Carey, 2004). In these cases, the invader uses these weapons to drive the invasion process. Enemy release describes the concept that once invader species are released from their native predator species or chemical warfare within their original community, they are more aggressive in their new community (Blumenthal 2006, Callaway and Aschelhoug 2000). The invader species may have characteristics that allow it to be more competitive than resident plant species such as grazing resistance, adaption to a harsh environment or another competitive ability (Tannas, 2011). Invading species can manipulate the environment to their advantage through resource competition. Mechanisms include modifying light interception, water uptake efficiency or change in soil water holding capacity, nutrient uptake and cycling (D'Antonio and Vitousek, 1992). The final outcome of invasion is establishment of the invading species which occurs as either dominance, coexistence, or exclusion from the indigenous plant community (Seabloom, 2003). D'Antonio and Vitousek (1992) stated grass invasions are particularly important because they are actively moved by humans and exotic grasses compete effectively with native species in many ecosystems. In addition, dominant grasses may change nutrient cycling, modify regional microclimates and alter fire dynamics.

Invasive Species Descriptions

Specifically, scientific literature on invasions by Kentucky bluegrass, smooth brome, spotted knapweed, leafy spurge and Canada thistle into rough fescue grasslands in Canada and Montana will be reviewed. Kentucky bluegrass invasion into rough fescue grasslands can take multiple pathways. Heavy grazing of rough fescue which reduces litter amount combined with timing of defoliation, winter versus growing season and abiotic factors like seasonal variation in soil moisture content can make native grasslands less resistant to invasion (Douwes, 2012, Tannas, 2012). Resilience of the native grassland is dependent on vigor and density of rough fescue and restoration establishment is more successful with cuttings and plugs than seeding (Tannas, 2011). Although, seeding rough fescue as a monoculture is effective (Sherritt, 2012). A study of grazing effects on a rough fescue at Stavely grassland, a Canadian research station, found that heavy grazing pressure by cattle resulted changes in plant species composition to an increase in shallow rooted species, less productive overall, but more resistant to grazing (Dormaar, 1990). In a study of seasonal biomass changes, Willms (1996) found that with grazing intensity the vegetation community composition shifted from one dominated by rough fescue to one dominated by parry oatgrass-Kentucky bluegrass in moderately grazed pastures to Kentucky bluegrass-sedge species in heavily grazed pastures. The rough fescue dominated community had the greatest forage value compared to communities resulting from moderate, heavy and severe grazing (Willms, 1996). More than 20 years of drastically reduced stocking rates were required to enable recovery (Willms, 1985). Soils associated with heavy grazing were transformed to a soil more characteristic of a drier microclimate (Johnston, 1962 and 1971), by reducing the thickness of Ah horizon, reducing percent organic matter and soil moisture and increasing soil temperature with grazing intensity. Heavy grazing also reduced the fertility and soil water holding capacity (Dormaar, 1998). Soil

organic matter, and nutrient cycling differed between grazed and ungrazed rough fescue grasslands (Willms, 1988). At a watershed scale, heavy grazing lead to larger summer storm and spring snow melt runoff compared to watersheds with less grazing (Chanasyk, 2002). The quantity and quality of surface runoff from these watersheds showed that grazing posed little risk of nutrient contamination of adjacent streams (Mapfumo, 2002). There was less snow accumulation in heavily and moderately grazed watersheds (Willms, 2006). A study on the effects of grazing on germinable seeds found that soil disturbance in fescue grassland is more likely to lead to a seral community dominated by annual broad-leafed plants, than a rough fescue dominated grassland (Willms, 1995). Skim grazing (light, once-over-spring defoliation) by cattle was not conducive to rough fescue conservation (Moisey, 2005). Rough fescue tolerated light winter-early spring elk grazing but not heavy grazing (Thrift, 2013). A rough fescue grassland in Rumsey Block, Alberta Canada tolerated moderate grazing which resulted in a community co-dominated with shortbristle needle and thread while heavy grazing and/or moderate to major oil and gas disturbance crossed a threshold requiring complete eradication of species and reseeding (Desserud, 2014). Another study of effects of human caused disturbance in rough fescue grasslands in Manitoba Canada, found it depends on invasive species introduction history (Gifford, 2013). Kentucky bluegrass tolerates grazing and can increase in abundance after heavy grazing. Therefore, Kentucky bluegrass resided in historically grazed areas, while smooth brome occurred along roads. In a study of smooth brome on rough fescue grasslands in Saskatchewan Canada, found that it is likely the combination of traits of smooth brome (higher productivity, abundant production of lower quality litter, clonal growth, and greater nutrient uptake capability) that allows it to invade native prairie (Piper, 2015). Smooth brome had a consistent negative impact on community structure and function across 8 grasslands in Alberta Canada with the impact on native species richness higher in species rich areas, while impact on native biomass was larger in productive, warmer and more variable sites (Stotz, 2016).
The noxious weed spotted knapweed was found to strongly reduce the final biomass and reproduction of native Idaho fescue grasslands. An insect biocontrol agent had little effect on spotted knapweed, while a native fungal pathogen killed it in a common garden experiment in Missoula Montana (Ridenour, 2003). Perry (2005) found that invasion of grasslands by spotted knapweed are mediated by root exudation of catechin, a potent phytotoxin. Catechin resistance was positively correlated with mean seed mass for eight species identified as resistant: Mountain brome, curlycup gumweed, needle and thread grass, basin wildrye, cicer milkvetch, boreal sweetvetch, common blanketflower, and alfalfa. Perry (2005) further found that residual soil catechin may interfere with reestablishment of native grassland species even after spotted knapweed populations are controlled.
Leafy spurge has an extensive rhizomatous root system, potential allelopathic properties and all parts contain high starch latex which seals wounds and is a possible deterrent against insect attacks. Areas with leafy spurge invasion that have been treated with herbicide application and mechanical removal still had higher bare ground area, significantly lower soil arthropod densities and lower plant species richness and cover (Pritekel, 2006). Jordan (2008) found that invasive plants, specifically leafy spurge, smooth brome and crested wheatgrass, are capable of modifying soil microbiota to facilitate further invasion by conspecifics and other invasive species. These soil alterations have the potential to impede restoration of native communities after removal of an invasive species. Successional management may require repeated treatments to achieve a desired outcome. Pokorny (2009) found that while broadleaf herbicide applications decreased hoary cress, Canada thistle and undesired forbs within a leafy spurge invaded site, the results were temporary, and seeding was necessary for native species establishment.

STATE 1.0:
Historic Reference state with no weedy species present.
Richardson’s needlegrass (*Achnatherum richardsonii*)-rough fescue (*Festuca campestris*)-Idaho fescue (*Festuca idahoensis*)/old man’s whiskers (*Geum triflorum*)-sticky purple geranium (*Geranium viscosissimum*)
COMMUNITY PHASE 1.1: This community phase is dominated by rough fescue, Idaho fescue, or Richardson’s needlegrass. Other grass species that occur frequently and provide moderate cover include timber oatgrass and prairie Junegrass, and bluebunch wheatgrass in drier areas. Shrubs generally are very low and cover no more than 10percent of the site. Diverse montane meadow forbs are associated with this site. Tree encroachment is very low, mainly consisting of lodgepole pine at the edges of the prairie.

COMMUNITY PHASE 1.2: This community has sustained shrub or tree encroachment due to a lack of fire. Likely shrub species to encroach on this community include serviceberry, kinnikinnick, sagebrush, shrubby cinquefoil, common juniper, Wood’s rose, snowberry, western snowberry, and dwarf bilberry. The tree species that encroach primarily are lodgepole pine.

Community Phase Pathway 1.1.A
This pathway represents a significant time without fire, so that the historical fire return interval is lengthened and shrub and conifer species invade.

Community Phase Pathway 1.2.A
This pathway represents a resumption of historic fire return intervals, so that woody shrub and conifer encroachments are suppressed and grasslands are sustained.

STATE 2.0:
Current Reference state with weedy species present at a very low canopy cover value.
Richardson's needlegrass (*Achnatherum richardsonii*)-rough fescue (*Festuca campestris*)-Idaho fescue (*Festuca idahoensis*)/old man's whiskers (*Geum triflorum*)-sticky purple geranium (*Geranium viscosissimum*)

COMMUNITY PHASE 2.1:
This community phase is dominated by rough fescue, Idaho fescue, or Richardson's needlegrass. Other grass species that occur frequently and provide moderate cover include timber oatgrass and prairie Junegrass, and bluebunch wheatgrass in drier areas. Shrubs generally are very low and cover no more than 10percent of the site. Diverse montane meadow forbs are associated with this site. Tree encroachment is very low, mainly consisting of lodgepole pine at the edges of the prairie.

COMMUNITY PHASE 2.2: This community has sustained either severe drought or heavy grazing, which has reduced the cover and vigor of rough fescue and increased the cover of Idaho fescue, needlegrass species, and prairie Junegrass. If these native bunchgrasses decreased significantly, then a transition would occur out of this State 1.

COMMUNITY PHASE 2.3: This community has sustained shrub or tree encroachment due to a lack of fire. Likely shrub species to encroach on this community include serviceberry, kinnikinnick, sagebrush, shrubby cinquefoil, common juniper, Wood's rose, snowberry, western snowberry, and dwarf bilberry. The tree species that encroach primarily are lodgepole pine.

Community Phase Pathway 2.1.A
This pathway represents heavy grazing or improper grazing management for sustained periods of time.

Community Phase Pathway 2.2.A
This pathway represents a ceasing of heavy grazing or improper grazing management for sustained periods of time.

Community Phase Pathway 2.1.B
This pathway represents a significant time without fire, so that the historical fire return interval is lengthened and shrub and conifer species invade.

Community Phase Pathway 2.3.A
This pathway represents a resumption of historic fire return intervals, so that woody shrub and conifer encroachments are suppressed and grasslands are sustained.

TRANSITION 1:
This represents the pathway from the historic Reference state in which there were no weedy species present in the vegetation community (State 1.0), to the introduction and establishment of weedy species, even at very low canopy cover values, within the vegetation community of State 2.0.

TRANSITION 2:
This pathway represents weed infestation from human, animal, or transportation corridors that allow non-native species to invade and establish within the grassland to the degree that native grass species decline.

STATE 3.0:
This state represents the community with significant increase in weedy species and concomitant decrease in native grass species.
COMMUNITY PHASE 3.1:
This community phase is dominated by the weedy species phleum pratense, poa pratensis, taraxacum offinale and *Centaurea stoebe* with less amounts rough fescue, Idaho fescue, or Richardson's needlegrass. Other grass species

that occur frequently and provide moderate cover include timber oatgrass and prairie Junegrass, and bluebunch wheatgrass in drier areas. Shrubs generally are very low and cover no more than 10percent of the site. Diverse montane meadow forbs are associated with this site. Tree encroachment is very low, mainly consisting of lodgepole pine at the edges of the prairie.

COMMUNITY PHASE 3.2:
This community has sustained shrub or tree encroachment due to a lack of fire, and is dominated by the weedy species phleum pratense, poa pratensis, taraxacum offinale and *Centaurea stoebe* with less amounts of the native vegetation community of this ecological site found in 2.1. Likely shrub species to encroach on this community include serviceberry, kinnikinnick, sagebrush, shrubby cinquefoil, common juniper, Wood's rose, snowberry, western snowberry, and dwarf bilberry. The tree species that encroach primarily are lodgepole pine.

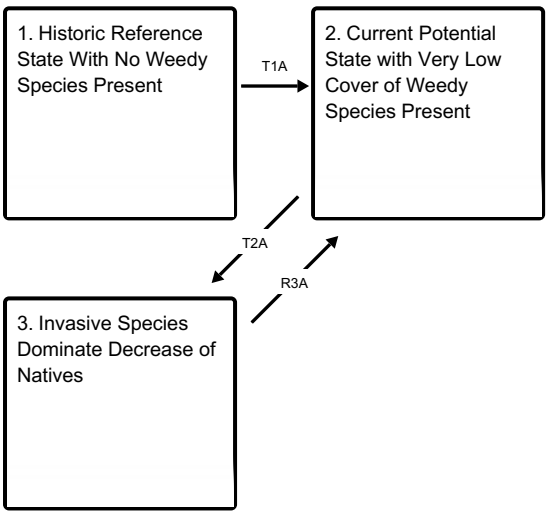
Community Phase Pathway 3.1.A
This pathway represents a significant time without fire, so that the historical fire return interval is lengthened and shrub species invade. Weedy species are still present within the community.

Community Phase Pathway 3.2A
This pathway represents a resumption of historic fire return intervals, so that woody shrub and conifer encroachments are suppressed and grasslands are sustained.

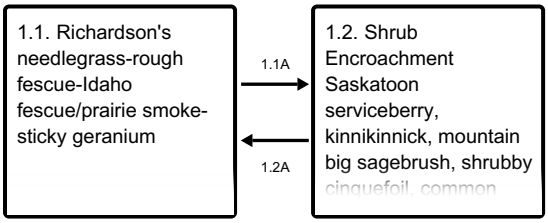
RESTORATION 1:
This pathway represents proper grazing management that allows the cover and vigor of native bunchgrass, particularly rough fescue, to be restored. Other means such as chemical, mechanical, or biological may be needed to restore native bunchgrass species to dominance.

State and transition model

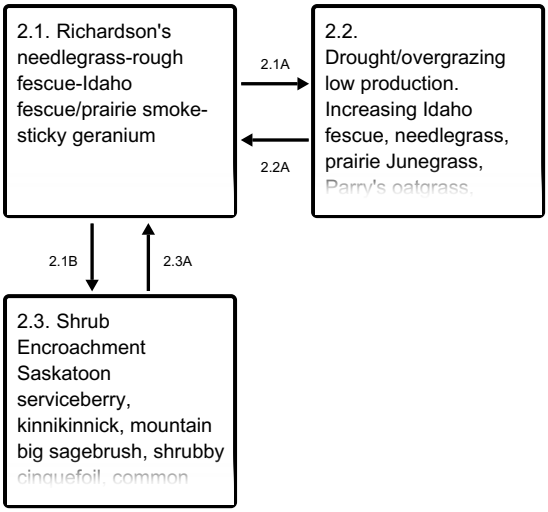
Ecosystem states



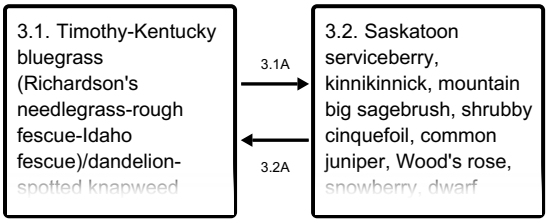
State 1 submodel, plant communities



State 2 submodel, plant communities



State 3 submodel, plant communities



State 1
Historic Reference State With No Weedy Species Present

Richardson’s needlegrass (*Achnatherum richardsonii*)-rough fescue (*Festuca campestris*)-Idaho fescue (*Festuca idahoensis*)/old man’s whiskers (*Geum triflorum*)-sticky purple geranium (*Geranium viscosissimum*) The Montane Loamy Outwash Terrace ecological site is dominated by a mixture of native, perennial, cool-season tufted bunch grasses. These grasses include rough fescue (*Festuca campestris*), Idaho fescue (*Festuca idahoensis*), Richardson’s needlegrass (*Achnatherum richardsonii*), bluebunch wheatgrass (pseudoroegneria spicata), timber oatgrass (*Danthonia intermedia*), and prairie Junegrass (*Koeleria macrantha*). These grasses can occur in varying amounts of cover, but generally are dominated by rough fescue, Richardson’s needlegrass, and Idaho fescue. The grasslands in western Montana, in general, are considered unique in that they have similar species to both grasslands of eastern Washington and northern Idaho (Palouse Region grasslands) as well as northern grasslands in Canada (Alberta fescue grasslands). Associated montane forbs include yarrow (*Achillea millefolium*), sticky purple geranium (*Geranium viscosissimum*), old man’s whiskers (*Geum triflorum*), northern bedstraw (*Galium boreale*), and yellow penstemon (*Penstemon confertus*). Shrubs with very low cover occur, including kinnikinnick (*Arctostaphylos uva-ursi*), serviceberry (Amalanchier alnifolia), shrubby cinquefoil (*Dasiphora fruticosa*), sulphur-flower buckwheat (*Eriogonum umbellatum*), common juniper (*Juniperus communis*), creeping barberry (*Mahonia repens*), Woods’ rose (*Rosa woodsii*), snowberry (*Symphoricarpos albus*), mountain big sagebrush (*Artemisia tridentata* var. vaseyana) and western snowberry (*Symphoricarpos occidentalis*). Only kinnikinnick occurs in any abundance, forming low-growing clumps. Some tree species occur in very low cover (1 percent canopy cover at 18 percent of the 22 sites visited). Conifer encroachment by lodgepole pine (*Pinus contorta*) usually occurs along the edges of the prairie. Big Prairie along the North Fork of the Flathead River in Glacier National Park is an excellent example of this site. This prairie has the highest number of microhabitat types for a grassland in this area, due to differential accumulation of glacio-alluvial material and the mix of subtle river swales and depressions on this former glacial outwash floodplain (Koterba and Habeck, 1971). Koterba and Habeck found in their ordination study of North Fork grasslands that species distribution was grouped by available soil moisture and soil attributes. Drier sites with available soil moisture of 17.7 percent and 60-70 percent sand and 5-10 percent clay had more bluebunch wheatgrass. Bluebunch wheatgrass usually is associated with drier areas and south facing aspects, but has very broad range of osmoregulation and can grow in a variety of sites. Areas with higher available soil moisture of 31.3 percent and less sandy soils (40-50 percent) had a higher proportion of rough fescue. Idaho fescue, timber oatgrass, and prairie Junegrass were found throughout. They surmised that the development and maintenance of the North Fork grasslands are attributed to the local climate (the “rain shadow effect” of the Whitefish Range), soil texture (coarse subsoil materials), and a long history of fire. The U.S. Forest Service (USFS) Fire Effects

Information System (FEIS) evaluates the fire regime for northwestern montane and foothill grasslands with a fire interval of 9-66 years, with 43-100 percent of the fires occurring as replacement severity and 0-57 percent of fires as mixed severity, and 0-35 percent of the fires as low severity. The National Park Service (NPS) states that the historic mean fire return interval for the Big Prairie specifically is 9-26 years (Barrett, 1983). The policy of full fire suppression resulted in an absence of fire for 77 years, with a concomitant increase in the encroachment of lodgepole pine (*Pinus contorta*) upon the prairies during this period. The NPS fire management process is to actively try to return the area to close to the historic fire return interval through the prescribed fire program (NPS Fire Ecology Annual Report (2014) and Prescribed fire in the North fork Grasslands of Big Prairie poster (Fire Effects Program, Glacier NPS). In October of 1996, a prescribed fire was conducted. The NPS objectives are to maintain existing native species without introducing an inordinate number of non-native species, and to reduce overstory and pole sized trees by 30-70 percent within five years postburn. Post fire analysis showed there was minimal change in relative cover of native and nonnative species, the overstory and pole-sized density was reduced, but the seedling establishment was initially reduced and then increased and requires further prescribed burning. This increase in seedling establishment might be expected of a fire adapted species.

Dominant plant species

- rough fescue (*Festuca campestris*), grass
- elk sedge (*Carex garberi*), grass
- Idaho fescue (*Festuca idahoensis*), grass
- Richardson's needlegrass (*Achnatherum richardsonii*), grass

Community 1.1
Richardson's needlegrass-rough fescue-Idaho fescue/prairie smoke-sticky geranium

This community phase is dominated by rough fescue, Idaho fescue, or Richardson’s needlegrass. Other grass species that occur frequently and provide moderate cover include timber oatgrass and prairie Junegrass, and bluebunch wheatgrass in drier areas. Shrubs generally are very low and cover no more than 10 percent of the site. Diverse montane meadow forbs are associated with this site. Tree encroachment is very low, mainly consisting of lodgepole pine at the edges of the prairie.

Community 1.2
Shrub Encroachment Saskatoon serviceberry, kinnikinnick, mountain big sagebrush, shrubby cinquefoil, common juniper, Wood's rose, snowberry dwarf huckleberry.

This community has sustained shrub or tree encroachment due to a lack of fire. Likely shrub species to encroach on this community include serviceberry, kinnikinnick, sagebrush, shrubby cinquefoil, common juniper, Wood’s rose, snowberry, western snowberry, and dwarf bilberry. The tree species that encroach primarily are lodgepole pine.

Pathway 1.1A
Community 1.1 to 1.2

This pathway represents a significant time without fire, so that the historical fire return interval is lengthened and shrub and conifer species invade. Shrub and conifer species invade the grassland because the soils and moisture availability are good and there is a lack of disturbance to reduce their numbers.

Pathway 1.2A
Community 1.2 to 1.1

This pathway represents a resumption of historic fire return intervals, so that woody shrub and conifer encroachments are suppressed, and grasslands are sustained. Herbaceous vegetation has an advantage over shrub and conifer species with regular fire intervals due to their ability to quickly resprout and tiller post-disturbance. Shrub and conifer species would need more time to establish from seed.

State 2
Current Potential State with Very Low Cover of Weedy Species Present

Current Potential State with weedy species present at a very low canopy cover value. Richardson’s needlegrass

(*Achnatherum richardsonii*)-rough fescue (*Festuca campestris*)-Idaho fescue (*Festuca idahoensis*)/old man’s whiskers (*Geum triflorum*)-sticky purple geranium (*Geranium viscosissimum*)

Community 2.1
Richardson's needlegrass-rough fescue-Idaho fescue/prairie smoke-sticky geranium

Figure 13. Vegetation at this ecological site, noting good growth and productivity of the rough fescue.

Figure 14. Very healthy, productive Loamy Outwash Terrace ecological site.

This community phase is dominated by rough fescue, Idaho fescue, or Richardson’s needlegrass. Other grass species that occur frequently and provide moderate cover include timber oatgrass and prairie Junegrass, and bluebunch wheatgrass in drier areas. Shrubs generally are very low and cover no more than 10percent of the site. Diverse montane meadow forbs are associated with this site. Tree encroachment is very low, mainly consisting of lodgepole pine at the edges of the prairie. This site has high average foliar cover (87%) and average basal cover (22%), dominantly rough fescue, with the soil surface dominantly litter with soil underneath (74%). There is fairly high moss 6% and trace gravel and lichen. The non-native species presence is only trace to 2%, and the most frequent species are timothy and butter-and-eggs. The species composition for production in pounds per acre averages rough fesceu 60 percent, old man whiskers 8 percent, Richardson's needlegrass 8 percent, sticky geranium 6 percent, common yarrow 5 percent, yellow penstemon 3 percent and Idaho fescue 2 percent.

Dominant plant species

- kinnikinnick (*Arctostaphylos uva-ursi*), shrub
- rough fescue (*Festuca campestris*), grass
- Idaho fescue (*Festuca idahoensis*), grass
- Richardson's needlegrass (*Achnatherum richardsonii*), grass
- timber oatgrass (*Danthonia intermedia*), grass
- prairie Junegrass (*Koeleria macrantha*), grass
- bluebunch wheatgrass (*Pseudoroegneria spicata*), grass
- old man's whiskers (*Geum triflorum*), other herbaceous

- sticky purple geranium (*Geranium viscosissimum*), other herbaceous
- yellow penstemon (*Penstemon confertus*), other herbaceous
- common yarrow (*Achillea millefolium*), other herbaceous
- Pacific anemone (*Anemone multifida*), other herbaceous
- Virginia strawberry (*Fragaria virginiana*), other herbaceous

Table 5. Soil surface cover

Tree basal cover	0%
Shrub/vine/liana basal cover	0-5%
Grass/grasslike basal cover	10-30%
Forb basal cover	5-20%
Non-vascular plants	0-10%
Biological crusts	0-10%
Litter	40-60%
Surface fragments >0.25" and <=3"	0-5%
Surface fragments >3"	0-5%
Bedrock	0%
Water	0%
Bare ground	0-20%

Table 6. Canopy structure (% cover)

Height Above Ground (M)	Tree	Shrub/Vine	Grass/ Grasslike	Forb
<0.15	0-5%	0-5%	5-20%	0-20%
>0.15 <= 0.3	0-5%	0-5%	5-20%	0-20%
>0.3 <= 0.6	0-5%	0-5%	40-60%	0-20%
>0.6 <= 1.4	–	–	0-10%	0-10%
>1.4 <= 4	–	–	–	–
>4 <= 12	–	–	–	–
>12 <= 24	–	–	–	–
>24 <= 37	–	–	–	–
>37	–	–	–	–

Community 2.2
Drought/overgrazing low production. Increasing Idaho fescue, needlegrass, prairie Junegrass, Parry's oatgrass, decreasing rough fescue.

This community has sustained either severe drought or heavy grazing, which has reduced the cover and vigor of rough fescue and increased the cover of Idaho fescue, needlegrass species, and prairie Junegrass. If these native bunchgrasses decreased significantly, then a transition would occur out of this State 2.

Community 2.3
Shrub Encroachment Saskatoon serviceberry, kinnikinnick, mountain big sagebrush, shrubby cinquefoil, common juniper, Wood's rose, snowberry, dwarf huckleberry.

This community has sustained shrub or tree encroachment due to a lack of fire. Likely shrub species to encroach on this community include serviceberry, kinnikinnick, sagebrush, shrubby cinquefoil, common juniper, Wood’s rose, snowberry, western snowberry, and dwarf bilberry. The tree species that encroach primarily are lodgepole pine.

Pathway 2.1A
Community 2.1 to 2.2

This pathway represents heavy grazing or improper grazing management for sustained periods of time.

Pathway 2.1B
Community 2.1 to 2.3

This pathway represents a significant time without fire, so that the historical fire return interval is lengthened, and shrub and conifer species invade.

Pathway 2.2A
Community 2.2 to 2.1

This pathway represents a ceasing of heavy grazing or improper grazing management for sustained periods of time.

Pathway 2.3A
Community 2.3 to 2.1

This pathway represents a resumption of historic fire return intervals, so that woody shrub and conifer encroachments are suppressed, and grasslands are sustained.

State 3
Invasive Species Dominate Decrease of Natives

This state represents the community with significant increase in weedy species and concomitant decrease in native grass species.

Community 3.1
Timothy-Kentucky bluegrass (Richardson's needlegrass-rough fescue-Idaho fescue)/dandelion-spotted knapweed (prairie smoke-sticky geranium)

This community phase is dominated by the weedy species phleum pratense, poa pratensis, taraxacum offinale and *Centaurea stoebe* with less amounts rough fescue, Idaho fescue, or Richardson’s needlegrass. Other grass species that occur frequently and provide moderate cover include timber oatgrass and prairie Junegrass, and bluebunch wheatgrass in drier areas. Shrubs generally are very low and cover no more than 10percent of the site. Diverse montane meadow forbs are associated with this site. Tree encroachment is very low, mainly consisting of lodgepole pine at the edges of the prairie.

Community 3.2
Saskatoon serviceberry, kinnikinnick, mountain big sagebrush, shrubby cinquefoil, common juniper, Wood's rose, snowberry, dwarf huckleberry/timothy-Kentucky bluegrass (Richardson's needlegrass-rough fescue-Idaho fescue)/dandelion-spotted knapweed

This community has sustained shrub or tree encroachment due to a lack of fire, and is dominated by the weedy species phleum pratense, poa pratensis, taraxacum offinale and *Centaurea stoebe* with less amounts of the native vegetation community of this ecological site found in 2.1. Likely shrub species to encroach on this community include serviceberry, kinnikinnick, sagebrush, shrubby cinquefoil, common juniper, Wood’s rose, snowberry, western snowberry, and dwarf bilberry. The tree species that encroach primarily are lodgepole pine.

Pathway 3.1A
Community 3.1 to 3.2

This pathway represents a significant time without fire, so that the historical fire return interval is lengthened and shrub species invade. Weedy species are still present within the community.

Pathway 3.2A
Community 3.2 to 3.1

This pathway represents a resumption of historic fire return intervals, so that woody shrub and conifer encroachments are suppressed, and grasslands are sustained.

Transition T1A
State 1 to 2

This represents the pathway from the historic Reference state in which there were no weedy species present in the vegetation community (State 1.0), to the introduction and establishment of weedy species, even at very low canopy cover values, within the vegetation community of State 2.0.

Transition T2A
State 2 to 3

Constraints to recovery. This pathway represents weed infestation from human, animal, or transportation corridors that allow non-native species to invade and establish within the grassland to the degree that native grass species decline.

Restoration pathway R3A
State 3 to 2

This pathway represents proper grazing management that allows the cover and vigor of native bunchgrass, particularly rough fescue, to be restored. Other means such as chemical, mechanical, or biological may be needed to restore native bunchgrass species to dominance.

Additional community tables

Table 7. Community 2.1 plant community composition

Group	Common Name	Symbol	Scientific Name	Annual Production (Kg/Hectare)	Foliar Cover (%)
Forb					
1	**Perennial and annual forbs**			–	
	sticky purple geranium	GEVI2	*Geranium viscosissimum*	0–448	0–5
	old man's whiskers	GETR	*Geum triflorum*	0–336	0–20
	yellow penstemon	PECO6	*Penstemon confertus*	0–224	0–10
	common yarrow	ACMI2	*Achillea millefolium*	0–168	0–20
	lupine	LUPIN	*Lupinus*	0–168	0–5
	starry false lily of the valley	MAST4	*Maianthemum stellatum*	0–112	0–3
	strawberry	FRAGA	*Fragaria*	0–112	0–3
	twin arnica	ARSO2	*Arnica sororia*	0–56	0–5
	bastard toadflax	COUM	*Comandra umbellata*	0–56	0–5
	Virginia strawberry	FRVI	*Fragaria virginiana*	0–28	0–10
	northern bedstraw	GABO2	*Galium boreale*	0–28	0–3
	smallflower woodland-star	LIPA5	*Lithophragma parviflorum*	0–28	0–3
	slender mountain sandwort	ARCA7	*Arenaria capillaris*	0–22	0–2
	arrowleaf balsamroot	BASA3	*Balsamorhiza sagittata*	–	0–10
	sticky cinquefoil	POGL9	*Potentilla glandulosa*	–	0–5
	slender cinquefoil	POGR9	*Potentilla gracilis*	–	0–5
	marsh valerian	VADI	*Valeriana dioica*	–	0–3
	sulphur-flower buckwheat	ERUM	*Eriogonum umbellatum*	–	0–3

	western stoneseed	LIRU4	*Lithospermum ruderale*	–	0–3
	alumroot	HEUCH	*Heuchera*	–	0–3
	autumn dwarf gentian	GEAM3	*Gentianella amarella*	–	0–2
	violet	VIOLA	*Viola*	–	0–2
	Pacific anemone	ANMU	*Anemone multifida*	–	0–2
Grass/Grasslike					
2	**Grasses, sedges and rushes**			–	
	rough fescue	FECA4	*Festuca campestris*	897–1457	0–90
	Richardson's needlegrass	ACRI8	*Achnatherum richardsonii*	0–448	0–30
	sedge	CAREX	*Carex*	0–112	0–5
	timber oatgrass	DAIN	*Danthonia intermedia*	0–67	0–5
	alpine bluegrass	POAL2	*Poa alpina*	0–56	0–5
	prairie Junegrass	KOMA	*Koeleria macrantha*	0–56	0–2
	pointedtip mariposa lily	CAAP	*Calochortus apiculatus*	0–22	0–5
	scouringrush horsetail	EQHY	*Equisetum hyemale*	0–22	0–3
	Geyer's sedge	CAGE2	*Carex geyeri*	–	0–5
	Idaho fescue	FEID	*Festuca idahoensis*	–	0–3
	spike trisetum	TRSP2	*Trisetum spicatum*	–	0–3
	green needlegrass	NAVI4	*Nassella viridula*	–	0–2
	mountain brome	BRMA4	*Bromus marginatus*	–	0–2
Shrub/Vine					
3	**Shrubs and subshrubs**			–	
	rosy pussytoes	ANRO2	*Antennaria rosea*	0–28	0–3
	pussytoes	ANTEN	*Antennaria*	0–22	0–5
	kinnikinnick	ARUV	*Arctostaphylos uva-ursi*	–	0–20
	western snowberry	SYOC	*Symphoricarpos occidentalis*	–	0–5
	dwarf bilberry	VACE	*Vaccinium cespitosum*	–	0–2
	creeping barberry	MARE11	*Mahonia repens*	–	0–2
	common snowberry	SYAL	*Symphoricarpos albus*	–	0–2

Table 8. Community 2.1 forest understory composition

Common Name	Symbol	Scientific Name	Nativity	Height (M)	Canopy Cover (%)
Grass/grass-like (Graminoids)					
rough fescue	FECA4	*Festuca campestris*	–	–	0.5–97.5
Richardson's needlegrass	ACRI8	*Achnatherum richardsonii*	–	–	2–60
Idaho fescue	FEID	*Festuca idahoensis*	–	–	0.5–40
bluebunch wheatgrass	PSSP6	*Pseudoroegneria spicata*	–	–	0.5–33
needleleaf sedge	CADU6	*Carex duriuscula*	–	–	30
timber oatgrass	DAIN	*Danthonia intermedia*	–	–	0.5–30
Geyer's sedge	CAGE2	*Carex geyeri*	–	–	0.5–15
arctic bluegrass	POAR2	*Poa arctica*	–	–	15
prairie Junegrass	KOMA	*Koeleria macrantha*	–	–	0.5–15
northern singlespike sedge	CASC10	*Carex scirpoidea*	–	–	10
smallwing sedge	CAMI7	*Carex microptera*	–	–	0.5–6

sedge	CAREX	*Carex*	–	–	0.5–3
Columbia needlegrass	ACNEN2	*Achnatherum nelsonii ssp. nelsonii*	–	–	0.5–3
mountain brome	BRMA4	*Bromus marginatus*	–	–	3
timothy	PHPR3	*Phleum pratense*	–	–	0.5–3
clustered field sedge	CAPR5	*Carex praegracilis*	–	–	2
Hood's sedge	CAHO5	*Carex hoodii*	–	–	1
Liddon sedge	CAPE7	*Carex petasata*	–	–	0.5
northwestern sedge	CACO11	*Carex concinnoides*	–	–	0.5
Rocky Mountain fescue	FESA	*Festuca saximontana*	–	–	0.5
pinegrass	CARU	*Calamagrostis rubescens*	–	–	0.5
smooth brome	BRIN2	*Bromus inermis*	–	–	0.5
western needlegrass	ACOC3	*Achnatherum occidentale*	–	–	0.5
rough bentgrass	AGSC5	*Agrostis scabra*	–	–	0.5
green needlegrass	NAVI4	*Nassella viridula*	–	–	0.5
bluegrass	POA	*Poa*	–	–	0.5
alpine bluegrass	POAL2	*Poa alpina*	–	–	0.5
Forb/Herb					
buckwheat	ERIOG	*Eriogonum*	–	–	3–37.5
old man's whiskers	GETR	*Geum triflorum*	–	–	0.5–37.5
arrowleaf balsamroot	BASA3	*Balsamorhiza sagittata*	–	–	1–22
rosy pussytoes	ANRO2	*Antennaria rosea*	–	–	0.5–20
silky lupine	LUSE4	*Lupinus sericeus*	–	–	0.5–20
spikemoss	SELAG	*Selaginella*	–	–	17
lupine	LUPIN	*Lupinus*	–	–	0.5–15
slender cinquefoil	POGR9	*Potentilla gracilis*	–	–	0.5–15
raceme pussytoes	ANRA	*Antennaria racemosa*	–	–	15
mountain big sagebrush	ARTRV	*Artemisia tridentata ssp. vaseyana*	–	–	0.5–15
sticky purple geranium	GEVI2	*Geranium viscosissimum*	–	–	0.5–15
strawberry	FRAGA	*Fragaria*	–	–	3–15
sulphur-flower buckwheat	ERUM	*Eriogonum umbellatum*	–	–	0.5–15
alpine golden buckwheat	ERFL4	*Eriogonum flavum*	–	–	3–12
twin arnica	ARSO2	*Arnica sororia*	–	–	0.5–10
sticky cinquefoil	POGL9	*Potentilla glandulosa*	–	–	1–10
spearleaf stonecrop	SELA	*Sedum lanceolatum*	–	–	0.5–7
tall cinquefoil	POAR7	*Potentilla arguta*	–	–	5
Virginia strawberry	FRVI	*Fragaria virginiana*	–	–	0.5–5
yellow avalanche-lily	ERGR9	*Erythronium grandiflorum*	–	–	3
Bonneville shootingstar	DOCO	*Dodecatheon conjugens*	–	–	3
umber pussytoes	ANUM	*Antennaria umbrinella*	–	–	3
slender mountain sandwort	ARCA7	*Arenaria capillaris*	–	–	0.5–3
ballhead sandwort	ARCO5	*Arenaria congesta*	–	–	3
prairie sagewort	ARFR4	*Artemisia frigida*	–	–	3
common yarrow	ACMI2	*Achillea millefolium*	–	–	0.5–3
small-leaf pussytoes	ANPA4	*Antennaria parvifolia*			3

small-leaf pussytoes	ANPA4	*Antennaria parvifolia*	–	–	3
Pacific anemone	ANMU	*Anemone multifida*	–	–	0.5–3
yellow penstemon	PECO6	*Penstemon confertus*	–	–	0.5–3
varileaf cinquefoil	PODI2	*Potentilla diversifolia*	–	–	3
cutleaf anemone	PUPAM	*Pulsatilla patens ssp. multifida*	–	–	0.5–3
cinquefoil	POTEN	*Potentilla*	–	–	3
narrowleaf hawkweed	HIUM	*Hieracium umbellatum*	–	–	3
western stoneseed	LIRU4	*Lithospermum ruderale*	–	–	0.5–3
northern bedstraw	GABO2	*Galium boreale*	–	–	0.5–3
yellowdot saxifrage	SABR6	*Saxifraga bronchialis*	–	–	3
saxifrage	SAXIF	*Saxifraga*	–	–	0.5–3
white spirea	SPBE2	*Spiraea betulifolia*	–	–	3
smooth blue aster	SYLA3	*Symphyotrichum laeve*	–	–	3
vetch	VICIA	*Vicia*	–	–	3
marsh valerian	VADI	*Valeriana dioica*	–	–	0.5–2
hairy false goldenaster	HEVI4	*Heterotheca villosa*	–	–	0.5–2
butter and eggs	LIVU2	*Linaria vulgaris*	–	–	0.5–2
pointedtip mariposa lily	CAAP	*Calochortus apiculatus*	–	–	0.5–2
bluebell bellflower	CARO2	*Campanula rotundifolia*	–	–	0.5–2
white thistle	CIHO	*Cirsium hookerianum*	–	–	0.5–1
nineleaf biscuitroot	LOTR2	*Lomatium triternatum*	–	–	0.5–1
Alaska oniongrass	MESU	*Melica subulata*	–	–	1
Pennsylvania cinquefoil	POPE8	*Potentilla pensylvanica*	–	–	0.5–1
spike trisetum	TRSP2	*Trisetum spicatum*	–	–	0.5–1
common mullein	VETH	*Verbascum thapsus*	–	–	0.5
common dandelion	TAOF	*Taraxacum officinale*	–	–	0.5
yellow salsify	TRDU	*Tragopogon dubius*	–	–	0.5
ragwort	SENEC	*Senecio*	–	–	0.5
Rocky Mountain goldenrod	SOMU	*Solidago multiradiata*	–	–	0.5
sulphur cinquefoil	PORE5	*Potentilla recta*	–	–	0.5
Douglas' knotweed	PODO4	*Polygonum douglasii*	–	–	0.5
longleaf phlox	PHLO2	*Phlox longifolia*	–	–	0.5
silver cinquefoil	POAR8	*Potentilla argentea*	–	–	0.5
starry false lily of the valley	MAST4	*Maianthemum stellatum*	–	–	0.5
white hawkweed	HIAL2	*Hieracium albiflorum*	–	–	0.5
autumn dwarf gentian	GEAM3	*Gentianella amarella*	–	–	0.5
field chickweed	CEAR4	*Cerastium arvense*	–	–	0.5
fireweed	CHANA2	*Chamerion angustifolium ssp. angustifolium*	–	–	0.5
tufted fleabane	ERCA2	*Erigeron caespitosus*	–	–	0.5
leafy spurge	EUES	*Euphorbia esula*	–	–	0.5
cushion buckwheat	EROV	*Eriogonum ovalifolium*	–	–	0.5
aspen fleabane	ERSP4	*Erigeron speciosus*	–	–	0.5
blanketflower	GAAR	*Gaillardia aristata*	–	–	0.5
roundleaf alumroot	HECY2	*Heuchera cylindrica*	–	–	0.5

alumroot	HEUCH	*Heuchera*	–	–	0.5
foothill arnica	ARFU3	*Arnica fulgens*	–	–	0.5
Holboell's rockcress	ARHO2	*Arabis holboellii*	–	–	0.5
Nuttall's rockcress	ARNU	*Arabis nuttallii*	–	–	0.5
sandwort	ARENA	*Arenaria*	–	–	0.5
field pussytoes	ANNE	*Antennaria neglecta*	–	–	0.5
pussytoes	ANTEN	*Antennaria*	–	–	0.5
pale agoseris	AGGL	*Agoseris glauca*	–	–	0.5
pearly pussytoes	ANAN2	*Antennaria anaphaloides*	–	–	0.5
Lyall's angelica	ANAR3	*Angelica arguta*	–	–	0.5
anemone	ANEMO	*Anemone*	–	–	0.5
littleleaf pussytoes	ANMI3	*Antennaria microphylla*	–	–	0.5
Fern/fern ally					
scouringrush horsetail	EQHY	*Equisetum hyemale*	–	–	0.5
horsetail	EQUIS	*Equisetum*	–	–	0.5
Shrub/Subshrub					
kinnikinnick	ARUV	*Arctostaphylos uva-ursi*	–	–	1–62.5
shrubby cinquefoil	DAFR6	*Dasiphora fruticosa*	–	–	10–15
common snowberry	SYAL	*Symphoricarpos albus*	–	–	0.5–15
western snowberry	SYOC	*Symphoricarpos occidentalis*	–	–	2–6
Saskatoon serviceberry	AMAL2	*Amelanchier alnifolia*	–	–	0.5–6
dwarf bilberry	VACE	*Vaccinium cespitosum*	–	–	3
common juniper	JUCO6	*Juniperus communis*	–	–	3
creeping barberry	MARE11	*Mahonia repens*	–	–	0.5–3
Woods' rose	ROWO	*Rosa woodsii*	–	–	0.5–1
Tree					
Douglas-fir	PSME	*Pseudotsuga menziesii*	–	–	3
lodgepole pine	PICO	*Pinus contorta*	–	–	0.5–3
Nonvascular					
lesser spikemoss	SEDE2	*Selaginella densa*	–	–	0.5–20

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Approval

Kirt Walstad, 5/06/2024

Rangeland health reference sheet

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

Author(s)/participant(s)	
Contact for lead author	
Date	12/18/2020
Approved by	Kirt Walstad
Approval date	
Composition (Indicators 10 and 12) based on	Annual Production

Indicators

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

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

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

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

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

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

---

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

---

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

---

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

---

10. **Effect of community phase composition (relative proportion of different functional groups) and spatial distribution on infiltration and runoff:**

---

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

---

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

    Dominant:

    Sub-dominant:

    Other:

    Additional:

---

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

---

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

---

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

---

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

for the ecological site:

---

17. **Perennial plant reproductive capability:**
